FORGING

AMERICAN SCHOOL of CORRESPONDENCE
CHICAGO ILLINOIS
U. S. A.

FORGING

INSTRUCTION PAPER

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FORGING.

Forging in general treats of the hammering, working, or forming of heated metals.

The Materials upon which the work of forging or blacksmithing is done, are wrought iron and steel. As explained in "Metallurgy," wrought iron is an iron from which "the silicon phosphorus and most of the carbon has been removed." Steel usually contains some of the impurities that are characteristic of cast iron with the marked peculiarity of holding a varying percentage of carbon. Mild steels are so called on account of the small amount of carbon which they contain. As the percentage of carbon increases, it becomes more difficult to weld the metal. Greater care must also be used in heating lest the metal be burned and its strength destroyed. Until recently all heavy forgings involving welding, were made of wrought iron, but now it is customary to make most forgings of mild steel, particularly large ones, although wrought iron is somewhat more satisfactory where a great amount of welding is required.

These metals may be roughly divided into three general classes; although the division line may not be sharply drawn between any two classes, the classes being *Wrought Iron, Machine Steel* and *Tool Steel.* The characteristics and method of manufacture of the three metals are described in "Metallurgy." A rough distinction such as a blacksmith would use is about as follows: *Wrought Iron* has a fibrous structure with stringy streaks of slag running lengthwise of the bar giving it a decided fibre, similar to wood. *Machine Steel,* more properly described as mild steel, or sometimes called soft steel, has much the same properties as wrought iron excepting that it lacks the fibre and is somewhat stronger. *Tool Steel* differs from the other two materials in the fact that by suddenly cooling from a high heat it may be made very hard, or hardens, as the technical term is. Wrought iron or machine steel are not hardened by the same treatment. Tool steel is practically the same thing as wrought iron or machine steel with a small percentage of carbon added. In fact, either of the two metals may be turned into tool steel by the addition of carbon. This principle is used in case hardening. Norway iron or Swedish iron is a grade of very pure wrought iron containing little slag. It is more expensive than ordinary wrought iron. Refined iron is a grade of wrought iron not as good as Norway iron but better than ordinary iron. Norway iron costs about twice as much as machine steel, which is somewhat cheaper than wrought iron of almost any grade. Machine steel, made by both the open-hearth and Bessemer processes, is used for forging.

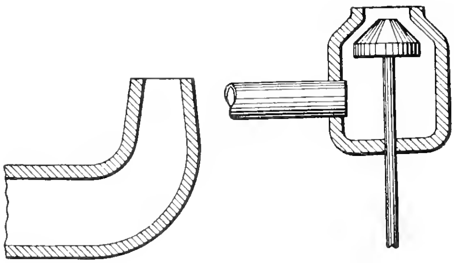

Fig. 1.

EQUIPMENT.

The equipment of the forge shop consists in general of a forge in which the metals are heated, an anvil for resting the metals on while hammering, and the various tools as described below for shaping and working.

The Forge. While forges or fires are of many shapes and sizes the principles of their construction remain the same. An ordinary blacksmith forge is a fireplace in the bottom of which there is a tuyere for admitting a blast of air to blow the fire. Where the air blast is furnished by a hand bellows, the pipe leading therefrom to the tuyere is open throughout. Where a power-driven blower furnishes the blast, there is a valve in the pipe for regulating the same.

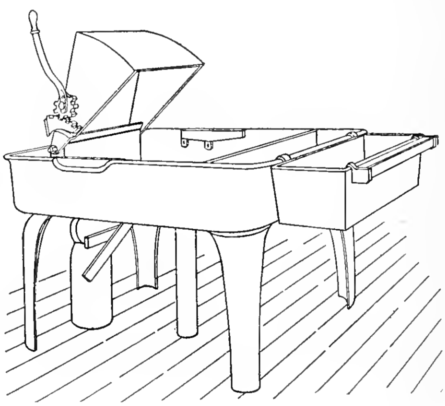

Fig. 2.

The usual form of tuyere consists of a single blast pipe, opening into the bottom of the fire pit. This may be a simple nozzle as in Fig. 1, with the blast regulated by a damper in the pipe; or, it may have a regulator at the mouth of the tuyere as shown. Sometimes the tuyere has several openings, and is then in the form of a

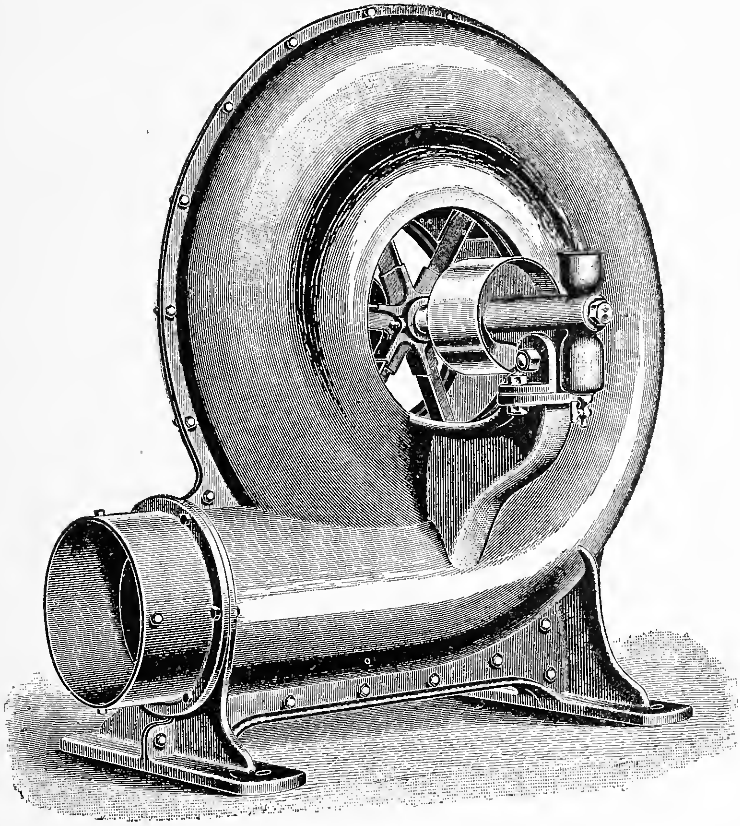

Fig. 3.

grate. Whatever its form, it should be possible to clean it from below, in order that coal and clinkers falling into it may be removed.

A modern type of forge is shown in Fig. 2. This is provided with a hood for carrying off the smoke. The pipe connected to the hood extends downward to an underground flue leading to an exhaust fan which draws out the air. The blast pipe is also underground, and a small pipe leads upward to the tuyere, the amount of blast admitted to the fire being regulated by a slide in this pipe. This system of underground piping is known as the *"Down Draft"* system.

In some shops no provision is made for carrying off the smoke, while in others hoods are placed above the forges and connected to overhead pipes, which may be either connected to an exhaust fan or led directly to the roof. The "Down Draft" system is the more modern and generally the best.

The Blast is furnished to the fires of a blacksmith shop by blowers of various kinds. For many years the ordinary bellows was used. This has been superseded by the fan blower which is now almost universally used, even for hand power.

Such a fan blower is shown in Fig. 3. It is formed of a thin cast-iron shell in which there are a set of rapidly revolving blades. These blades set up a current of air which presses against the side

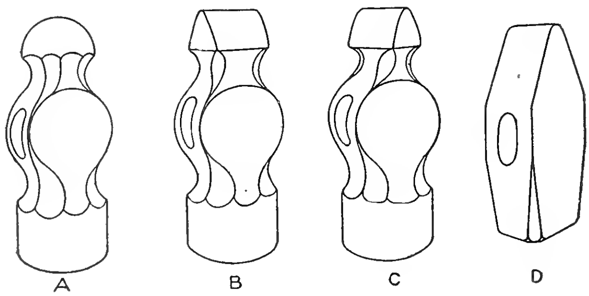

Fig. 4.

of the shell and escapes through the tangential opening. The pressure of the blast used for an open blacksmith fire varies from about 2 to 7 ounces per square inch. The lower pressure is used for a light fire and light work. The higher pressure is suitable for heavy classes of work.

Hammers. Several kinds of hammers are used in a forge shop. The commonest shape is the *ball pene* shown at A, Fig. 4. Other kinds are the *straight pene* and *cross pene* illustrated at B and C. A *square faced* hammer sometimes called a blacksmith's hammer, is shown at D. This is occasionally used on tool work. Commonly a ball pene hammer of about a pound and a half weight is used.

In the fitting of the handle to the head great care should be taken. Hammer handles are made elliptical in cross section. The major axis of this ellipse should exactly coincide with that of the eye of the head. The reason is that the hand naturally grasps the handle so that its major axis lies in the direction of the line of motion. Hence, unless the handle is properly fitted in this particular, there will be constant danger of striking a glancing blow. The handle should also stand at right angles to a center line drawn from the ball of the pene to the face. The eye in the head is usually so set that the

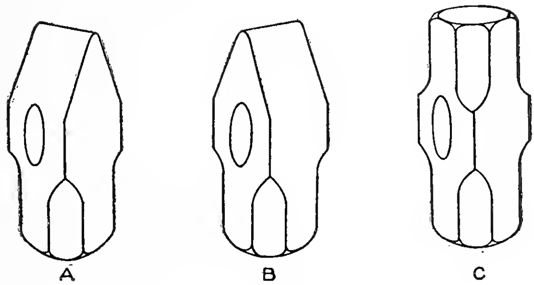

Fig. 5.

weight on the face side is greater than that on the pene. The effect of this is to so balance the tool that heavier and more accurate blows can be struck than if the weight were evenly balanced on each side of the eye.

Sledges are heavier hammers used by the blacksmith's helper and vary in weight from five to twenty pounds. The three common shapes are shown in Fig. 5; A, B, and C being *cross pene, straight pene* and *double faced* sledges respectively. A sledge for common work ordinarily weighs about 12 pounds. Sledge handles are generally about 30 to 36 inches long, depending on the nature of the work to be done.

Anvils. Next to the hammer in importance is the anvil. This may be any block of metal upon which the piece to be shaped is laid. The anvil must be of such a weight that it can absorb the blows that are struck upon it without experiencing any perceptible motion in itself.

The ordinary anvil, Fig. 6, has remained unchanged in form for many hundreds of years. As now made, the body *a* is of wrought iron to which a face of hardened steel is welded. From one end there projects the horn *b*, and the overhang of the body at the other end *c*, is called the tail. At the bottom there are four projections *d*, called the feet, which serve to increase the base upon which the anvil rests as well as to afford the means for clamping it down into position. In the tail there is a square and a circular hole. The former is called the hardie hole, the latter the spud hole.

An anvil of this form serves for the execution of any work that may be desired.

Anvils are also made with a body of cast iron, to which a face of steel is welded.

The anvil should be placed upon the end of a heavy block of wood sunken into the ground to a depth of at least two feet, so that it may rest upon a firm but elastic foundation. As the anvil is sub-

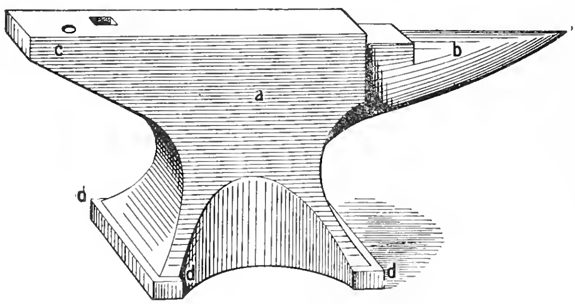

Fig. 6.

jected to constant vibrations, by the nature of the work, it is necessary that it should be firmly fastened to the block.

Anvils are classed and sold by weight. The weight is generally stamped on the side of the anvil. Three numbers are used. The first to the left shows the weight in cwt. of 112 pounds each. The middle number shows the additional quarters of cwt. and the right hand figure the number of odd pounds. For instance, an anvil marked 2-3-4 would weigh $2\times112+\frac{3}{4}$ of $112+4$ lbs.$=312$ lbs. and would be known as about a 300-pound anvil. Anvils are sometimes made of special shapes, but the one here shown is the common one.

Tongs. Next to the hammer and anvil in importance and usage are the tongs. They vary in size from those suitable for holding the smallest wires to those capable of handling ingots and bars of many tons in weight. The jaws are also adapted to fit over the piece to be handled and are of a great variety of shapes. As the

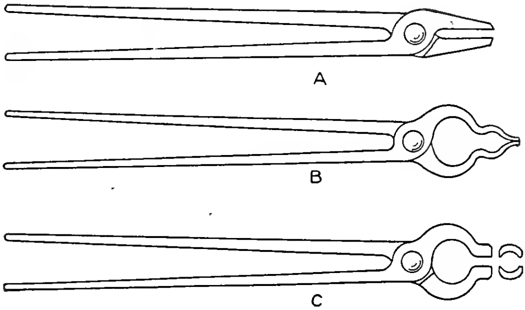

Fig. 7.

requirements of each piece of work varies so much from that which precedes and follows it, it is customary for the blacksmith to dress his own tongs and adapt them, from time to time, to the work he has in hand. Comparatively few, therefore, of the various shapes of tongs found in shops are manufactured and for sale. A few of the general types and forms in common use are here given.

A, Fig. 7, shows a pair of *flat-jawed* tongs, the commonest shape used. B is a pair of *pick-up* tongs used for holding work while tempering, and picking up pieces of hot metal. C is a common shape used for holding both square and round iron, the jaws being bent to fit the stock in each case. A modification of this shape is also used for heavy steam hammer work. Tongs frequently have the jaws made in some special shape for a particular piece of work, the object always being to have the jaws grip the work as firmly as possible.

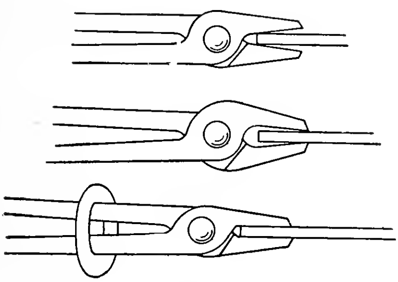

Fig. 8.

Fitting Tongs. Tongs must be always carefully fitted to the work. Tongs which take hold of the work as shown in Fig. 8. should not be used. The first pair shown have the jaws too close together, the second, too far apart. When properly fitted the jaws should touch the work throughout the entire length as shown in the lower sketch. To fit tongs the jaws are heated red hot, the piece to be held

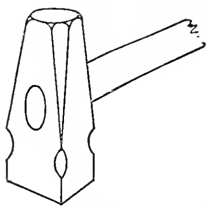

Fig. 9.

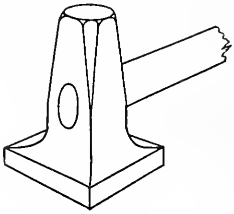

Fig. 10.

placed between them, and the jaws hammered down until touching their entire length. Tongs which do not fit the work perfectly should never, under any circumstances, be used. When in use on all but the smallest work, a link is driven over the handles to grip the tongs in position as shown.

Set Hammers and Flatters are used for smoothing off flat work when finishing. The *set hammer,* Fig. 9, is used for working up into corners and narrow places. The *flatter,* Fig. 10, is used on wide flat surfaces. The face of the set hammer used on light work is generally about $1\frac{1}{4}$ inches square. That of the flatter about $2\frac{1}{2}$ inches square, although the sizes vary depending upon the kind of work.

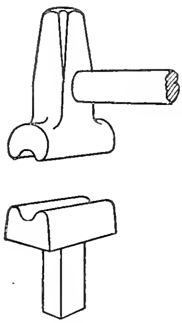

Fig. 11.

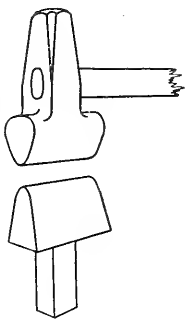

Fig. 12.

Swages, shown in Fig. 11, are used for finishing round and convex surfaces. The upper tool is known as the top swage and is provided with a handle. The lower one is the bottom swage and is held in place by a square stem or shank which extends downward and fits into the hardie hole of the anvil. Tools of this character should never be used on an anvil where they fit so tight that it is necessary to drive them into place. The swages shown here are used for round work. Swages are also made for octagonal, hexagonal and other shapes.

Fullers, used for working grooves or hollows into shape, are also made top and bottom as shown in Fig. 12. The top fuller is for finishing into round corners, around bosses, and on the inside of angles as illustrated later on. The fuller is also used to spread metal, when it is wished to work the metal only in one direction. The metal spreads at right angles to the working edge of the fuller.

Swage Blocks, a common sort of which is shown in Fig. 13, are used for a variety of purposes mostly for taking the place of

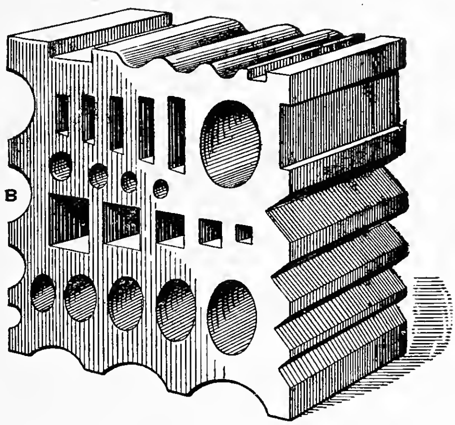

Fig. 13.

bottom swages. These blocks are commonly made from cast iron and weigh about 150 pounds.

Other Tools. The tools used commonly are calipers, a carpenter's two-foot steel square, dividers, a rule, shovel, tongs, ladle, poker and a straight bar for loosening the fire. In addition to the ordinary calipers, a blacksmith usually has a pair of double calipers similar to those shown in Fig. 14. With these, two dimensions may be used, one side being set for the thickness, and the other for the width, of the material. When several measurements are to be made particularly on large work, a strip of light stock about $\frac{1}{8}$-inch by 1 inch wide is used. The different dimensions are laid off on this with chalk or soapstone. In use the strip is held against the work and used in the same manner as a rule. A light rod having a small bent end, made by bending over about $\frac{1}{2}$ inch of stock at right angles, is also sometimes used, particularly when working under the steam hammer. The dimensions may be laid off from the inside of the hooked end. When in use the hooked end is pulled against the end of the material. Soap-stone crayon is ordinarily used for marking on iron. The marks do not burn off, but will not show at a red heat. Marks to show at a high heat must be made by nicking the corner of the bar with a chisel or by marking with the center punch. Another common way of making measurements on hot material is to lay off the different distances on the side of the anvil with chalk, the dimensions being laid off from one corner or end.

Fuel. The common fuel for small fires is "soft" or bituminous coal, coke for large fires and furnaces, and occasionally hard coal in small furnaces. The soft coal used is of a grade known as smithing coal. It should be very clean and free from impurities. A lump of good forge coal breaks easily with a crumbly looking fracture and the coal shows clean and bright on all faces. It will not break up into layers as "steaming" coal will, these seamy looking breaks being caused by the more or less earthy impurites. If forge coal splits and shows dull looking streaks or layers, it is poor coal. Good coal has little clinker and breaks easily. When used, the coal is dampened and kept wet before putting on the fire. It should be broken up fine before dampening, and not used in lumps.

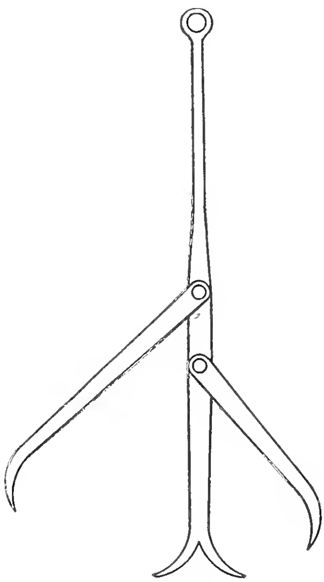

Fig. 14.

Fires. The fire must be carefully watched. It is very important that it should be in first class condition at all times for the work in hand. A certain depth of fire is always necessary. If the fire be too shallow, the cold blast will penetrate the fire in spots, making it impossible to heat the metal. There should be depth enough to the fire to prevent this. For small work there should be at least three or four inches of fire below the metal that is heating. There should also be thickness enough of fire above the work being heated to prevent the metal from losing heat to the outside air. The fire should be kept as small as possible to heat the work properly. As a general rule the fire will follow the blast. If the fire is wanted larger it may be made so by loosening the edges of the fire by a bar, allowing the blast to come through around the sides, causing the fire to spread. When a small fire is wanted the damp coal should be packed down tightly around the sides and the center of the fire loosened up slightly. For light work a small round fire is used. For heavier heating the fire is started by placing a large block on top of the tuyere, on each side of which green coal is packed down hard in the shape of an oblong mound. The block is then removed and the fire started in the hole left. These mounds are left undisturbed and fresh fuel is added to the fire in the shape of coke which has either been previously made by loosely banking a quantity of green coal over the fire and partially burning it to coke, or is bought ready made. With a small fire the fuel is constantly added around the sides where it is turned into coke. This coke is raked into the center of the fire as wanted and more coal added around the sides and patted down to keep the fire in shape.

Oxidizing and Reducing Fires. When too much blast is blown through the fire all the oxygen is not burned out of the air. This attacks the iron, forming a heavy coat of oxide, or scale, (the black scale which falls from heated iron). This sort of a fire is known as an oxidizing fire and should not be used when it is possible to avoid it. When just enough air is being admitted to keep the fire burning brightly and all of the oxygen is burned, the fire is in good condition for heating. Very little scale is formed and some of the scale already formed may even be turned back to iron. This sort of a fire is known as a reducing fire. In other words, when the fire is in condition to give oxygen to anything, it is an oxidizing fire. If in condition to take away oxygen, it is a reducing fire.

Banking the Fire. The fire may be kept for some time by placing a block of wood in the center and covering over with fresh coal.

Stock. Material from which forgings are ordinarily made comes to the forge shop in the shape of bars having uniform sections throughout; generally round, square, or rectangular in section, and varying from $\frac{1}{8}$-inch thick to 18 inches square. Heavier sizes may be had to order. Bars are ordinarily 12 to 20 feet in length. Thin stuff, $\frac{1}{8}$ of an inch or less in thickness, usually comes in strips of about 40 feet. This may be had from stock up to six or eight inches wide. Tool Steel also comes in bars generally about six or eight feet long. The ordinary sizes of tool steel stock are known as base sizes and the price is fixed on these base sizes. Stock of a larger or smaller size than the base sizes is generally charged for at an increase in price. Thus inch square tool steel, which is a base size, is worth in certain grades about 14 cents a pound. Steel of exactly the same grade and character, $\frac{3}{16}$ of an inch square, costs about 18 cents.

WELDING.

If a piece of steel or iron be heated, as the temperature is raised the metal becomes softer. Finally a heat is reached, called the welding heat, at which the metal is so soft that if two pieces similarly heated be placed in contact, they will stick. If the pieces so heated be placed together and hammered, they may be joined into one piece. This process is known as welding. The greatest difficulty in welding is to heat properly, which must be done evenly and cleanly. If the temperature is raised too high, the iron will burn, throwing off bright star-like sparks. If the temperature be too low, the pieces will not stick to each other. The proper heat can only be determined by experimenting, which may be easily done by doubling over a piece of scrap iron for two or three inches and welding into a solid piece.

When heating wrought iron and mild steel, as the welding heat is reached, small particles of the metal are melted and blown upward from the fire by the blast. As these small particles come in contact with the air they burn and form small explosive sparks, like little white stars. Whenever these sparks are seen coming from the fire, it is a sure indication that the iron is burning. These sparks are sometimes used as a sort of an indication of the welding heat. The only sure way of determining the heat is by the appearance of the heated iron, which might be described as sort of creamy white. The welding heat is sometimes described as a white heat. This is not correct, as iron or steel is never raised to a white heat even when melted. This may be easily proved by comparing a piece of wrought iron at welding heat, with an ordinary arc lamp. When two pieces of metal are welded together there must be nothing between them. Heated iron or steel is always covered with scale (iron oxide). This scale, if allowed to stay on the surfaces to be joined, will prevent a good weld. It is necessary when welding, to heat the iron or steel to a high enough temperature to melt this scale and when the two pieces are put together, if the joint or scarf is properly made, most of this melted scale is easily forced from between the two pieces, leaving the clean surfaces of the metal in contact. This scale only melts at a very high heat, much higher than the heat at which it would be possible to weld the iron could it be kept free from scale.

Fluxes. These are used to lower the melting point of the scale. The flux is sprinkled on the surfaces to be joined just before the metal reaches the welding heat. The metal is then put back into the fire, raised to the welding heat and the weld made as usual. The scale is acted upon by the flux and melts at a lower heat than when no flux is used. As the flux melts it spreads, or runs, over the hot metal and forms a sort of protective covering, which, by keeping out the air, prevents to a large extent, the formation of more scale. The flux in no way acts as a cement or glue to stick the pieces together, but merely helps to melt off the scale already formed, and prevents the formation of more.

Sand and Borax. These substances are common fluxes. Sand may be used when welding wrought iron and machine steel; borax in place of sand for fine work and when welding tool steel. Borax is a better flux as it melts at a lower temperature than sand, and thus makes welding possible at a lower heat. Borax and salammoniac (ammonium-chloride) are sometimes mixed and used as a welding compound, or flux, the proportion being about four parts borax to one part salammoniac. This mixture is also a good flux for brazing. Borax contains a large amount of water which makes it boil and foam when melting and in this condition is very liable to drop away from the heating metal. If borax be heated red hot and allowed to cool, the water is driven off and the borax left in a glass like condition.

Borax treated this way and then powdered, is the best for welding, as it melts and sticks to the metal without any boiling.

Welding Compounds are fluxes serving the same purpose as sand or borax. Some of the better ones use borax as a basis. Some of these compounds are first class for their purpose and others are not as good, being simply intended as cheap substitutes for borax.

Fagot Weld. This is made by simply placing two or more pieces on top of each other and welding them in a lump or slab. Scrap iron is worked up in this way by making a pile six or eight inches square and eighteen inches or two feet long on a board, such as

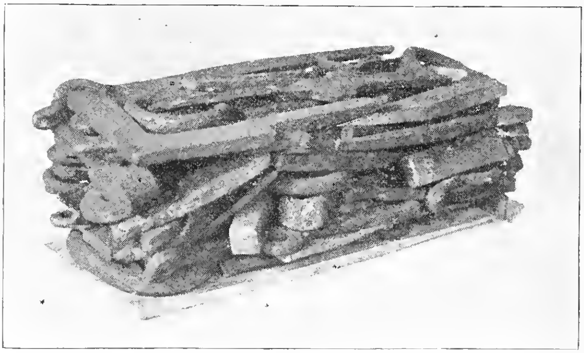

Fig. 15.

shown in Fig. 15. This pile is bound together with wires and placed in a furnace, fluxed with sand, and welded into a solid lump under a steam hammer. These lumps are afterwards worked out in bars or slabs by rolling or hammering. When a large piece is wanted, two or more of these bars are placed together and welded.

Scarfing. For most welding the ends of the pieces to be joined must be so shaped that when welded they will make a smooth joint. This shaping of the ends is known as *scarfing*, and the shaped end is called a *scarf*. The scarfed ends should not fit tightly before welding, but should be so shaped that they touch in the center of the joint, leaving the sides somewhat open. In this way when the weld is made, the melted scale is forced from between the pieces. If the scarfs were made to touch on the edge of the joint, leaving the center hollow, the scale not having a chance to escape, would be held in the center of the joint, leaving a weak place, and making a bad weld.

Lap Weld. This is the common weld used for joining flat bars together. The ends to be welded are scarfed or shaped as shown in Fig. 16. In preparing, the ends of the pieces to be welded should

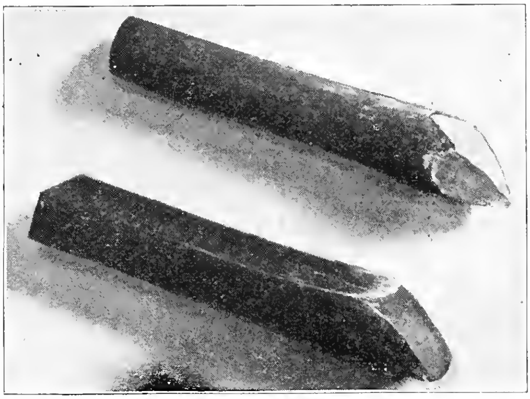

Fig. 16.

be first upset until they are considerably thicker than the rest of the bar. This is done to allow for the iron that burns off, or is lost by scaling, and also to allow for the hammering when welding the pieces together. To make a proper weld the joint should be well hammered, and as this reduces the size of the iron at that point, the pieces must be upset to allow for this reduction in size. For light work the scarfing may be done with a hand hammer. For heavy work a fuller and sledge should be used. After upsetting on light work, the end to be

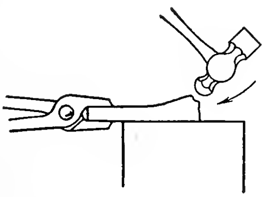

Fig. 17.

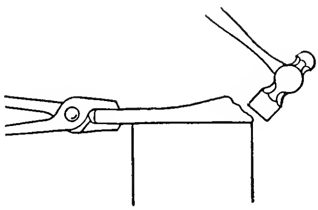

Fig. 18.

scarfed is roughly shaped with the pene end of the hammer as illustrated in Fig. 17, the final finishing being done with the flat face of the hammer.

For this work (finishing the edge of the scarf) as well as all pointed work, the end of the bar should be brought to the extreme edge of the anvil in the manner indicated in Fig. 18. In this way a hard blow may be struck with the center of the face of the hammer without danger of striking the hammer on the anvil. For all ordinary lap welding the length of the scarf may be about $1\frac{1}{2}$ times the thickness of the bar Thus on a bar $\frac{1}{2}$-inch thick, the scarf will be about $\frac{3}{4}$ of an inch long. The width of the end, Fig. 16, should be slightly less than the width of the bar. In welding the pieces together the the first piece held by the helper should be placed scarf side up on the anvil and the second piece laid on top, scarf side down, overlapping them to about the amount shown in Fig. 19. As it is generally somewhat difficult to lay the top piece directly in place, it should be steadied by resting lightly against the corner of the anvil and thus "steered" into place.

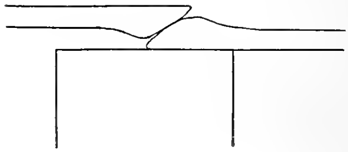

Fig. 19.

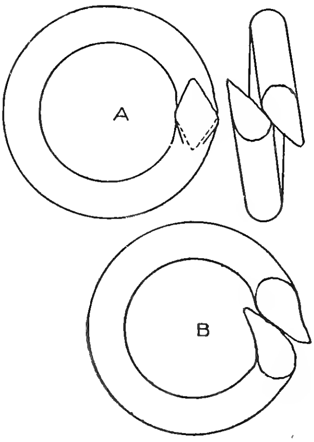

Fig. 20.

Round Lap Weld. This is the weld used to join round bars end to end to form a continuous bar. All the precautions regarding the scarf, etc., used for making the lap weld should be taken with this as well. The general shape of the scarf is shown in Fig. 16. It will be noticed that the end is hammered to a sharp point. If the scarf be made with a flat or chisel-shaped end similar to the flat lap weld, the corners will project beyond the sides of the bar in welding and cause considerable trouble, as it will then be necessary to work entirely around the bar before the joint be closed down. With a pointed scarf the weld may be frequently made by hammering on two sides only. This is not so important when welding between swages.

Ring Round Stock. When a ring is made, the exact amount of stock may be cut, the ends upset and scarfed as though making a round lap weld, the stock bent into shape as shown in Fig. 20 and welded. The ends should be lapped sideways as shown. In this position a ring may be welded by simply laying it flat on the anvil, while if lapped the other way, B, one end in, the other out, it would be necessary to do the welding over the horn of the anvil. In all weld- the piece should be so lapped that the hammering may be done in ing the quickest and easiest manner.

Allowance for Welding. In work of this character when the stock is cut to a certain length, allowance is sometimes made for loss due to welding. The exact amount is hard to determine, depending on how carefully the iron is heated and the number of heats required to make the weld. The only real loss which occurs in welding is the amount which is burned off and lost in scale. Of course when preparing for the weld, the ends of the pieces are upset and the stock consequently shortened. The piece is still further shortened by overlapping the ends when making the weld, but as all of this material is afterwards hammered back into shape no loss occurs. No rules can be given for the loss in welding, but as a rough guide on small work, a length of stock equal to from $\frac{1}{4}$ to $\frac{3}{4}$ the thickness of the bar will probably be about right for waste. Work of this kind should be watched very closely and the stock measured before and after welding in order to determine exactly how much stock is lost.

Chain Links. The first step in making a chain link is to bend the stock into a "U" shape, care being taken to have the legs of the "U" exactly even in length. The scarf used is approximately the pointed shape used for a round lap weld scarf. An easy method of scarfing is as follows: One end of the "U" shaped piece is laid on the anvil as indicated in Fig. 21. This is flattened by striking directly down with the flat face of the hammer, the piece being moved slightly to the left, as shown by the arrow, after each blow, until the end is reached.

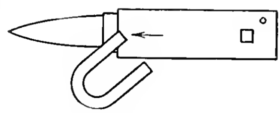

Fig. 21.

This operation leaves a series of little steps at the end of the piece and works it out in a more or less pointed shape as shown in

Fig. 22 at A. The point should be finished by placing it over the horn of the anvil and touching up with a few light blows. After scarfing the other end of the "U" in the same manner the ends are overlapped as indicated at B and welded together. The second link is scarfed, spread open, and the first link inserted. It is then closed up again and welded. The third is joined on this, etc. When made on a commercial scale, light links are not always scarfed but sometimes simply hammered together and welded in one heat. This is not possible in ordinary work.

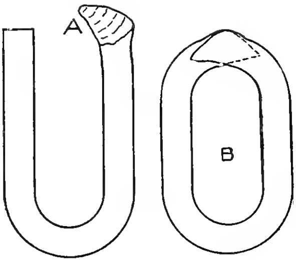

Fig. 22.

Band Ring. A method of making a band ring from iron bent flat ways is illustrated in Fig. 23. Stock is cut to length, the ends upset and scarfed, using a regular flat weld scarf, and the ring bent into shape and welded; the welding being done over the horn of the anvil. The heating must be carefully done or the outside lap will be burned before the inside is nearly hot enough to weld.

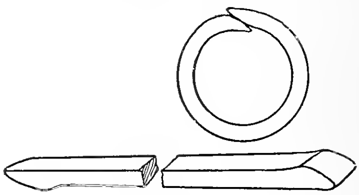
Fig. 23.

Flat or Washer Ring. This is a ring made by bending flat iron edgeways. The ends of the stock are first upset but not scarfed, except for careful work, the ring bent into shape, and the corners trimmed off on radial lines as shown in Fig. 24. The ends are then scarfed with a fuller or pene of a hammer and lapped over ready for welding as shown in Fig. 25.

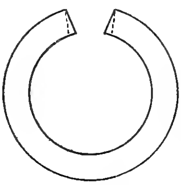
Fig. 24.

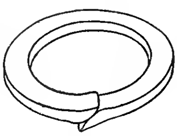
Fig. 25.

Butt Weld. When pieces are simply welded together end to end making a square joint through the weld, it is known as a butt weld. It is best when making a weld of this kind to round the ends slightly as illustrated in Fig. 26. The ends are heated and driven together and this round shape forces out the scale and leaves a clean joint. As the pieces are driven together they are more or less upset at the joint, making a sort of a burr. This upset part should be worked down at a welding heat between swages. A butt weld is not as safe or as strong as a lap weld. Long pieces may be butt welded in the fire. This is done

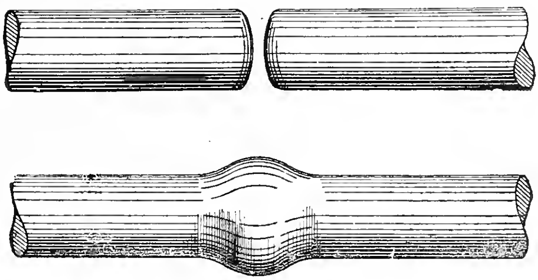

Fig. 26.

by placing one piece in the fire from each side of the forge. When the welding heat is reached the pieces are placed end to end, one piece "backed up" with a heavy weight, and the weld made by striking with a sledge hammer against the end of the other piece.

Jump Weld. Another form of butt weld shown in Fig. 27 is a jump weld which however is a form which should be avoided as much as possible, as it is very liable to be weak. In making a weld

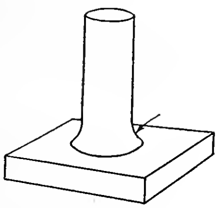

Fig. 27.

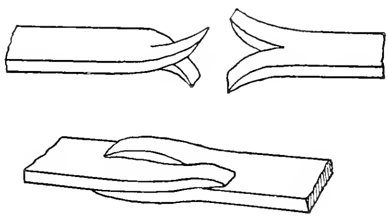

Fig. 28.

of this kind the piece to be butted on the other should have its end upset in such a manner as to flare out and form sort of a flange, the wider the better. When the weld is made, this flange may be worked down with a fuller or set hammer, thus making a fairly strong weld.

Split Weld for Thin Stock. Very thin stock is sometimes difficult to join with the ordinary lap weld for the reason that the pieces lose their heat so rapidly that it is almost impossible to get them together on the anvil before they have cooled below the welding heat. This difficulty is somewhat overcome by shaping the ends as shown in Fig. 28. The ends are tapered to a blunt edge and split down the center for half an inch or so, depending upon the thickness of the stock. Half of each split edge is bent up, the other down, the pieces are driven tightly together and the split parts closed down on each other as shown in Fig. 28. The joint is then heated and welded. This is a weld sometimes used for welding spring steel, or tool steel.

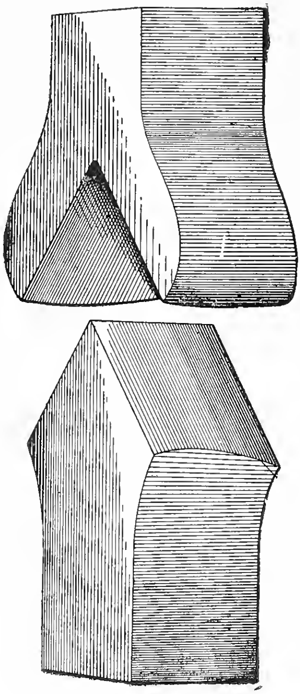

Fig. 29.

Cleft or Split Weld for Heavy Stock. Heavy stock is sometimes welded by using a scarf of the shape shown in Fig. 29. One piece is split and shaped into a "Y" while the other has its end brought to a blunt point. When properly shaped, the pieces are heated to the welding heat and driven together. The ends of the "Y" are then closed down over the other piece and the weld completed. A second heat is sometimes taken to do this. This weld is often used when joining tool steel to iron or machine steel. Sometimes the pieces are placed together before taking the welding heat.

Angle Weld. In all welding it should be remembered that the object of the scarfing is to so shape the pieces to be welded that they will fit together and form a smooth joint when properly hammered. Frequently there are several equally good methods of scarfing for the same sort of a weld, and it should be remembered that the method given here is not necessarily the only way in which that particular weld may be made. Fig. 30 shows one way of scarfing for a right angled weld made of flat iron. Both pieces are scarfed exactly alike, the scarfing being done by the pene end of the hammer. If necessary, the ends of the pieces may be upset before scarfing. Care should

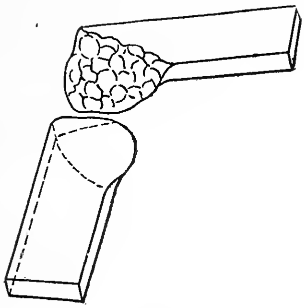

Fig. 30.

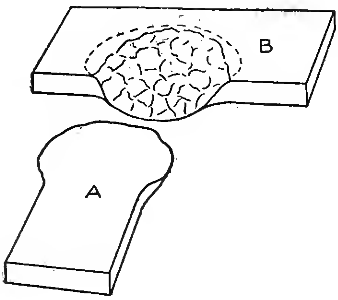

Fig. 31.

be used here as in other welds to see that the pieces touch first in the center of the scarf, otherwise a pocket will be formed which will retain the scale and spoil the weld.

T=Weld. A method of scarfing for a T-weld is illustrated in Fig. 31. The stem A should be placed on the bar B, when welding, in about the position shown by the dotted line.

T=Weld Round Stock. Two methods of scarfing for a T-weld made from round stock are shown in Fig. 32. The scarfs are formed mostly with the pene end of the hammer. The illustration will explain itself. The stock should be well upset in either method.

Welding Tool Steel. The general method of scarfing is the same in all welding but greater care must be used in heating when welding tool steel. The flux used for welding tool steel should be the salammoniac and borax mixture mentioned before. Spring steel or low carbon steel may be satisfactorily welded if care is used. To weld steel successfully the following precautions should be observed. Clean the fire of all cinders and ashes. Put sufficient coal upon the fire so that it will be unnecessary to add more coal while taking the welding heat. Upset both pieces near the end and scarf carefully. When possible, punch a hole and rivet the two pieces together. Heat the steel to a full red heat and sprinkle with borax. Replace in the fire and raise to the welding heat. Clean the scarfed surface and strike lightly at first, followed by heavier blows. The appearance of steel when at a welding heat is a pale straw color.

Always avoid a weld of high carbon steel alone, when possible.

Steel may also be welded to wrought iron. This is done in the manufacturing of edged tools. The body of the tool is of iron, to which a piece of steel is welded to form the cutting edge. This class of work is best done with a fire of anthracite coal, though coke or charcoal may be used. The fire should be burning brightly when the heating is done. Lay the iron and steel on the coal until they are red hot. Then sprinkle the surfaces of both with the flux and let it vitrify. A convenient method of doing this is to have the powdered flux (borax preferred) in a pepper pot. As soon as the heat has changed the metals to a straw color lay them together and strike. A single blow of a drop hammer, or four or five with a light sledge will do the work. Be sure that these pieces are well covered with a flux before attempting to weld.

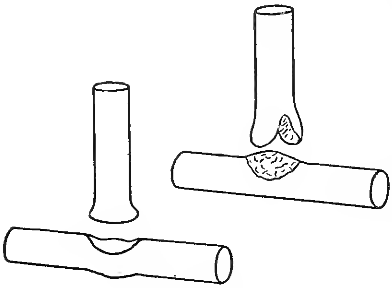

Fig. 32.

CALCULATION OF STOCK FOR BENT SHAPES.

It is always convenient and frequently necessary to know the exact amount of stock required to make a given piece of work. There are four

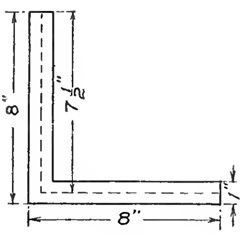

Fig 33.

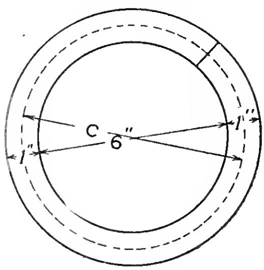

Fig. 34.

general methods used for determining this. The first and most accurate method, if it can be used conveniently, is mathematical calculation. Taking as an example the bent piece illustrated in Fig. 33. If the outside of this be measured, it would seem as though 16 inches of stock were required. If the inside be measured, 14 inches would seem the proper amount. It has been found by experiment that if a piece of straight stock be taken and a line drawn on it through the center, and this piece of stock then be bent and the lengths of the inside, center, and outside lines be measured, the outside line will lengthen considerably as the piece is bent. The inside line will shorten correspondingly, while the center line will remain comparatively unaltered in length. This is universally true, and the proper length of stock required for making any bent shape may always be obtained by measuring the center line of the curve or bend. To return to the first example: In this case, if the center line of the stock be measured, $7\frac{1}{2}$ inches will be the length for each leg, thus making a total of 15 inches of stock required to make that particular bend. This is a universal rule which should always be followed when measuring stock, to take the length of the center line.

Circles. On circles and parts of circles the length of stock may be easily calculated. The circumference, or distance around a circle, is found by multiplying the diameter by $3\frac{1}{7}$ or, more accurately, 3.1416. As an illustration, the stock necessary to bend up the ring in Fig. 34, would be calculated as follows: The inside diameter of the ring is six inches and the stock is one inch thick. This would make the diameter of the circle made by the center line, shown by C, which may be called the *Calculating Diameter*, seven inches, and the length of stock required would be $7 \times 3\frac{1}{7}$ or 22 inches.

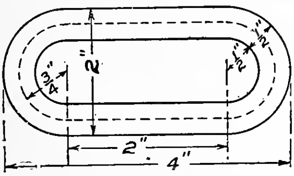

Fig. 35.

Link. A combination of circle and straight lines is illustrated in Fig. 35. This link may be divided into two semicircles at the end, with two straight pieces at the sides. The outside diameter of the ends being two inches, would leave the straight sides each two inches long. The *calculating* diameter for the ends would be $1\frac{1}{2}$ inches. The total length of stock then required for the ends would be $1\frac{1}{2} \times 3\frac{1}{7} = 4\frac{5}{7}$ or approximately $4\frac{11}{16}$ inches. As each of the straight sides will take two inches of stock, the total length required would be $4'' + 4\frac{11}{16}'' = 8\frac{11}{16}$ inches With a slight allowance for welding, the amount cut should be $8\frac{3}{4}''$. Another method of measuring stock is by using a measuring wheel such as is shown in Fig. 36.

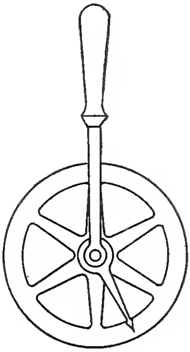

Fig. 36.

This is simply a light running wheel mounted on a handle with some sort of a pointer attached. The wheel is sometimes made with a circumference of 24 inches and the rim graduated in inches and eights. To use it, the wheel is placed lightly in contact with the line or object which it is wished to measure, with the zero mark on the wheel corresponding to the point from which the measurement is started. The wheel is then pushed along the surface following the line to be measured, with just enough pressure to cause it to revolve. By counting the revolutions and parts of a revolution made by the wheel, the required distance may be easily measured.

Scrolls and Irregular Shapes may be measured by either of two methods. The commoner way is to lay the scroll or shape off full size and measure the length by laying on this full sized drawing a string or thin piece of wire, causing the string or wire to follow the center line of the bent stock. The wire or string is then straightened and the length measured. This is about the easiest and best way of measuring work of this character. Another method which is more practical in the drafting room, consists of using a pair of dividers. The points of the dividers are set fairly close together and the center line is then stepped off and the number of steps counted. The same number of spaces are then laid off along a straight line and the length measured.

FORGING OPERATIONS.

Shaping. After the metal has been heated it is shaped with the hammer. This shaping may consist of drawing, upsetting or bending. In *drawing* a bar of iron it is made longer and of a smaller diameter. *Upsetting* consists of shortening the bar with a corresponding increase of diameter. This work is usually done with a helper using a sledge hammer; the smith using a light hand hammer.

They strike alternate blows. The helper must watch the point upon which the smith strikes and strike in the same place. Where two helpers are employed the smith strikes after each man. A blow on the anvil by the smith is a signal to stop striking.

Finishing. As the hammer usually marks the metal, it is customary to leave the metal a little full and finish by the use of flatters and swages. This applies to work that has been shaped under the sledge. Light work can be dressed smoothly, and the hammer can be made to obliterate its own marks.

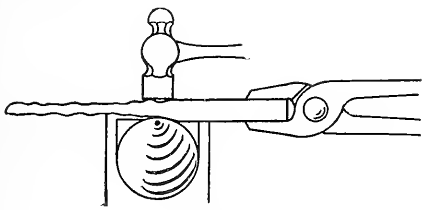

Fig. 37.

Drawing Out. In drawing out as well as in all other forging operations where heavy work is to be done, it is always best to heat the work to as high a temperature as the metal will stand without injury. Work can sometimes be drawn out much faster by working over the horn of the anvil than on the face, the reason being this: When a piece of work is hammered on the anvil face it flattens out and spreads nearly as much in width as it does in length, working it out longer and wider. As the piece is not wanted wider but merely longer, all the work spent in increasing the width of the stock is wasted. If the hammering is done over the horn of the anvil as illustrated in Fig. 37, the rounded horn acts as a blunt wedge, forcing the metal lengthwise and thus utilizes almost the entire energy of a blow in stretching the metal in the desired direction. Fullers are also used to serve the same purpose and when working under the steam hammer a round bar sometimes takes the place of the fuller or horn of the anvil.

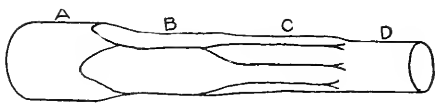

Fig. 38.

Drawing Out and Pointing Round Stock. When drawing out or pointing round stock, it should always first be forged down square to the required size and then in as few blows as possible, rounded up. Fig. 38 illustrates, in a general way, the different steps in drawing down a round bar from a large to a smaller size, the first step being to hammer it down square as at B. This square shape is then made octagonal as at C and the octagon is finally rounded up as at D. If an attempt be made to hammer the bar by pounding it round and round without the preliminary squaring, the bar is very liable to split through the center, the action being a good deal as illustrated in Fig. 39, the effect of the blow coming as shown by the arrows A. The metal is squeezed together in this direction and forced apart in the direction at right angles as indicated by the arrows B. Then if the piece be slightly rolled for another blow, the sides will roll by each other, and cracks and splits will sooner or later develop, leaving the bar, if it should be sawed through the center, in a good deal the shape shown in Fig. 40. Particular care should be taken in making conical points as it is almost impossible to work stock down to a round point unless the point be first forged down to a square or pyramidal shape.

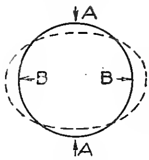

Fig. 39.

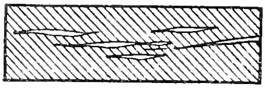

Fig. 40.

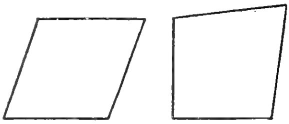

Fig. 41.

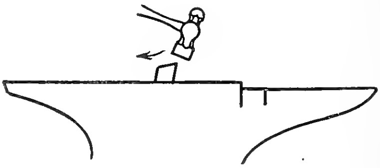

Fig. 42.

Truing Up Work. In drawing out it often happens that the bar becomes worked into an irregular or diamond shape, similar to the section shown in Fig. 41. To remedy this, and square up the bad corners, the bar should be laid across the anvil and worked much as shown in Fig. 42, the blows coming in the direction indicated by the arrow. Just as the hammer strikes the work it should be given a sort of sliding motion. No attempt should be made to square up a corner by striking squarely down upon the work. The hammering should all be done in such a way as to force the metal back into the bar and away from the high corner.

Upsetting. When a piece is worked in such a way that its length is shortened and either or both its thickness and width increased, the piece is said to be upset and the operation is known as upsetting. There are several methods of upsetting, the one used depending largely upon the shape of the work. In short pieces the work is generally stood on end on the anvil, the hammering being done directly down upon the upper end. The work should always be kept straight, and as soon as a bend or kink is started, it should be straightened out. When a long piece is to be upset it is generally swung back and forth horizontally and the upsetting done by ramming the end against the anvil. The effect of the blow has a decided influence upon the shape of the upset piece, as shown by the sketches of the two rivets in Fig. 43. Light blows affect the metal for a short distance only, as shown by the swelled out end, while the effect of heavier blows is felt more uniformly throughout the entire length.

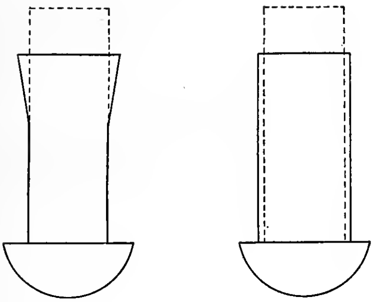

Fig. 43.

When rivets are to be driven to fill holes tightly, the blows should be heavy, thus upsetting the rivet tightly into the holes. If a rivet is wanted to hold two pieces together in such a way that they may move, as for instance the rivet in a pair of tongs, the head should be formed with light blows, thus working only the end of the rivet. The part of the work which is heated to the highest temperature is the part which will be most upset, and when upsetting is wished at one point only, that point should be heated to the highest temperature, leaving the other parts of the bar as cold as possible. Upsetting long pieces is sometimes done by raising the piece and allowing it to drop on a heavy cast-iron plate set in the floor. These plates are known as upsetting plates.

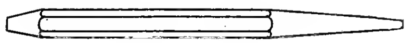

Fig. 44.

Punching. Two kinds of punches are commonly used for making holes in hot metal; the straight hand punch used with a hand hammer and the one used for heavier stock, provided with a handle and used with a sledge hammer. Punches should of course be made of tool steel. For punching small holes in thin iron a hand punch is ordinarily used. This is a bar of round or octagonal steel, eight or ten inches in length, with the end forged down tapering to the same shape, but slightly smaller than the hole to be punched. Such a punch for round holes is shown in Fig. 44. The end of the punch should be perfectly square across, not at all rounding. For heavier and faster work with a helper, a punch similar to Fig. 45 is used, the striking being done with a sledge hammer.

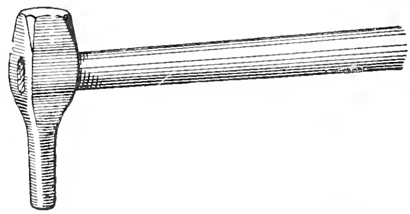

Fig. 45.

Fig. 46 illustrates the successive steps in punching a clean hole through a piece of hot iron. The work is first laid flat on the anvil and the punch driven about half way through as shown at A. This compresses the metal directly underneath the end of the punch and

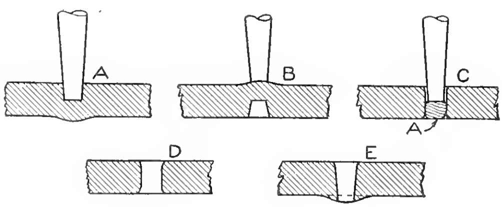

Fig. 46.

raises a slight bulge on the opposite side of the bar. The piece is then turned over and the punch driven into the bar from this side (the hole being located by the bulge) while the bar is lying flat on the anvil. The punch should be driven about half of the way through, leaving the work as at C. The bar is then moved over the small round hole in the end of the anvil, or is placed on some object having a hole slightly larger than the hole to be punched, and the punch driven clear through, driving out the small piece A and leaving the hole as shown at D. It would seem easier to drive the punch completely through the work from one side. If this were done, however, the hole would be left as shown at E, one side would be rounded in, and the other side would be bulged out, while the hole would have a decided taper, being larger at the end from which the punching was done. If the piece be thick, after the hole is started, a little powdered coal is put in and the punching continued. The coal prevents the punch from sticking to some extent.

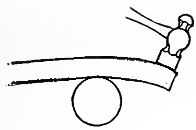

Fig. 47.

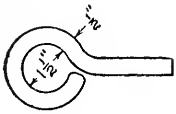

Fig. 48.

Ring and Eye Bending. In making a ring or eye the first step is of course, to calculate the amount of stock required. In making ordinary rings four or five inches in diameter, the stock should be heated for about half its length. In starting the bend, the extreme end of the piece is first bent by placing the bar across the horn of the anvil and bending it down as illustrated in Fig. 47. The bar is then pushed ahead and bent down as it is fed forward. The blows should not come directly on top of the horn but fall outside of the point of support as illustrated. This bends the iron and does not hammer it out of shape. One-half of the circle is bent in this way, the stock

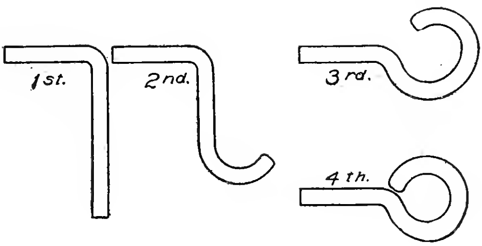

Fig. 49.

turned end for end, the other end heated, and the second half bent in the same way as the first, the bending being started from the end as before.

Eye bending is done in a somewhat different manner. Suppose it be required to bend up an eye as shown in Fig. 48. To calculate the amount of stock required: The diameter in this case to be used is two inches, and the amount of stock required $2'' \times 3\frac{1}{7}'' = 6\frac{2}{7}''$, or practically $6\frac{3}{8}''$. This distance is laid off by making a chalk mark on the anvil $6\frac{3}{8}''$ from the end. The iron is heated and placed against the anvil with one end on the chalk mark and the other end extending over the end of the anvil. The hand hammer is then held on the bar with one edge at the edge of the anvil, thus measuring off the required distance on the bar. Still holding the hammer on the bar the piece is laid across the anvil, with the edge of the hammer even with the edge of the anvil and the $6\frac{3}{8}$ inches extending over the edge or corner. This piece is then bent down into a right angle as shown in the first illustration of Fig. 49. The eye is bent in much the same manner as the ring, except that all the bending is done from one end, the successive steps being shown in the illustration. Small eyes are closed up in the manner shown in Fig. 50.

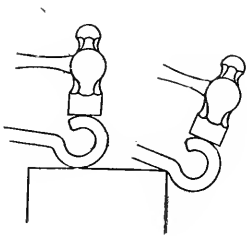

Fig. 50.

Bend with Square Forged Corner. Brackets and other forgings are frequently made with the outside corner square and sharp, as shown at C, Fig. 51. This may be done in either of two ways; by the first method the corner is bent from the size of stock required for the sides, being first bent to the shape of A. This corner is then

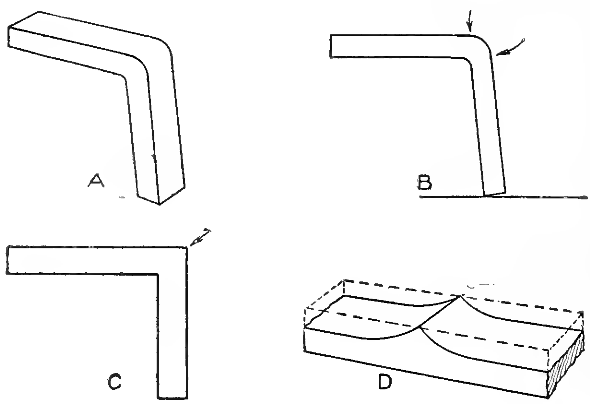

Fig. 51.

squared by upsetting the metal at the bend, the blows coming as shown by the arrows at B. The work should rest on the anvil face, and not over one corner, while being hammered.

The second method is to use thicker stock and draw out the ends leaving a hump, shown at D, where the outside corner of the

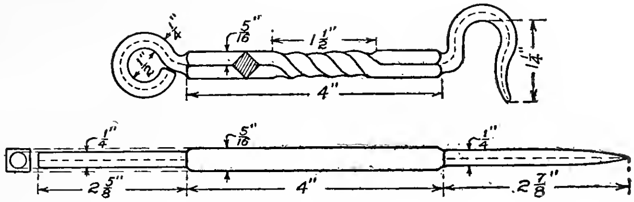

Fig. 52.

bend is to come. The dotted lines show the original shape of the bar; the solid lines the shape before bending. Sometimes stock is taken of the size used in the first method and upset to form the ridge, in place of drawing out the heavier stock.

The first method is the one more commonly used on medium sized work.

SIMPLE FORGING.

Twisted Gate Hook. It should be understood that the description given here will serve not only as a description of the particular piece in question but also as a general description of a variety of

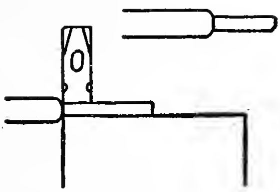

Fig. 53.

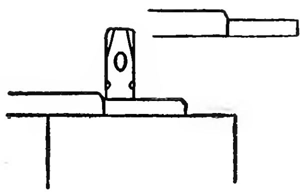

Fig. 54.

similarly shaped forgings. The methods used may be employed on other forgings of the same general shape.

Fig. 52 shows a twisted gate hook. To start with, it is necessary to determine exactly what lengths the different parts of the hook will have after they are forged to dimensions, and before they are bent to shape. Before bending, the work is first drawn down to size as is indicated. The bar is left square in the center for the central part, and each end is drawn to one-quarter inch round to form the hook and eye ends. The length of stock after being drawn out to $\frac{1}{4}''$ round required to make the eye, is $2\frac{3}{8}$ inches. Allowing about one-quarter of an inch for the straight part before the eye is reached would make the total amount of stock required for the eye $2\frac{5}{8}$ inches. To obtain the amount of stock for the hook it is necessary to lay off the hook full size. If the drawing be full sized the measuring may be done directly on the drawing, but if not, a rough sketch having the proper dimensions should be laid off and the measuring done on that, the measuring of course being done along the dotted center line. This measuring is done by simply laying a string on the dotted line, then straightening out the string and measuring its length. In this way it will be found that $2\frac{7}{8}$ inches is required by the hook. The first step is then to forge the work into the shape shown in Fig. 52.

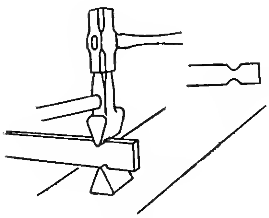

Fig. 55.

Forming Shoulders. The shoulder where the round stock joins the square should be forged in the manner indicated in Fig. 53. The bar is laid across the anvil with the point where the shoulder is wished, lying directly on the corner of the anvil. The set hammer is then placed on top of the work in such a way that the edge of the set hammer comes directly in line with the edge of the anvil. The set hammer is then driven into the work with a sledge hammer. The bar should be turned continually or an uneven shoulder will be the result. If a shoulder is wanted on one side only, as illustrated in Fig. 54, it should be worked in as indicated there. That is, one side of the iron should lie flat on the anvil face while the set hammer works down the metal next to the shoulder.

After the two ends of the hook are drawn out, the eye and the hook are bent up into shape. The twist in the center of the hook may be made by using either two pairs of tongs or twisting in a vise. By the latter method a mark is first made on the vise in such a way that when the end of the hook is placed even with the mark, the edge of the vise will come at the end of the point where the twist is wanted.

The hook should be heated and placed in the vise, the other end being grasped by a pair of tongs in such a way that the distance between the tongs and the vise is just equal in length to the twist. The twist is made by simply revolving the tongs around. In making a twist of this kind, no allowance need be made in length, as it practically has no effect on the length of the stock.

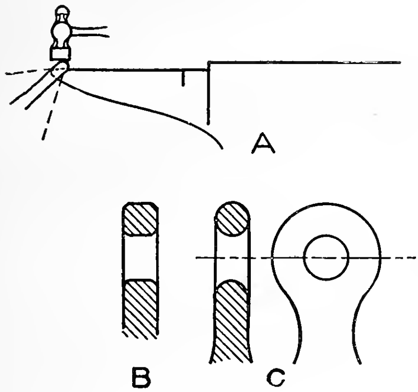

Fig. 56.

Eye Bolts are made by two general methods, being either solid or welded. The solid eye bolt is much the stronger. A solid eye bolt, or forged eye, as it is sometimes called, may be started in the general manner illustrated in Fig. 55. A nick is made on either side of a flat bar by using top and bottom fullers as illustrated. The end is then rounded up as shown in Fig. 56. Particular attention should be given to seeing that the eye is forged as nearly to a perfect circle as possible before any punching is done. The stock around the eye is rounded up over the horn of the anvil, by swinging it back and forth as it is hammered. The hole when first punched is like B, but when finished should be like C. The other end of the bar is then drawn down to form the round shank. If a very long shank is wanted a short stub shank may be formed and a round bar of the proper size welded on.

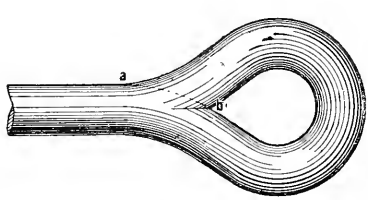

Fig. 57.

Welded eye bolts may be made in two different ways. The easier method produces an eye shaped as in Fig. 57. To make such a bolt, first scarf the end so that it will fit over the bend of the rod along the dotted line *a b*. Bend the eye over the horn of the anvil. Finally bring to a welding heat and weld in accordance with instructions already given.

An eye of better appearance, as shown in Fig. 58, is made as follows: Upset the body of the metal as a seat for the scarf at the end,

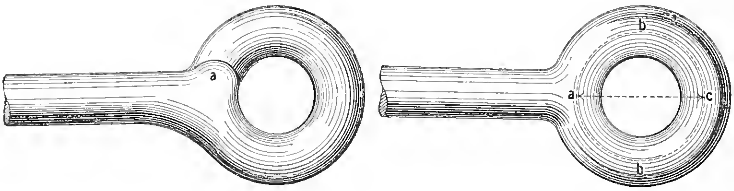

Fig. 58.

shown at *a*, Fig. 58. Scarf the end of the bar and bend over the horn of the anvil into a true circle to fit the seat at *a*, and then weld as before.

The length of metal required for an eye or ring is nearly equal to the length of the circumference of a circle whose diameter is equal to the mean diameter of the ring. Thus in Fig. 58 the length required for the eye will be approximately the length of the circle *a b c b* whose diameter is *a c*.

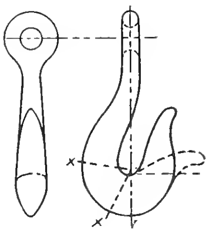

Fig. 59.

Chain Hooks. These are made in a variety of shapes and with solid or welded eyes, the general method of making the eyes being exactly as described before under "Eye Bolts". A common shape is shown in Fig. 59. The stock is forged into shape similar to Fig. 60 before being bent. To determine the length A the drawing is measured in the same way as described in making the gate hook. The weakest point in most hooks is the part lying between the lines marked *x x* in Fig. 59. This part of the hook should be heavier and stronger than the other parts. When a strain is put on the hook, there is always a tendency to straighten out or to assume the shape shown by the dotted lines. When forging the hook into shape, the dimension B, Fig. 60, should be made such that the heaviest part of the hook comes in this weakest point. After the hook is entirely forged to size, it should be bent into shape. Hooks

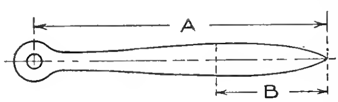

Fig. 60.

are also made from round and square iron. When made for hooking over a link, and so shaped that the throat or opening is just large enough to slip easily over a link edgewise, but too narrow to slip off of this link down to the one which, of course, is turned at right angles, the hook is known as a grab hook.

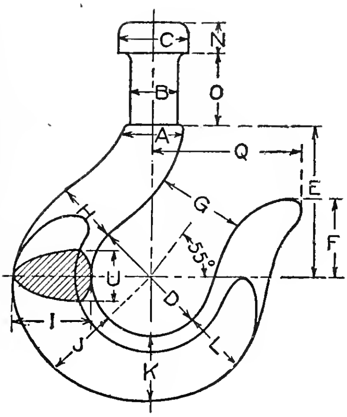

Fig. 61.

Hoisting Hooks. A widely accepted shape for hooks of this character used on cranes is shown on Fig. 61. The shape and formulae for the dimensions are given by Mr. Henry R. Town in his "Treatise on Cranes". T = Working load in tons of 2,000 lbs. A = Diameter of round stock, in inches, used to form the hook. The size of stock required for a hook to carry any particular load is given below. The load for which the hook is designed is given in the upper line, the lower line gives the size of the stock to be used in making the hook.

T =	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	3	4	5	6	8	10
A =	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$1\frac{1}{16}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{7}{8}$	$3\frac{1}{4}$

The other dimensions of the hook are found by the following formulae, all of the dimensions being given in inches.

D = .5 T + 1.25	I = 1.33 A
E = .64 T + 1.6	J = 1.2 A
F = .33 T + .85	K = 1.13 A
G = .75 D	L = 1.05 A
O = .363T + .66	M = .5 A
Q = .64 T + 1.6	N = .85 B − .16
H = 1.08 A	U = .866A

To illustrate the use of the table, suppose it be required to make a hook to raise a load of 500 lbs. or one-quarter of a ton. In the line marked "T" is found the load $\frac{1}{4}$. Directly below are figures

$\frac{11}{16}$ showing the size of stock to be used. The dimensions of the hook will be found as follows:

$$D = .5 \times \tfrac{1}{4} + 1.25'' = 1\tfrac{3}{8}''.$$
$$E = .64 \times \tfrac{1}{4} + 1.6'' = 1\tfrac{3}{4}'' \text{ about.} \qquad \text{Etc.}$$

....

$$I = 1.33\ A = 1.33 \times \tfrac{11}{16} = .915 \text{ or about } \tfrac{29}{32}''.$$

When reducing the decimals the dimensions which have to do only with the bending of the hook, *i.e.*, the opening, length, the length of point, etc., may be taken to the nearest 16th, but the dimensions through the body of the hook or stock should be reduced to the nearest 32nd on small hooks. The completed dimensions of the hook in question, 500 lbs. capacity, would be as follows:

$D = 1\frac{3}{8}''$	$I = \frac{29}{32}''$
$E = 1\frac{3}{4}''$	$J = \frac{13}{16}''$
$F = \frac{15}{16}''$	$K = \frac{25}{32}''$
$G = 1''$	$L = \frac{23}{32}''$
$O = \frac{3}{4}''$	$M = \frac{11}{32}''$
$Q = 1\frac{3}{4}''$	$U = \frac{9}{16}''$
$H = \frac{3}{4}''$	

Bolts. Bolts are made by two methods, the head being made by either upsetting or welding. The first method is more common on small bolts and machine made bolts. The welded head is more commonly used for heavy, hand forged bolts. The upset head is the stronger provided both are equally well made. The size of the bolt is always given as the diameter and length of shank or stem. Thus a bolt known as $\frac{1}{2}'' \times 6''$, or $\frac{1}{2}''$ bolt $6''$ long, would mean a bolt having a shank $\frac{1}{2}''$ in diameter and $6''$ long from the under side of the head to the end of the stem, having the dimensions of the bolt shown in Fig. 62. The dimensions of the bolt heads are always the same for the same sized bolt, and are determined from the diameter of the shank. The diameter of the head, shown at D, Fig. 62, is the distance across the head from flat side to flat side, and is known as the diameter *across the flats.*

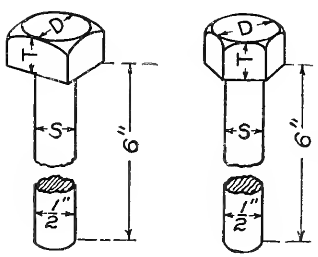

Fig. 62.

The thickness of the head is taken, as shown at T. If S equals the diameter of the shank of the bolt, the dimensions of the head would be as follows:

$$D = 1\tfrac{1}{2} \times S + \tfrac{1}{8}''$$
$$T = S$$

For a two-inch bolt the dimensions would be as follows:

Diameter of head $1\frac{1}{2} \times 2'' + \frac{1}{8}'' = 3\frac{1}{8}''$

The thickness of head would be equal to diameter of the shank, or 2″. These dimensions are for rough or unfinished heads. Each dimension of a finished head is $\frac{1}{16}$ of an inch less than the same

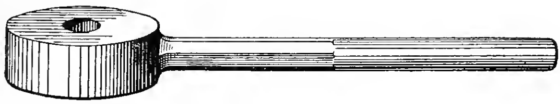

Fig. 63.

dimension of a rough head. Bolts generally have the top corners of the head rounded or chamfered off. This may be done with a hand hammer; or a cupping tool, which is simply a set hammer with the bottom face hollowed out into a cup shape, may be used.

Upset Head Bolts. The general method of making bolts of this kind, when a single bolt is wanted, is described below. The method of upsetting is shown in Fig. 64.

Where large quantities of bolts are to be made, the bars are heated in a furnace and headed by special machinery. Where the work is done by hand the tools are of the simplest character. The header consists of a disc in which a hole has been drilled to correspond to the diameter of the bolt. A handle 12 or 15 inches in length is welded to the disc. Such a tool is shown in Fig. 63. The hole should be about $\frac{1}{32}$ inch larger than the nominal size of iron. To

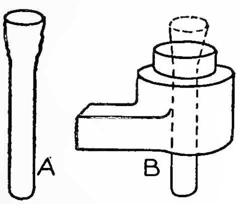

Fig. 64.

make a bolt with this tool: First cut off the iron to the required length; then heat the end to be headed, to a dull straw color; strike the end with a hammer or against the anvil and upset it so that the portion intended for the formation of the head will not pass through the header. Then place the hole of the header over the square hole in the tail of the anvil and drop the cold end of the bolt through it. Strike the projecting portion of the bar and upset it until the requisite thickness of head is obtained. This will probably leave a head of curved but irregular outline. Remove from the header and square the head thus upset, on the face of the anvil. This will probably thicken the head. Again drop the cold end through the header and strike the head until it is reduced to proper thickness. After which, again square the edges on the face of the anvil. In doing this work, the smith will hold the header in his left hand. The work will be facilitated if a helper assists with a sledge hammer.

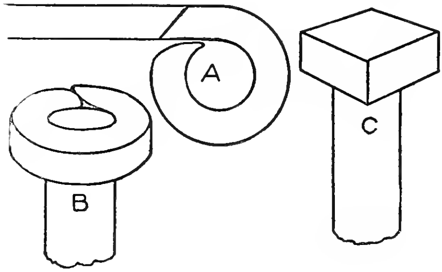

Fig. 65.

There are a number of simple tools in use for clamping the

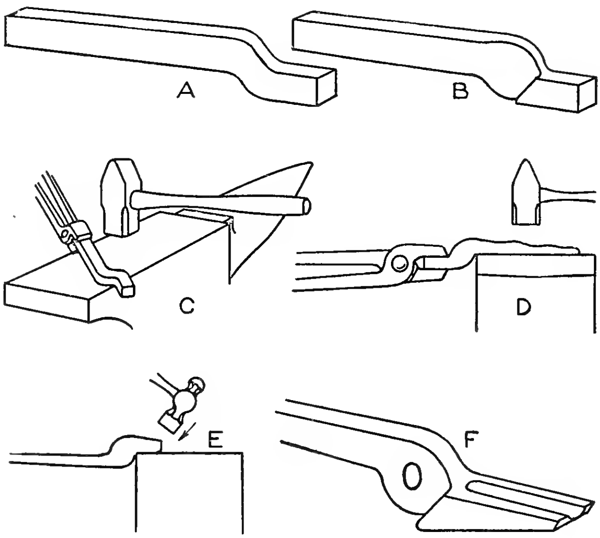

Fig. 66.

bar while it is being headed so as to avoid the preliminary upsetting.

Welded Head Bolts are made by welding a ring of square iron around the end of the shank to form the head. The ring is generally bent up on the end of a bar as shown at A, Fig. 65, but not welded. This ring is cut off and placed on the end of the shank as shown at B. The joint in the ring should be left slightly open to allow for the expansion in welding. The ring is fastened to the end of the shank by striking it on one side and squeezing it against the shank. The bolt is put into the fire, heated to the welding heat, and the head welded up into the required shape. The ring should not be welded round at first, as it is difficult in this way to make a sound joint, there being a much better chance of doing sound work by welding the head directly square or hexagonal as required. No attention need be paid to the joint in the ring as this will take care of itself. Considerable care must be used in taking the welding heat, as all the heat which reaches the joint must pass through the ring and there is a good chance of burning the ring before the shank reaches the welding heat if the heating is not done slowly and carefully.

Fig. 67.

Tongs. Common flat jawed tongs, such as are used for holding light work up to about three-quarters of an inch thick, may be made as follows: Stock should be about three-quarters of an inch square. The first step is to make a bend near the end similar to A in Fig. 66. The bent stock is then laid across the anvil in the position shown at C and the eye formed by striking down upon it with a sledge hammer. A set hammer may be used for this work by placing the work flat side down on the top of the anvil and working down the stock for the eye, next to the shoulder, with the set hammer. To make the handle, enough stock may be taken and drawn out as shown at D and a complete handle forged in this way, or a small amount of stock may be taken and a short stub forged out. Enough round stock is then welded on to make the proper length

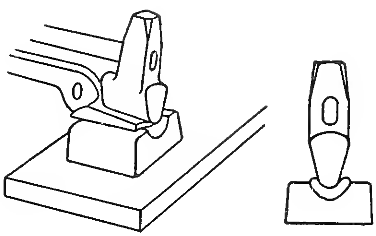

Fig. 68.

of handle, as shown in Fig. 67. The jaw is tapered down as shown at E. The last step is to punch the hole for the rivet. It is always a good plan to slightly crease the inside face of the jaw with a fuller, as this insures the jaws gripping the work firmly with the edges, and not touching it simply at one point in the center, as they sometimes do if this crease is not made. The tongs are then riveted together, the riveting being done with the round end of the hammer; in this way a head is formed on the rivet without upsetting the shank of the rivet very much where it passes through the hole. After riveting, the tongs will probably be stiff or hard to move. They may be loosened up by heating the eye part red hot and moving the handles forward and backward two or three times. They should then be firmly fitted to the work to be handled.

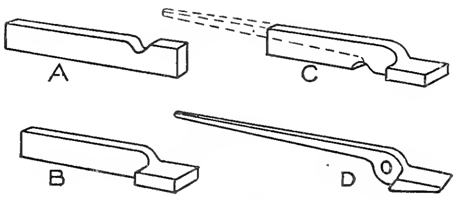

Fig. 69.

Tongs for Round Stock may be made by the general method described above, the only difference being that after the jaws are shaped, and before riveting together, they should be rounded up as illustrated in Fig. 68, using a fuller and swage as shown.

Light Tongs may be made from flat stock in the manner illustrated in Fig. 69. A cut is made in a piece of flat stock, with a fuller, near one end. This end is twisted over at right angles as shown at B. Another cut is made on the opposite side, as at C, and the end drawn out as indicated by the dotted lines. The tongs are then finished in the usual way. Tongs of this character may be used for very light work and are easily made.

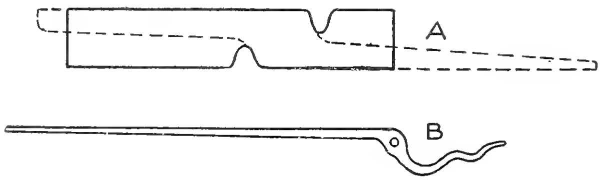

Fig. 70.

Pick-Up Tongs are made in much the same way as described above, the different steps being illustrated in Fig. 70.

Bolt Tongs may be made from round stock, although square may be sometimes used to advantage. The first step is to bend the bar in the shape shown in Fig. 71. This may be done by the fuller at the edge of the anvil, shown at A, or on a swage block as at B. The jaw proper is rounded and finished with a fuller and swage as shown in Fig. 72. The part between the jaw proper and the eye may be worked down into shape by the fuller and set hammer. The finishing may be done as indicated in Fig. 73. The eye and handle are then flattened down and drawn out, the tongs are punched, riveted together, finished, and fitted in the usual manner.

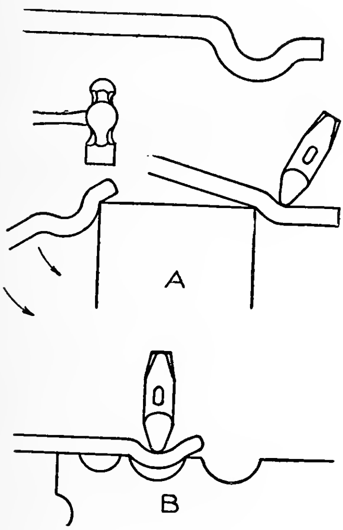

Fig. 71.

Ladles similar to the one shown in Fig. 74, may be made from two pieces welded together, one forming the handle, the other the bowl, or as sometimes is done, the handle may be riveted on. A piece of flat stock is first "laid out" as shown in Fig. 75. This is

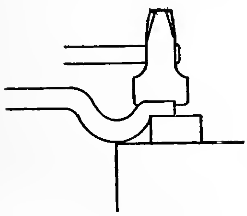

Fig. 72.

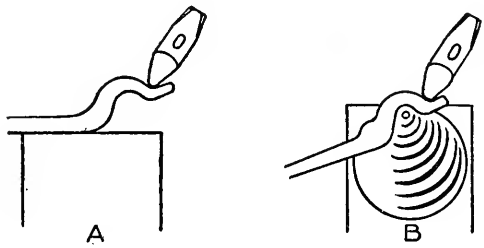

Fig. 73.

then cut out with a cold chisel and the handle welded on at the projecting point. The bowl is formed by heating the stock to an even heat and placing it over a round hole in a swage block or other object.

This hole should be slightly smaller than the outside diameter of the piece to be worked. To round the bowl it is worked as indicated in Fig. 76, with the pene end of the hammer. The forming should be done as much as possible by working near the edge of the piece rather than in the center. After the bowl has been properly shaped the edges should be ground off smooth and the lips formed as shown in Fig. 77. This is done by placing the part from which the lip is made against one of the small grooves in the side of the swage block and driving in a piece of small round iron, thus hollowing out the lip. The stock draws in somewhat when being rounded up. For the bowl of a ladle $3\frac{1}{2}''$ in diameter, the stock when flat should have an outside diameter of about four inches, and be one-eighth of an inch thick. Machine steel should be used for making the bowl. If ordinary wrought iron is used the metal is almost sure to split.

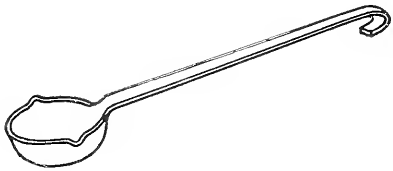

Fig. 74.

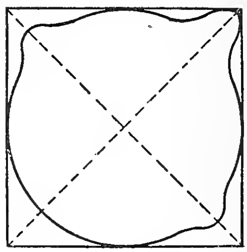

Fig. 75.

CALCULATION OF STOCK FOR FORGED WORK.

The calculations made previously for stock, were for stock which was simply bent into shape, the original section or size of the stock remaining unaltered. There is a large variety of work where the shape of the stock is considerably changed, and where it is essential to know the amount required to make a given forging. In doing this kind of work one rule must be remembered, *i.e.*, that the volume of the stock remains unaltered although its shape may be changed. Take as an example the forging shown in Fig. 78, let us determine the amount of stock required to make the piece.

The forging is made in the general manner shown in Fig. 79. A piece of stock should be taken large enough in section to make the block B, which will mean that it will be one inch wide and half an inch thick. The metal is worked by making the fuller cuts as shown in Fig. 79 and then drawing down the ends to the required size, it being, of course, necessary to know the amount of stock required for each end.

For convenience in calculating, the forging will be divided into

Fig. 76.

three parts, the rounded end A, the central rectangular block B, and the square end C. The stock used being $1'' \times \frac{1}{2}''$ the block B will of course require just two inches of stock. The end C would have a volume of $\frac{1}{2}'' \times \frac{1}{2}'' \times 3'' = \frac{3}{4}$ of a cubic inch. The stock has a volume of, $\frac{1}{2}'' \times 1'' \times 1''$, $= \frac{1}{2}$ of a cubic inch for each inch of length. The number of inches of stock required for the end C would then be $\frac{3}{4} \div \frac{1}{2}$ or $1\frac{1}{2}$ inches. The end A is a round shaft or cylinder four

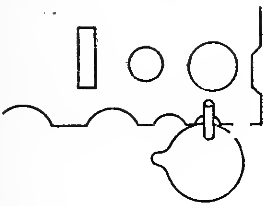

Fig. 77.

inches long and $\frac{1}{2}''$ in diameter. To find the volume of a cylinder, multiply the square of the radius ($\frac{1}{2}$ the diameter) by $3\frac{1}{7}$ and then multiply this result by the length of the cylinder. This will give the volume of A as $\frac{1}{4} \times \frac{1}{4} \times 3\frac{1}{7} \times 4 = \frac{11}{14}$ and the amount of stock required to make this

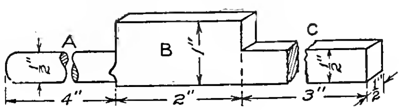

Fig. 78.

piece would be $\frac{11}{14} \div \frac{1}{2} = 1\frac{4}{7}$, which may be taken as $1\frac{5}{8}$ inches. There is, of course, some slight loss due to scaling in working the iron, which must be allowed for. This is generally done by adding a slight amount to the minimum amount required in each case. The amount of stock required in this case would be about,

Round shaft A. . . . . $1\frac{3}{4}''$
Block B . . . . $2''$
Square shaft C. . . . . $1\frac{5}{8}''$

Total. . . . . $5\frac{3}{8}''$

When the forging is started, cuts, which are afterward opened up with a fuller, may be made as shown by the upper sketch in Fig. 79.

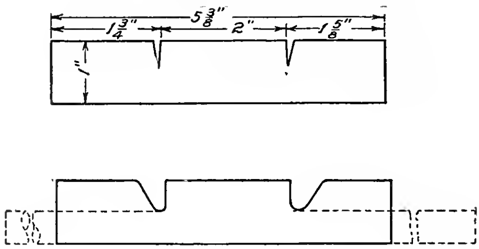

Fig. 79.

In this particular case it is not absolutely necessary that exactly the proper amount of stock be taken, as it would be a very easy matter to take a little too much and trim off the surplus from the ends, after the forging was made.

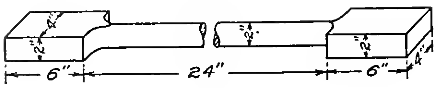

Fig. 80.

With the forging such as shown in Fig. 80, however, it is essential that the exact amount be used. This forging, which is the general shape of a connecting rod, would be started as shown in Fig. 81, and it is quite important that the distance A be correct. The stock used should be $2'' \times 4''$. Each end will, of course, require just $6''$ of stock. The center part is a cylinder $2''$ in diameter and $24''$ long, the volume of which would be $1'' \times 1'' \times 3\frac{1}{7} \times 24'' = 75\frac{3}{7}$ cubic inches, which may be taken as $75\frac{1}{2}$ cubic inches. For each inch in length the $2'' \times 4''$ stock would

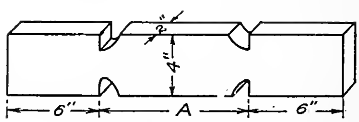

Fig. 81.

have a volume of 4″ × 2″ × 1″ = 8 cubic inches. Therefore it would require $75\frac{1}{2} \div 8 = 9\frac{7}{16}''$ of stock, to form the central piece, consequently the distance between the cuts shown at A in Fig. 81 will be $9\frac{7}{16}''$. To this might be added a slight allowance for loss in scaling. The total amount of stock required would be $6'' + 6'' + 9\frac{7}{16}'' = 21\frac{7}{16}''$. Any forging may generally be separated into simple parts of uniform shape as was done above. In this form the calculation may be easily made.

Weight of Forging. To find the weight of any forging the volume may first be found in cubic inches and this multiplied by .2779, the weight of wrought iron per cubic inch. If the forging be made of steel, the figures .2936 should be used in place of .2779. This gives the weight in pounds. Below is given the weight of wrought iron, cast iron and steel both in pounds per cubic inch and per cubic foot.

Cast Iron	450 per cu. ft.	.2604 per cu. inch.
Wrought Iron	480 " " "	.2779 " " "
Steel	490 " " "	.2936 " " "

Suppose it were required to find the weight of the forging shown in Fig. 78. A has a volume of $\frac{11}{14}$ cubic inch, C $\frac{3}{4}$ cubic inch and B 1 cubic inch, making a total of $2\frac{15}{28}$ cubic inches. If the forging were made of wrought iron it would weigh $2\frac{15}{28} \times .2779 =$ .7 lbs. The forging in Fig. 80 has a total volume of $171\frac{3}{7}$ cubic inches and would weigh, if made of wrought iron, 47.64 lbs.

A much easier way to calculate weights is to use tables such as given on pages 46 and 47. The first table gives the weights *per foot* of flat iron bars. In the second table is given the weights for each foot of length of round and square bars.

When using the table on page 46 to ascertain the weight of any size of flat iron per foot of length, look in the first column at the left for the thickness. Then follow out in a horizontal line to the column giving the width. The number given will be the weight in pounds of one foot of the desired size.

To use the table for calculating weights, the procedure would be as follows:

Taking Fig. 80 as an example, each end is 2″ × 4″ and 6″ long and the two ends would be equal, as far as weight is concerned, to a bar

WEIGHT OF FLAT ROLLED IRON.

Length, 12 inches.

Thickness.	WIDTHS.																				
	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	3
$\frac{1}{8}$	.208	.260	.313	.365	.417	.469	.521	.573	.625	.677	.729	.781	.833	.885	.938	.989	1.04	1.09	1.15	1.20	1.25
$\frac{1}{4}$	.416	.521	.625	.729	.833	.938	1.04	1.15	1.25	1.35	1.46	1.56	1.67	1.77	1.88	1.98	2.08	2.18	2.29	2.39	2.50
$\frac{3}{8}$	.624	.781	.938	1.09	1.25	1.41	1.56	1.72	1.88	2.03	2.19	2.35	2.50	2.65	2 81	2.97	3.13	3.28	3.44	3.59	3.75
$\frac{1}{2}$	.833	1.04	1.25	1.46	1.67	1.88	2.08	2.29	2.50	2.71	2.92	3.13	3.33	3.54	3.75	3.96	4.17	4.37	4.58	4.79	5.00
$\frac{5}{8}$		1.30	1.56	1.82	2.08	2.35	2.60	2.86	3.13	3.39	3.65	3.91	4.17	4.43	4.69	4.95	5.21	5.47	5.73	5.99	6.25
$\frac{3}{4}$			1.88	2.19	2.50	2.81	3.13	3.44	3.75	4.06	4.38	4.69	5.00	5.31	5.63	5.94	6.25	6.56	6.88	7.19	7.50
$\frac{7}{8}$				2.55	2.92	3.28	3.65	4.01	4.38	4.74	5.10	5.46	5.83	6.19	6.57	6.92	7.29	7.65	8.02	8.38	8.75
1					3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67	7.08	7.50	7.91	8.33	8.75	9.17	9.58	10.00
$1\frac{1}{8}$						4.22	4.69	5.15	5.63	6.09	6.56	7.03	7.50	7.97	8.44	8.90	9.38	9.84	10.31	10.78	11.25
$1\frac{1}{4}$							5.21	5.73	6.25	6.77	7.29	7.81	8.33	8.85	9.38	9.89	10.42	10.94	11.46	11.98	12.50
$1\frac{3}{8}$								6.30	6.88	7.45	8.02	8.59	9.17	9.74	10.32	10.88	11.46	12.03	12.60	13.17	13.75
$1\frac{1}{2}$									7.50	8.12	8.75	9.37	10.00	10.62	11.25	11.87	12.50	13.12	13.75	14.37	15.00
$1\frac{5}{8}$										8.80	9.45	10.14	10.83	11.51	12.19	12.86	13.54	14.22	14.90	15.57	16.25
$1\frac{3}{4}$											10.21	10.94	11.67	12.40	13.13	13.85	14.58	15.31	16.04	16.77	17.50
$1\frac{7}{8}$												11.72	12.50	13.28	14.06	14.84	15.63	16.41	17.19	17.97	18.75
2													13.33	14.16	15.00	15.83	16.67	17.50	18.33	19.16	20.00
$2\frac{1}{8}$														15.05	15.94	16.81	17.71	18.59	19.48	20.36	21.25
$2\frac{1}{4}$															16.88	17 80	18.75	19.69	20.63	21.56	22.50
$2\frac{3}{8}$																18.80	19.79	20.78	21.78	22.76	23.75
$2\frac{1}{2}$																	20 83	21.87	22.93	23.96	25.00
$2\frac{5}{8}$																		22.97	24.07	25.16	26.25
$2\frac{3}{4}$																			25.21	26.35	27.50
$2\frac{7}{8}$																				27.55	28.75
3																					30.00

2″ × 4″ and 1 ft. long. From the table it will be seen that a bar 2″ × 2″ weighs 13.33 lbs. and a bar 2″ × 4″, being twice as thick would weigh twice that, or 26.66 lbs. A bar two inches in diameter weighs 10.47 lbs. per foot and as the central part of the forging is 2 ft. long, it will weigh 20.94 lbs., making the total weight of the forging 47.6 lbs.

Finish. Many forgings are machined or "finished" after leaving the forge shop. The drawings are always made to represent the finished work and therefore give the finished dimensions, and it is necessary when this finishing is to be done, to make allowance for it when making the forging, that all parts which have to be *finished* or "machined" may be left with extra metal to be removed in finishing. The parts required to be finished are generally marked on the drawing. Sometimes the finished surfaces have the word "finished" marked on them. Sometimes the finishing is shown simply by the symbol f, as used in Fig. 82, showing that the shafts and pin only of the crank are to be finished. When all surfaces of a piece are to be finished the words *finish all over* are sometimes marked on the drawing.

WEIGHTS OF ROUND AND SQUARE ROLLED IRON.

Length, 12 Inches.

Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.	Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.	Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.
0								
1/16	.013	.010	11/16	24.08	18.91	3/8	96.30	75.64
1/8	.052	.041	3/4	25.21	19.80	7/16	98.55	77.40
3/16	.117	.092	13/16	26.37	20.71	1/2	100.8	79.19
1/4	.208	.164	7/8	27.55	21.64	9/16	103.1	81.00
5/16	.326	.256	15/16	28.76	22.59	5/8	105.5	82.83
3/8	.469	.368	3	30.00	23.56	11/16	107.8	84.69
7/16	.638	.501	1/16	31.26	24.55	3/4	110.2	86.56
1/2	.833	.654	1/8	32.55	25.57	13/16	112.6	88.45
9/16	1.055	.828	3/16	33.87	26.60	7/8	115.1	90.36
5/8	1.302	1.023	1/4	35.21	27.65	15/16	117.5	92.29
11/16	1.576	1.237	5/16	36.58	28.73	6	120.0	94.25
3/4	1.875	1.473	3/8	37.97	29.82	1/8	125.1	98.22
13/16	2.201	1.728	7/16	39.39	30.94	1/4	130.2	102.3
7/8	2.552	2.004	1/2	40.83	32.07	3/8	135.5	106.4
15/16	2.930	2.301	9/16	42.30	33.23	1/2	140.8	110.6
1	3.333	2.618	5/8	43.80	34.40	5/8	146.3	114.9
1/16	3.763	2.955	11/16	45.33	35.60	3/4	151.9	119.3
1/8	4.219	3.313	3/4	46.88	36.82	7/8	157.6	123.7
3/16	4.701	3.692	13/16	48.45	38.05	7	163.3	128.3
1/4	5.208	4.091	7/8	50.05	39.31	1/8	169.2	132.9
5/16	5.742	4.510	15/16	51.68	40.59	1/4	175.2	137.6
3/8	6.302	4.950	4	53.33	41.89	3/8	181.3	142.4
7/16	6.888	5.410	1/16	55.01	43.21	1/2	187.5	147.3
1/2	7.500	5.890	1/8	56.72	44.55	5/8	193.8	152.2
9/16	8.138	6.392	3/16	58.45	45.91	3/4	200.2	157.2
5/8	8.802	6.913	1/4	60.21	47.29	7/8	206.7	162.4
11/16	9.492	7.455	5/16	61.99	48.69	8	213.3	167.6
3/4	10.21	8.018	3/8	63.80	50.11	1/4	226.9	178.2
13/16	10.95	8.601	7/16	65.64	51.55	1/2	240.8	189.2
7/8	11.72	9.204	1/2	67.50	53.01	3/4	255.2	200.4
15/16	12.51	9.828	9/16	69.39	54.50	9	270.0	212.1
2	13.33	10.47	5/8	71.30	56.00	1/4	285.2	224.0
1/16	14.18	11.14	11/16	73.24	57.52	1/2	300.8	236.3
1/8	15.05	11.82	3/4	75.21	59.07	3/4	316.9	248.9
3/16	15.95	12.53	13/16	77.20	60.63	10	333.3	261.8
1/4	16.88	13.25	7/8	79.22	62.22	1/4	350.2	275.1
5/16	17.83	14.00	15/16	81.26	63.82	1/2	367.5	288.6
3/8	18.80	14.77	5	83.33	65.45	3/4	385.2	302.5
7/16	19.80	15.55	1/16	85.43	67.10	11	403.3	316.8
1/2	20.83	16.36	1/8	87.55	68.76	1/4	421.9	331.3
9/16	21.89	17.19	3/16	89.70	70.45	1/2	440.8	346.2
5/8	22.97	18.04	1/4	91.88	72.16	3/4	460.2	361.4
			5/16	94.08	73.89	12	480.	377.

The allowance for finishing on small forgings is generally about $\frac{1}{16}''$ on each surface. Thus, if a block were wanted to finish $4'' \times 2'' \times 1''$ and $\frac{1}{16}''$ were allowed for finishing, the dimensions of the forging would be $4\frac{1}{8}'' \times 2\frac{1}{8}'' \times 1\frac{1}{8}''$. On a forging like Fig. 80, about $\frac{1}{8}''$ allowance would be made for finishing, if it were called for. Thus the diameter of the central shaft would be $2\frac{1}{4}''$, the thickness of the ends $2\frac{1}{4}''$, etc. On larger work $\frac{1}{4}''$ is sometimes allowed for machining. The amount of finish allowed depends to a large extent on the way the forging is to be finished. When hand finishing is done, that is, filing or scraping, $\frac{1}{32}''$ or even $\frac{1}{64}''$ is enough; when all of the finishing is done in a lathe or other machine, more material should be left.

When a forging calls for *finish*, in calculating the amount of stock, or weight, the dimensions taken should not be the actual ones

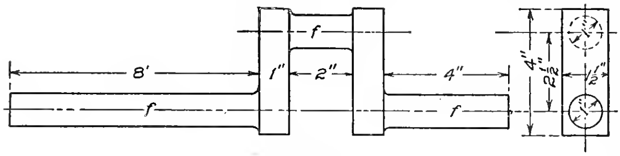

Fig. 82.

shown by the drawing, but these dimensions with the proper allowance made for *finish*.

Crank Shafts. There are several methods of forging crank shafts. The more commonly used is the commercial method, as described in detail below. When forgings were mostly made of wrought iron, the

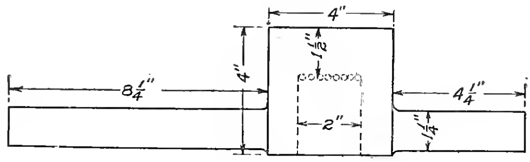

Fig. 83.

cranks were welded up of several pieces. One piece was used for each of the shafts, one piece for each cheek or side, and another piece for the crank pin. Cranks are sometimes bent up out of round stock, but this method is only used on small work. The common method now employed where machine steel is used, is to forge the crank from one solid piece of material. The stock is taken large enough to shape

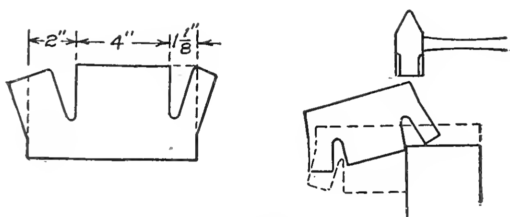

Fig. 84.

the largest part of the crank without any upsetting. If a crank be required similar to Fig. 82, the size of stock to be used should be $1\frac{1}{2}''$ by $4''$ in section.

When the forging leaves the shop, it will be left in a shape similar to the shape shown by the solid lines in Fig. 83, the dimensions shown here allowing for the necessary finishing. The crank itself would be left in a solid block, the throat being afterwards cut out as indicated by the dotted lines. A line of holes is first drilled as shown, and the block of metal to be taken out is removed by making two slits with a cold saw and the block then knocked out with a sledge hammer. It is possible to form this throat by chopping out the surplus metal with a hot chisel in the forge shop, but on small cranks in particular, such as here shown, it is generally cheaper in a well equipped shop to use the first method.

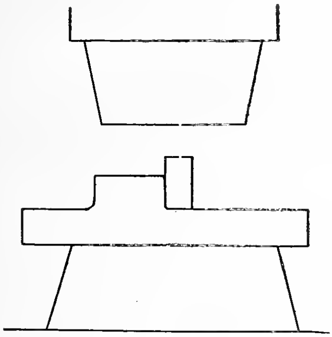

Fig. 85.

The first step is of course to calculate the amount of stock required. The long end would contain 10.13 cubic inches. As each inch of stock contains 6 cubic inches, it would require 1.7″ of stock to form this end provided there was no waste from scale. Waste does take place, however, and must be allowed for, so about 2″ of stock should be taken. The short end contains 5.22 cubic inches and would require .87″ of stock, without allowance for scale. About $1\frac{1}{8}$″ should be taken. The total stock then required would be $7\frac{1}{8}$″.

The first step is to make the cuts, and spread the ends as shown in Fig. 84. These ends may then be forged down with a sledge hammer as illustrated or may be worked out under the steam hammer, the finishing up against the shoulders being done as illustrated in Fig. 85. The shaft may be rounded down and finished between swages. Care must be taken to see that the cuts are properly spread before drawing out the ends. If the cuts are left without spreading, the metal will act somewhat after the manner shown in Fig. 86. The top part of the bar, as it is

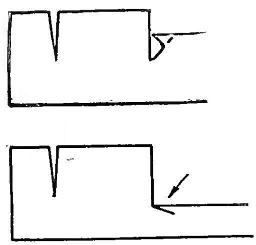

Fig. 86.

worked down, will fold over and leave a crack or *cold shut* as illustrated. When the metal starts to act in this way the fault should be corrected by trimming off the overlapping corner along the dotted line shown in the upper sketch.

Multiple-Throw Cranks. When a crank shaft has more than one

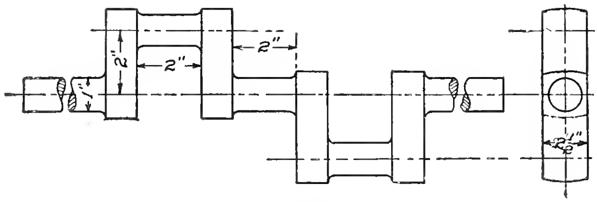

Fig. 87.

crank or crank pin, it is spoken of as a multiple-throw crank. A double-throw crank is a crank shaft with two cranks. A three throw or triple throw, one with three cranks, etc. As a general rule multiple-throw cranks are forged flat, *i.e.*, the cranks are all forged in

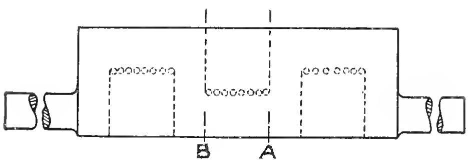

Fig. 88.

line with each other. The shafts and pins are then rough turned and the cranks are heated and twisted into shape. The forging for the double-throw crank shown in Fig. 87 would first be made in the general shape shown in Fig. 88. The parts shown by the dotted lines would then be cut out with a drill and saw as described above, and the shafts and pins rough turned, *i.e.*, turned round, but left as large as possible. The forging is then returned to the forge shop where it is heated and the cranks twisted to the desired angle. When twisting, the crank would be gripped just to the right of the point marked A. This may be done with a vise, or wrench if the crank is small, or

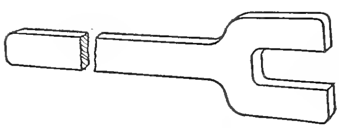

Fig. 89.

it may be held under the steam hammer. The twisting may be done with a wrench similar to Fig. 89 which may be easily made by bending up a U of flat stock and welding on a handle.

A Three-Throw Crank without any intermediate bearings is shown in Fig. 90. The rough forging for this is shown in Fig. 91. The extra metal is removed as indicated by the dotted lines and the twisting done as described before.

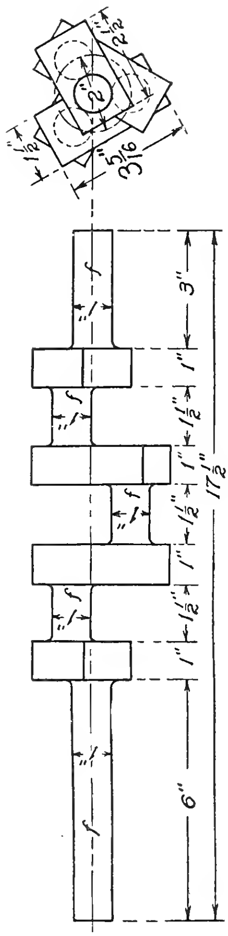

Fig. 90.

Weldless Rings. Rings and eyes forged solid without any welds may be made in the general manner described below. As an example, suppose it be required to make a ring such as illustrated in Fig. 92. A flat bar is first forged rounding on the ends, punched and split as shown, this split is opened out and the ring hammered into shape. It is necessary, of course, to calculate the amount of stock required. This may be done as follows: The first step is to determine the area of the ring, which is done by taking the area of the outside circle, and subtracting from it the area of the inside circle.

Area of outside circle	12.57	sq. in.
" " inside "	7.07	" "
" " ring	5.50	" "

The stock used when making small thin rings should be twice

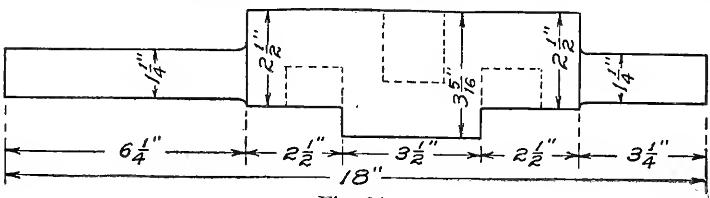

Fig. 91.

the width of the side of the ring to which is added at least one-quarter of an inch. When the bar is split the stock is more or less deformed and when worked back into shape is slightly thinned. Although no stock is lost by the hammering, an allowance must be made for the thinning and stretching and it is necessary to make the stock slightly wider on this account, as noted above. Allowing $\frac{1}{2}''$ for hammering, and taking stock $1\frac{1}{2}''$ wide, the amount of stock required would be $5.5 \div 1.5$, equal to $3.66''$. Allowing a small amount for loss by scale, etc., $3\frac{11}{16}''$ of stock should be taken. In making this calculation, the thickness of the stock is not taken into consideration, as the thickness of the finished ring is the same as the stock. This general method is used on a large variety of work, particularly where rings are to be made of tool steel and should be made without a weld.

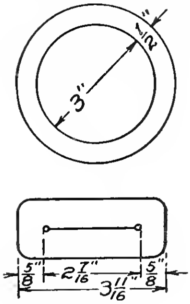

Fig. 92.

Another method of making weldless rings, under the steam hammer, is illustrated in Fig. 93. The proper amount of stock is first forged into a disk, a hole is punched into this disk and a *mandril* inserted. A U-shaped rest is then placed on the anvil of the steam hammer and the mandril laid on this. The ring is turned on the mandril and forged into shape. Larger and larger mandrils are substituted as the hole in the ring increases in size.

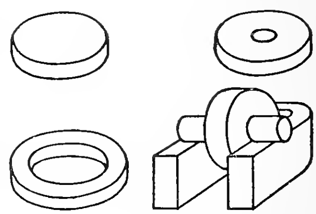
Fig. 93.

Lever with Boss. The following description will serve for

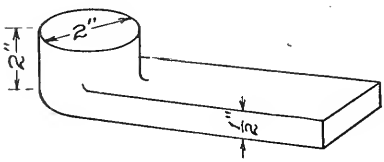

Fig. 94.

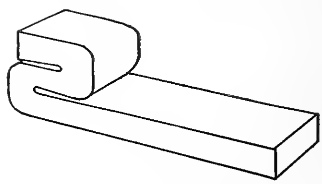
Fig. 95.

many forgings of the same general shape. The forging shown in

Fig. 94 will be taken as an example. There are two general ways of making work of this character. One is to take stock of the proper size for the lever and weld on a chunk for the boss. The other is to take stock large enough to form the boss and draw out either the entire

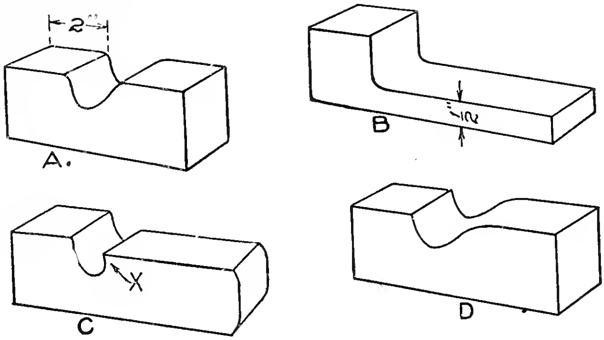

Fig. 96.

lever, or a short stub, to which the lever is welded. The work may be started for the first method by doubling over the end of the stock as illustrated in Fig. 95. This is welded up and rounded by the same general method as afterwards described for the other boss. The

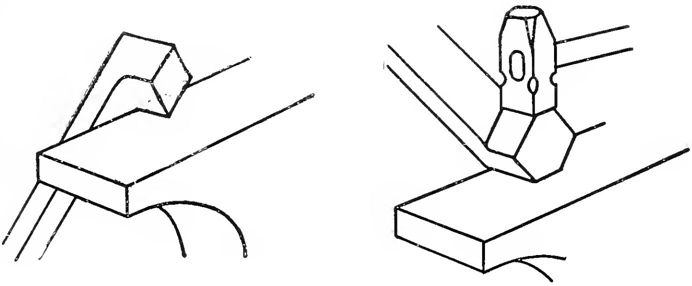

Fig. 97.

second method of shaping is illustrated in Fig. 96. The stock in this case would be two inches square. The fuller cut is first made as illustrated at A. The end is then drawn out into the shape shown at B. In drawing out the stock, if the metal be allowed to flatten down into shape like C, a "cold-shut" will be formed close to the boss, as the corner at X will overlap and work into the metal, making a crack in the work. The proper way to draw out the stock is shown at D. The square piece left for the boss is rounded up over the corner of the anvil as shown in Fig. 97. Sometimes to make the work easier to get at, the end is bent back out of the way and straightened after the forging is completed. The boss may be smoothed up by using a set hammer or swage in the manner indicated.

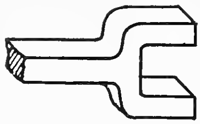
Fig. 98.

Knuckles. One example of a very numerous class of forgings is shown in Fig. 98. This is the shape used for what are known as marine ends of connecting rods, knuckle joints on valve rods, and various other places. A common method employed to make such a forging is shown in Fig. 99. Two fuller cuts are first made as indicated at A and the part for the shaft of the forging drawn out. The thick end is then punched and split, as indicated at B. This split end is opened up and forged out in the manner indicated in Fig. 100, if the work is done on the anvil. Fig. 101 illustrates the method of working out under the steam hammer, the end being first flattened as indicated and then gradually tipped up to the position shown by the dotted lines. When drawn to size, the ends are flattened out straight across and the finishing done around the shank with a fuller as indicated in Fig. 102. The forging is then bent into a U-shaped loop of approximately the shape of the finished knuckle. A bar of iron the same dimension as the inside of the finished knuckle is inserted between the sides of the loop, and the sides closed down flat as shown in Fig. 103. Fig. 104 shows other forgings which may be shaped by this same general method. Trim E, Fig. 99, to the dotted line.

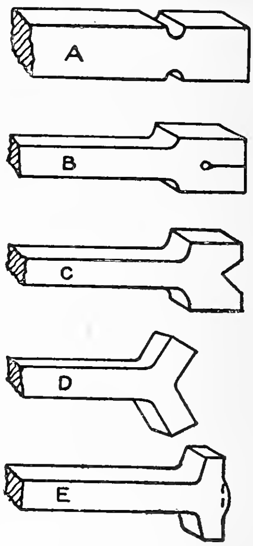

Fig. 99.

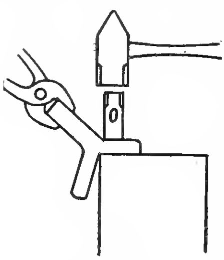
Fig. 100.

Wrenches. A simple tool that is frequently called for is the S wrench. This wrench is usually made with a gap at each end suited for nuts of different sizes. It is shown complete in Fig. 105.

The jaws at the end should be parallel with each other. A line drawn from one jaw to the other should make an angle of 30 degrees with the center line of each. There are two ways in which such a wrench can

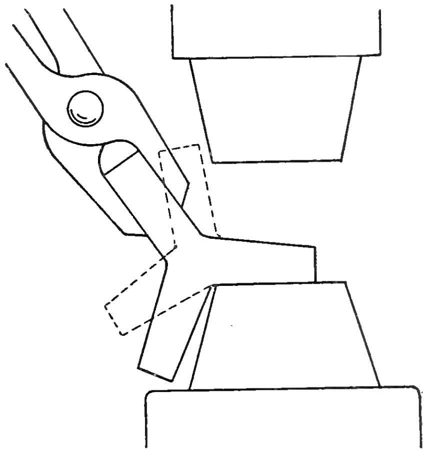

Fig. 101.

be forged. One is to forge the jaws separately and then weld to the handle. In the other the jaws are cut from a solid piece of metal and the iron between is then drawn down to the proper size for the handle. The latter is preferable, since it avoids all welds. To make the wrench by the second process, select a piece of steel large

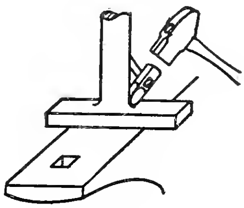

Fig. 102

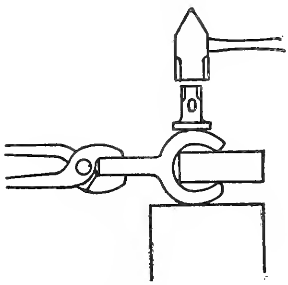

Fig. 103.

enough to form the head. Fuller it down back of the head as shown in A, Fig. 106, at *a a*. Round the end and punch the hole *b*. Next treat the other end in the same way and draw out the intermediate metal giving the form shown at B. Now cut out the holes *b b* securing the form shown at C. It now remains to bend the heads to the proper angle and give the desired curve to the shank. In forging such

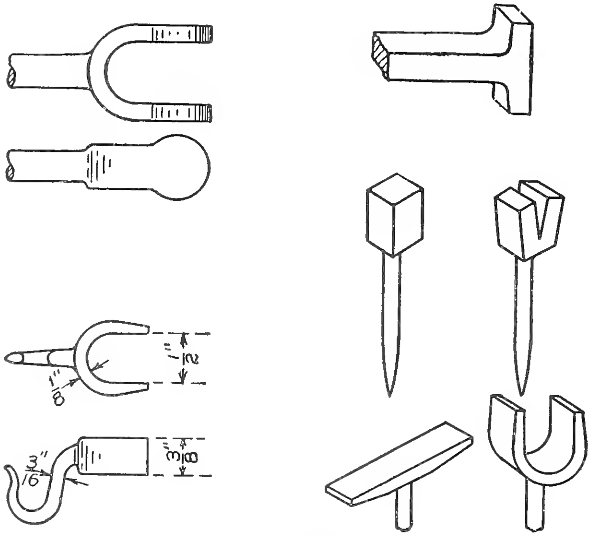

Fig. 104.

a wrench the outer edges should be slightly rounded so that they will not cut the hand. The inside of the jaws should be perfectly square with sharp edges. This finish can be best obtained by filing.

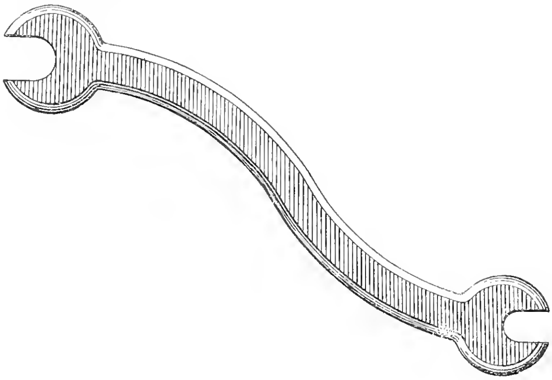

Fig. 105.

Socket Wrenches are made in several ways. The easiest way in "hurry up" work is the method illustrated in Fig. 107. A stub is forged to the same size and shape as the finished hole is to be, and a ring, bent up of thin flat iron, welded round this stub. When finishing the socket, a nut or bolt head of the same size that the wrench is intended to fit, should be placed in the hole and the socket finished

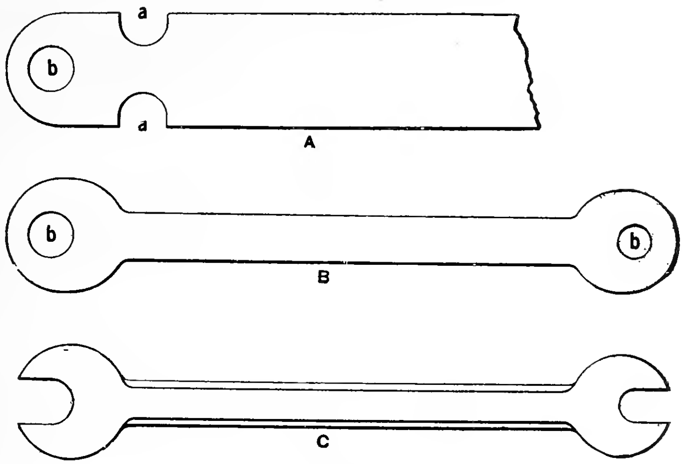

Fig. 106.

over this, between swages. A better way of making wrenches of this kind is to make a forging having the same dimensions as the finished wrench with the socket end left solid. The socket end is then

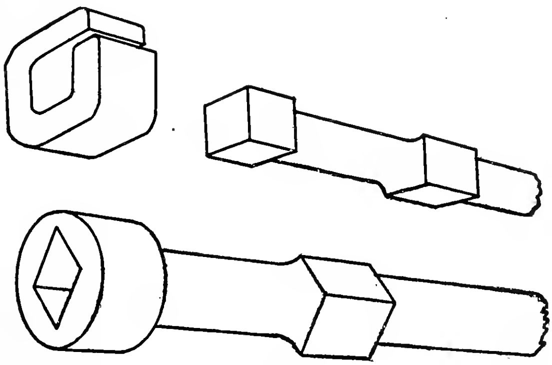

Fig. 107.

drilled to a depth slightly greater than the socket is wanted. The diameter of the drilled hole should be as shown in Fig. 108, equal to the shortest diameter of the finished hole. After drilling, the socket end is heated and a punch, of the same shape as the finished hole, driven into it. The end of the punch should be square across and the corners sharp. As the punch is driven in, it will shave off some of the metal around the corners of the hole and force it to the bottom,

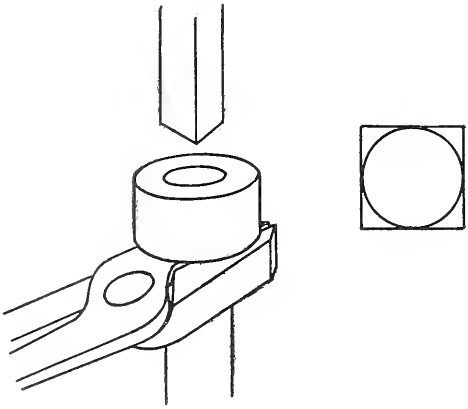

Fig. 108.

thus making it necessary to have the drilled hole slightly deeper than the finished socket.

Ladle Shank. The ladle shank shown in Fig. 109 may be made in several ways. The ring may be welded up of flat stock and a round handle welded on with a T-weld. Or square stock may be taken, worked out and split as shown in Fig. 110, these split ends being afterwards welded to make the ring. Another method of making without any welds at all would be to split the stock as indicated in Fig. 111 and work out in the same way that a weldless ring is made. The latter method would take more time but would make the sounder forging.

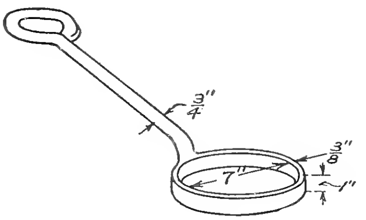

Fig. 109.

Molder's Trowel. The molder's trowel illustrated in Fig. 112 is a sample of a large class of forgings, having a wide, thin face with a comparatively small thin stem forged at one end. The stock used for the trowel would be about $\frac{1}{4}'' \times 1''$. This is thick enough to allow for the formation of a ridge at R. Fig. 113 shows the general method employed. Two nicks are first made with fullers as illustrated at A and the stem drawn down, roughly, to size. This stem is then bent up at right angles and forged to a square corner as illus-

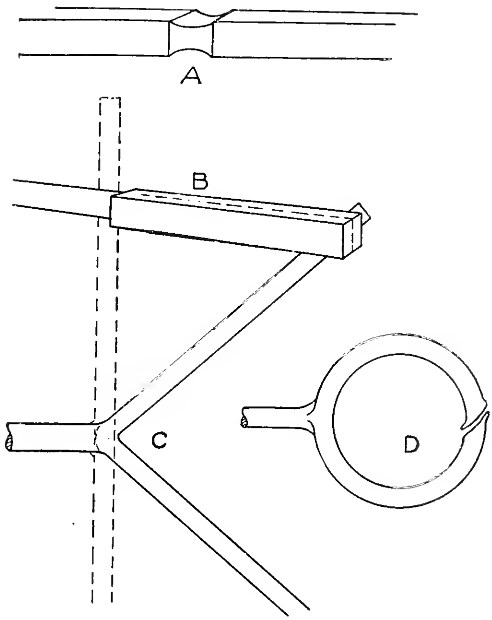

Fig. 110.

trated at B, in the same general manner as the square corner of a bracket is formed. When flattening out the blade in order to leave the ridge shown at R, Fig. 112, the work should be held as shown at C, Fig. 113. Here the handle is held pointing downward and against the side of the anvil. By striking down on the work and covering the part directly over the edge of the anvil with the blows, all the metal on the anvil will be flattened down. By swinging the piece around

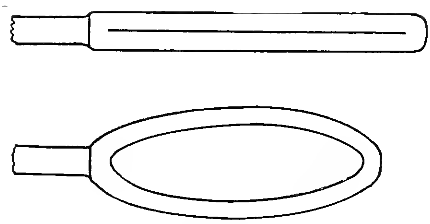

Fig. 111.

into a reversed position, the other edge of the blade is then thinned down. This leaves the small triangle shown by the dotted lines unworked and forms the ridge shown at R. The same result could be obtained by placing the work flat on the anvil face and using a set hammer.

TOOL STEEL WORK.

Tool Steel. Although not strictly true technically, for ordinary purposes tool steel may be considered simply a combination of iron and carbon. The more common grade contains perhaps 1 per cent

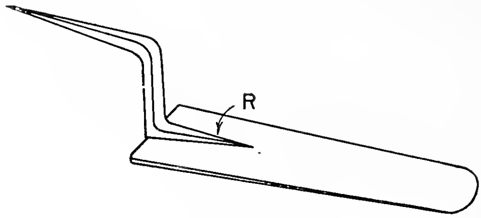

Fig. 112.

of carbon. Machine steel and wrought iron do not contain this element carbon to any great extent. If a piece of wrought iron or machine steel be heated red hot and suddenly cooled, the metal remains practically as it was before heating, but if a piece of tool steel be subjected to this treatment, it becomes very hard and brittle. By a modification of this heating and cooling, almost any degree of hardness may be imparted to the steel. When tool steel is heated red hot and then suddenly cooled, becoming very hard, the process is known as *Hardening*. For more detailed explanations of hardening, tempering, etc., the student is referred to "Tool Making", as merely general statements and explanations

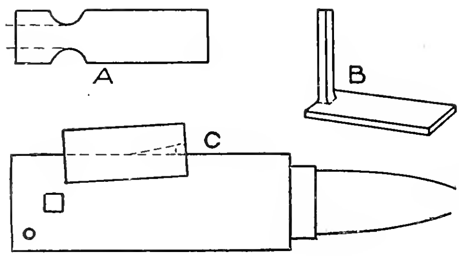

Fig. 113.

will be given here. If two pieces of tool steel be heated, one to a comparatively high heat and one to a lower heat and the two pieces suddenly cooled in water, if the ends be then snapped off, a decided difference will be noticed in the fractures. The piece cooled from the higher temperature will have a very coarse grain, while that cooled from the lower temperature will have a finer grain. Two things are fixed when hardening a piece of tool steel—hardness and grain. The hardness depends upon the rapidity with which the steel is cooled. The more rapid the cooling, the harder the steel. The grain depends upon the heat from which the steel is cooled. There is only one heat from which the steel may be cooled and have the proper grain. This heat is known as the *hardening heat.* A piece of steel when cooled from this hardening heat has an extremely fine silky looking grain and is left very hard and brittle.

Hardening. The *hardening heat* varies with the amount of carbon the steel contains, the greater the percentage of carbon, the lower the hardening heat.

To determine the hardening heat, a bar $\frac{1}{4}''$ or $\frac{3}{8}''$ square is heated to a good red heat on one end, and cooled in cold water. This end is then tested, if too hard to file it has been hardened, and the heat from which it was cooled was either the proper hardening heat or some higher heat. If the end can be filed it was cooled from some heat below the hardening heat. If the end proves to be soft it should be rehardened by cooling from a higher heat, if hard it should be broken off and the fracture examined. If the grain of the broken end is very fine the steel is properly hardened, if coarse, it was heated too hot and the end should be rehardened at a lower heat. The experiment should be repeated until the operator is able to give the steel a very fine grain every time. Any variation either above or below the hardening heat will make the grain coarse. A temperature lower than the critical heat will not make the steel as coarse in structure as a temperature correspondingly higher, but there will be some difference.

Hardening Baths. Various baths are used for cooling steel when hardening, on account of the different rates at which they cool the heated metal. An oil bath is used when the steel is wanted tougher and not excessively hard, as the oil cools the steel slower than water. Brine or an acid bath are used when the steel is wanted very hard, as they absorb heat more rapidly than water. For excessively hard work mercury, or quicksilver, is sometimes used, as it absorbs the heat very rapidly.

General Laws of Hardening. The two simple general facts of hardening that must be remembered are as follows: First, the heat from which the steel is cooled determines the grain; secondly, the rapidity of cooling determines the hardness, everything else being equal, the more rapid the cooling, the harder the steel.

Annealing. When steel is annealed it is softened. This is done by cooling the steel very slowly from the hardening heat, the cooling being done as slowly as possible. This cooling in some cases takes several days. As noted under hardening, the rapidity of cooling determines the final hardness of the steel and if the steel be cooled very slowly it will be left very soft; while if cooled rapidly, it will be left hard. This difference in the time taken to cool the steel is the only difference between hardening and annealing. Both should be done from the same heat. The details of various methods of annealing are described in "Tool Making".

Tempering. Tools which are simply hardened as described above are, with few exceptions, too brittle for use and it is necessary to reduce the brittleness. This process is known as tempering. Tools are always left as hard as it is possible to leave them and still have them tough enough for the work for which they are intended. In reducing the brittleness of the steel, some of the hardness is of necessity taken out and tempering is therefore sometimes spoken of as a reduction of the hardness, but it is in reality, merely a reduction of the brittleness. After a tool or piece of steel has been hardened, some of the brittleness is taken out by a slight reheating to a low temperature. These temperatures vary from 200° F., to about 650° F. These temperatures are determined in various ways. The simplest and perhaps the most commonly used, is to polish the steel after it has been hardened and then reheat the part to be tempered until the surface shows a certain color.

If any bright piece of iron or steel be heated, when a temperature of about 400° F is reached, the surface will turn pale yellow. As the temperature is increased this yellow grows darker until at about 500° F it is a decided brown. When 600° F is reached, a deep blue color shows on the surface. These colors are produced by a thin scale which is formed on the surface of the steel and are no indication whatever of hardness, merely showing to what heat steel or iron has been raised.

Tempered tools may be divided into two general classes: First, those which have one edge only tempered; second, those which are tempered throughout. To the first class belong most lathe tools, cold chisels, etc. To the second class, taps, dies, milling cutters, etc. When tempering tools of the first class, considerably more of the tool is heated than is wanted hardened. The cutting edge is then hardened by cooling in water. The tool is then taken from the water, the hardened edge polished, and reheated by allowing the heat to "come down" from the body of the tool, which is still quite hot. Tools of the second class are first hardened by being heated to a uniform hardening heat and then cooled completely. The tool is then polished and the temper drawn by placing the steel either over the fire or on a piece of metal which has previously been heated red hot. It is absolutely essential that the steel should be heated to a uniform temperature when hardened. The parts to be hardened should show no difference whatever in color when being heated. If points or corners of tools are allowed to come to the hardening temperature before the body of the tool is hot, these overheated corners are almost sure to crack off. Absolute uniformity in heating to the proper hardening heat is necessary to insure success in hardening operations.

Lead Bath. To insure uniformity in heating, various methods are used, and when the work is done on a large scale the heating is generally done in a furnace fired with gas. Another common method is to heat the steel in a bath of red hot lead. The lead is heated in a pot or crucible, to the hardening heat of the steel. The top of the lead is covered with powdered charcoal or coal to prevent the formation of the slag or dross on top. When steel is heated in lead it must be perfectly clean, dry, and free from rust.

TOOL FORGING AND TEMPERING.

Forging Heat. Before attempting any work with tool steel, a piece of scrap steel is to be experimented with, heated and hardened several times at various heats until the manipulator is sure of the effect of the various heats upon the grain of the steel. The steel should also be experimented with to determine just how high a heat it will stand. When heavy forging is to be done, *i. e.*, when the first rough shaping is done upon a tool, a comparatively high heat should be used. The steel should be forged at about what might be called a good yellow heat. The lighter hammering, when finishing, should be done at a lower heat, about the hardening heat. Very little, if any, hammering should be done below the hardening heat. If the grain

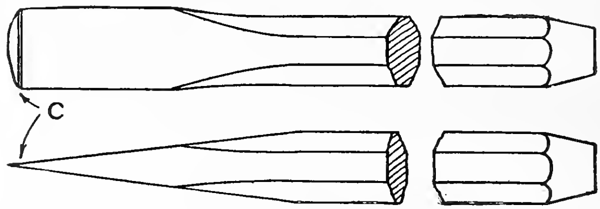

Fig. 114.

of the steel has been raised by too high a heat, it can generally be quite decidedly reduced by a little hammering at some heat above the hardening temperature.

Cold Chisels. The stock should be heated to a good yellow heat and forged into shape and finished as smoothly as possible. When properly forged, the end or cutting edge will bulge out as shown in Fig. 114. It is a good plan to simply nick this end across at the point where the finished edge is to come and then after the chisel has been tempered, this nicked end may be broken off and the grain examined. Whenever possible, it is a good plan to leave an end of this sort on a tool that may be broken off after the tempering is done. When hardening, a chisel should be heated red hot about as far back from the cutting edge as the point A, Fig. 115. Care must be taken to heat slowly enough to keep the part being heated at a uniform temperature throughout. If the point becomes overheated, it should not be dipped in water to cool off, but allowed to cool in the air to below the hardening heat and then reheated more carefully. When properly heated, the end should be hardened by dipping in cold water to the point B. As soon as the end is cold, the chisel should be withdrawn from the water and the end polished bright by rubbing with a piece of emery paper. The part of the chisel from A to B will still be red hot

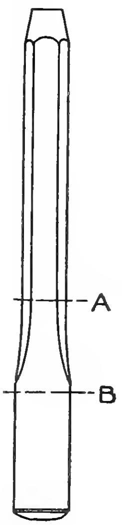

Fig. 115.

and the heat from this part will gradually reheat the hardened point. As this cold part is reheated, the polished surface will change color showing at first yellow, then brown, and at last purple. As soon as the purple (almost blue color) reaches the nick at the end, the chisel

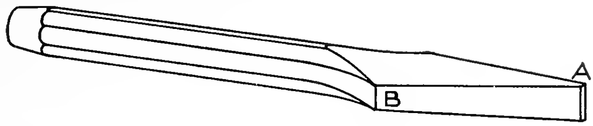

Fig. 116.

should be completely cooled. The waste end may now be snapped off and the grain examined. If the grain is too coarse the tool should be rehardened at a lower temperature, while if the metal is too soft, and the end bends without breaking, it should be rehardened at a higher temperature.

Cape Chisel. This is a chisel used for cutting grooves, key seats, etc. The end A should be wider than the rest of the blade back

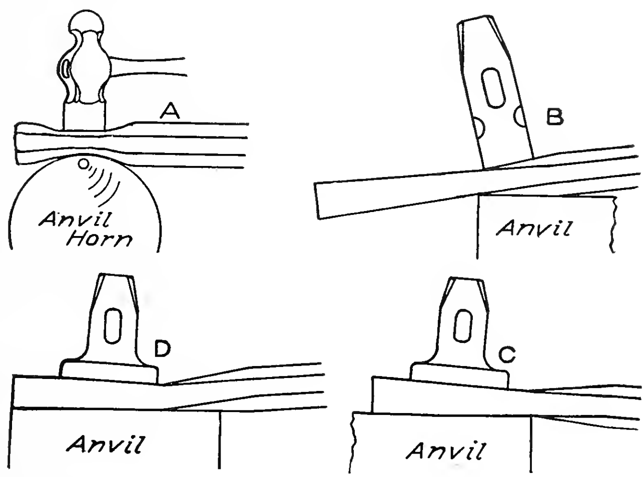

Fig. 117.

to B, Fig. 116. The chisel is started by thinning down B with two fullers, or over the horn of the anvil as shown at A, Fig. 117. The end is then drawn out and finished with a hammer or flatter in the manner illustrated at B. A cape chisel is given the same temper as a cold chisel.

Square and Round Nose Chisels. These two chisels, the ends of which are shown in Fig. 118, are forged and tempered in practically the same way as the ordinary cape chisel, the only difference being in the shape of the ends. Round nose cape chisels are sometimes used for centering drills and are then known as centering chisels.

Lathe Tools. The same general forms of lathe tools are used in nearly all shops, but the shapes are altered somewhat to suit individual tastes.

Right Hand and Left Hand Tools. Many lathe tools are made in pairs and are called right and left hand tools. If a tool is made in such a way that the cutting edge comes toward the left hand as the tool is held in position in the lathe, it is known as a *right hand tool, i. e.,* a tool which begins a cut at the right hand end of the piece and moves from right to left is known as a right hand tool. The one commencing at the left hand end and cutting toward the right would be known as a *left hand tool.* The general shape of right and left hand tools for the same use is generally the same excepting that the cutting edges are on opposite sides.

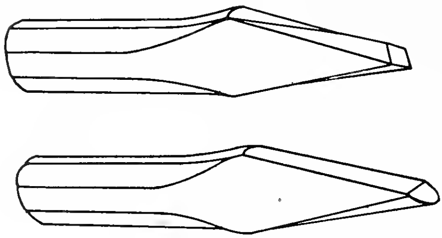

Fig. 118.

Clearance. When making all lathe tools, care must be taken to see that they have proper clearance, *i. e.,* the cutting edge must project beyond or outside of the other parts of the tool. In other words, the sides of the tool must be undercut or slant downwards and backwards away from the cutting edge. This is illustrated in the section A B of Fig. 119, where the lower edge of the tool is made considerably

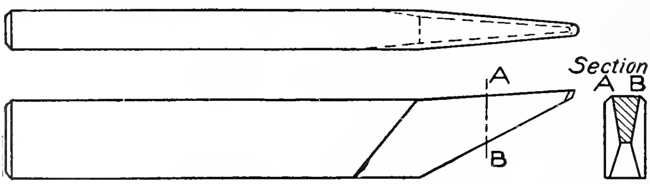

Fig. 119.

thinner than the upper edge, in order to give the proper clearance.

Round Nose and Thread Tools. These tools are practically alike excepting for a slight difference in the way the ends are ground. The general shape is shown in Fig. 119. When hardening, the tools should be heated about as far as the line A, Fig. 120, and cooled up to the line B. The temper is then drawn in the same general way as described for tempering of cold chisels excepting that when a light yellow color shows at the cutting edge the tool is cooled for the second time. All lathe tools are given practically the same temper. Sometimes tools are left much harder. In one quite well known plant the tools are simply reheated until the water evaporates from the cutting end, indicating a reheating to a temperature of about 200°F.

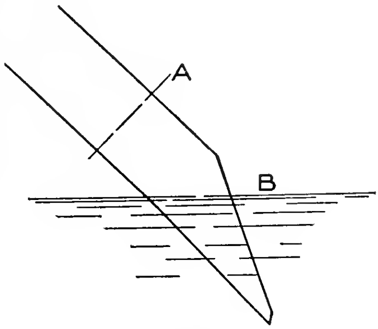

Fig. 120.

Cutting off Tools are forged with the blade either on one side or in the center of the stock. The easier way to make them is to forge the blade with one side flush with the side of the tool. Such a tool is shown in Fig. 121. The cutting edge, A, the extreme tip of the blade, should be wider than any other part of the thinned end, B. In other words, this edge should have clearance in all directions as indicated in the drawing. The clearance angle at the end of the tool as shown in the sketch, is about correct for lathe tools. For heavier tools for the planer, the angle should be as shown by the line X X. When hardening, the end of the tool should be heated to about point C C and cooled to about the line D D, and the temper drawn as described for the round nose tool. Tools may be forged in the general way shown in Fig. 122. The tool is started by making a fuller cut as shown

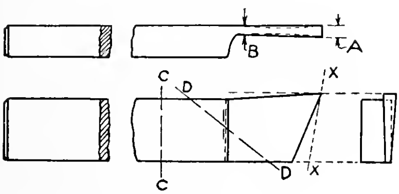

Fig. 121.

at A. After roughly shaping, the end is trimmed off with a hot chisel along the dotted line at C. Great care must be taken to see that the blade of the tool has proper clearance in all directions.

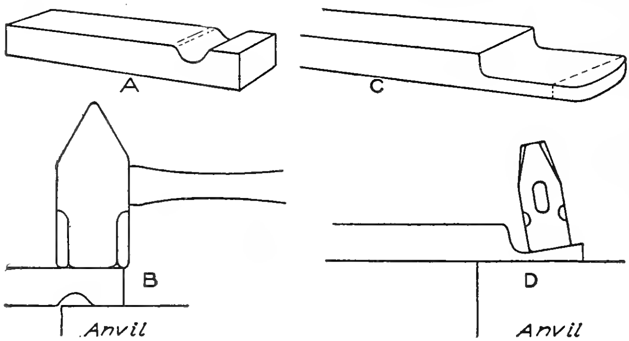

Fig. 122.

When a tool is wanted with a blade forged in the center, it should be first started by using two fullers instead of one, then making two cuts, one on each side of the stock, in place of the single cut shown at A.

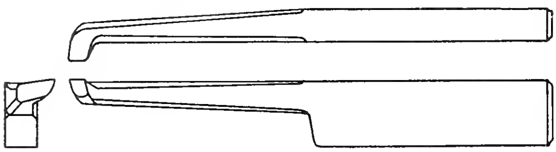

Fig. 123.

Boring Tool. The general shape of this tool is shown in Fig. 123. The length of the thin end depends upon the depth of the hole in which the tool is to be used and as a general rule should be made as short and thick as possible, in order to avoid springing. The tool may be started in the same general way as the cutting off tool, the fuller cut being made on the edge of the stock instead of on the side. The cutting edge of the tool is at the end of the small "nose," and this "nose" is the only part which should be tempered.

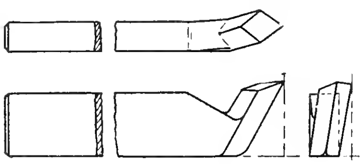

Fig. 124.

Diamond Points. These tools are made in a variety of modifications of the shape shown in Fig. 124. There are various methods used for shaping them, one of which is illustrated in Fig. 125. The shape is started as indicated at A. After the nick has been made as shown, the end of the tool is shaped as shown by the dotted lines, the blows coming in the direction of the arrow. Further shaping is done as indicated at B. To square up the end of the nose of the tool, it is worked backward and forward as indicated at C. The tool is finished by trimming off the end to the proper angle with a hot chisel and touching it up with a set hammer When hardened it should be dipped about as shown at D.

Side Tools or side finishing tools as they are sometimes called, are generally made in about the shape shown at F, Fig. 126. The tool

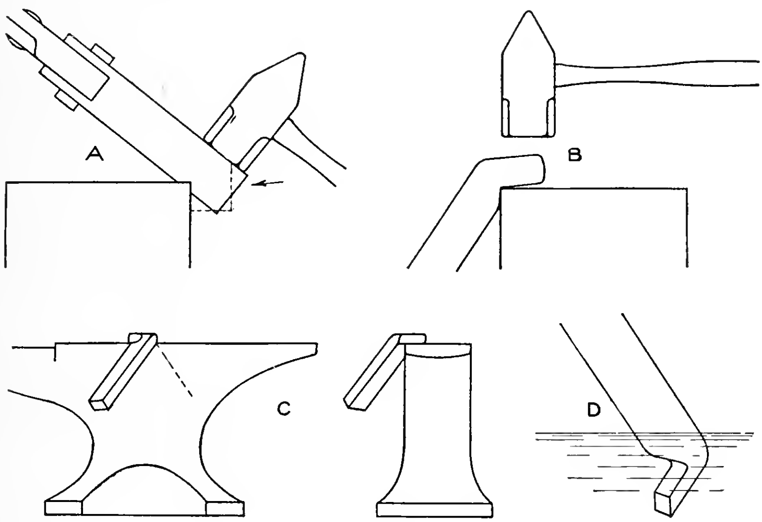

Fig. 125.

may be started by making a fuller cut as shown at A. The end x is then drawn out with a fuller into the shape B. After smoothing up with a set hammer the blade is trued into shape along the dotted lines at C. The tool is finished by giving the proper "*offset*" to the top edge of the blade. This is done by placing the tool flat side down with the blade extending over, and the end of the blade next the shank about $\frac{1}{8}''$ beyond, the outside edge of the anvil. A set hammer is placed on the blade close up to the shoulder and slightly tipped, so that the face of the hammer touches the thin edge of the blade only, as illustrated at D. One or two light blows with the sledge will give the necessary offset and after touching up the blade, the tool is ready for tempering. When heating for hardening, the tool should be placed in the fire with

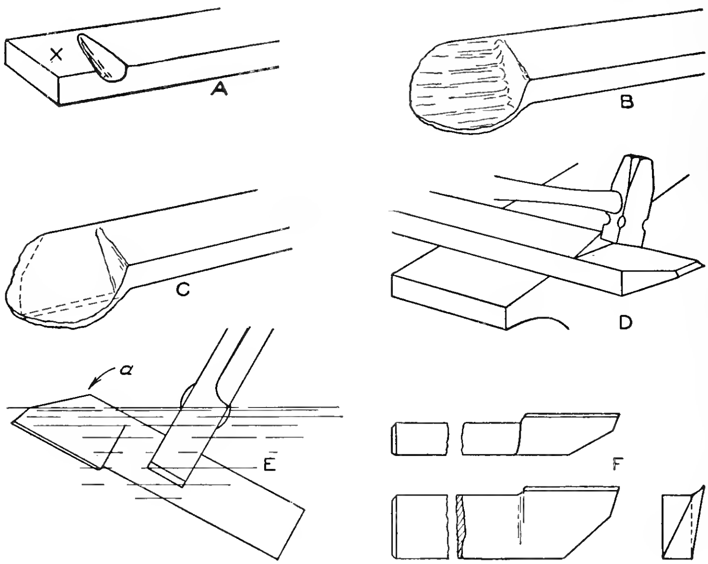

Fig. 126.

the cutting edge *up*. In this way it is more easy to avoid overheating the edge. The hardening should be done by dipping the tool in water as illustrated at E, only the small part A being left above the surface. The tool is taken from the water, quickly rubbed bright

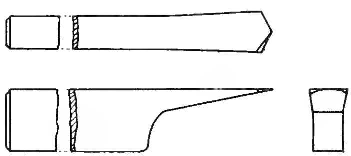

Fig. 127.

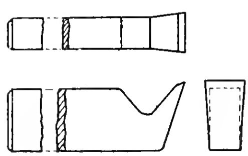

Fig. 128.

on the flat side, and the temper drawn until the cutting edge shows a light yellow. The same color should show the entire length of the cutting edge. If the color shows darker at one end, it indicates that that end of the blade was not cooled enough and the tool should be rehardened, this time dipping the tool in such a way as to bring that end of the blade which was too soft before, deeper in the water.

Centering Tool. The centering tool shown in Fig. 127 is used for starting holes on face-plate and chuck work. The end may be shaped by making a fuller cut and then flattening out the metal, trimming the cutting edge to shape with the hot chisel.

Forming Tools for Turret Lathes are sometimes forged up in the same general shape as above and tempered like other lathe tools.

Finishing Tool. This tool, Fig. 128, may be started either with a fuller cut or in the same way as the diamond point. The end is then flattened out and shaped with a set hammer as shown in Fig. 129. This generally leaves the end bent out too nearly straight, but it may be easily bent back into shape as indicated at B. This bending will probably leave the point something like C. A few blows of the hammer at the point indicated by the arrow will give the tool the shape as at D. The cutting edge should be tempered the same as other lathe tools. For planer and shaper tools of this shape, the end should be more nearly at right angles to the edge of the tool, making an angle of about six or eight degrees less than the perpendicular. In other words, the tool should have less end rake.

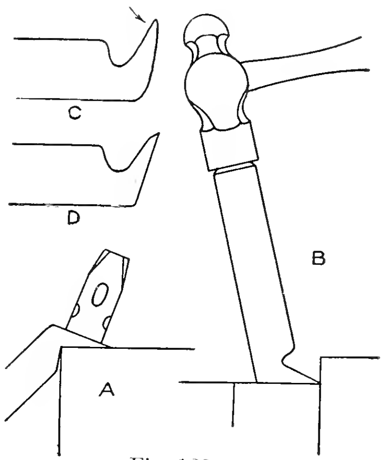

Fig. 129.

Flat Drills need no particular description as to forging and shaping. The size of the drill is determined by the width of the flat end, this being the same size as the hole the drill is intended to bore. If this dimension were one inch, the drill would be known as a one-inch drill. The drill should be made somewhat softer than lathe tools, the temper being drawn until a light brown shows at the cutting edge.

Springs are generally tempered in oil. The spring is heated to a uniform hardening heat and hardened by cooling in oil. The temper is drawn by holding the spring, still covered with oil, over the flame of the forge, and heating until the oil burns over the entire spring. If the spring is not uniform in section throughout, it is generally advisable, while heating it, to plunge every few seconds into the oil bath, taking it out instantly and continuing the heating. This

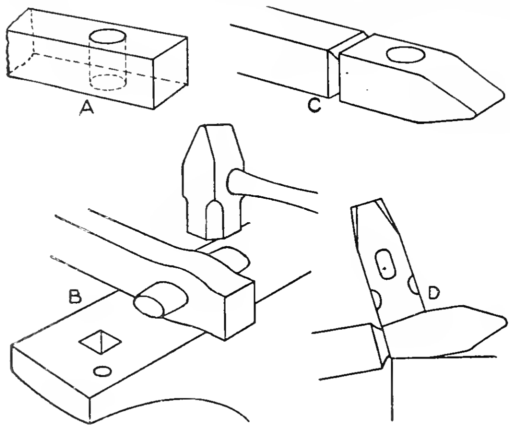

Fig. 130.

momentary plunge tends to equalize the heat by cooling the thinner parts.

Lard oil or fish oil are generally used as mineral oil is too uncertain in composition. The above method of tempering is known as *blazing off*, the blazing point of the oil being used to indicate the temperature in place of the color of the scale. The same results could be obtained by polishing the spring and heating until it turned blue.

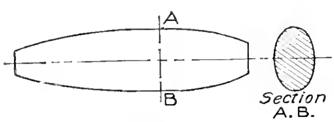

Fig. 131.

Hammers. When making a hammer the stock should be taken large enough to make the largest part of the hammer without any upsetting. As a general rule the hammer is forged on the end of a bar and finished as completely as possible before cutting off.

Riveting Hammer. About the easiest hammer to shape is the riveting hammer shown at D, Fig. 4. This hammer, as well as all other hammers, is started by first punching the hole for the eye as shown at A, Fig. 130. When the eye is punched the stock is generally bulged out sideways and in order to hold the shape of the eye while flattening down this bulge, a drift pin such as shown in Fig. 131 is used. This pin is made larger in the center and tapering at both ends. The center or larger part of the pin has the same shape as the finished eye of the hammer. This pin is driven into the punched hole and the sides of the eye forged into shape as illustrated at B, Fig. 130. After the eye has been properly shaped, the next step is to shape down the tapering pene leaving the work, after a nick has been made around the bar where the face of the hammer will come, as shown at C. The end of the hammer toward the face is then slightly tapered in the manner indicated at D. After the hammer has been as nearly as possible finished, it is cut from the bar and the face trued up. For tempering, the whole hammer is heated to an even hardening heat. The hammer is then grasped by placing one jaw of the tongs through the eye. Both ends are tempered, this being done by hardeneng first one end and then the other. The small end is first hardened by dipping in the water as shown at Fig. 132. As soon as this end is cooled the position of the hammer is instantly reversed and the face end hardened. While the large end is in the water the smaller end is polished and the temper color watched for. When a dark brown scale appears on the small end the hammer is again reversed bringing the large end uppermost and the pene in the water. The face end is then polished and the temper drawn. If the large end is properly hardened before the temper color appears on the small end, the hammer may be taken completely out of the water, the large end polished, and the colors watched for on both ends at once. As soon as one end shows the proper color it is promptly dipped in water, the other end following as soon as the color appears there, but under no circumstances should the eye be cooled while still red hot. For some special work hammer faces should be left harder, but for ordinary use the temper as given above, is very satisfactory.

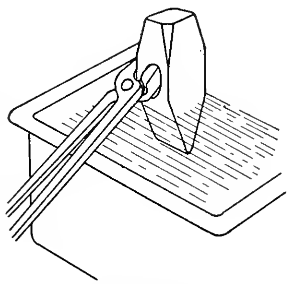

Fig. 132.

Ball Pene Hammer. The general method of making this hammer is illustrated in Fig. 133. After punching the hole, the hammer is roughed out by using the fullers as shown at A and B. The ball end is then rounded up, the octagonal parts shaped with the fullers and the hammer cut from the bar, ground and tempered. Ball

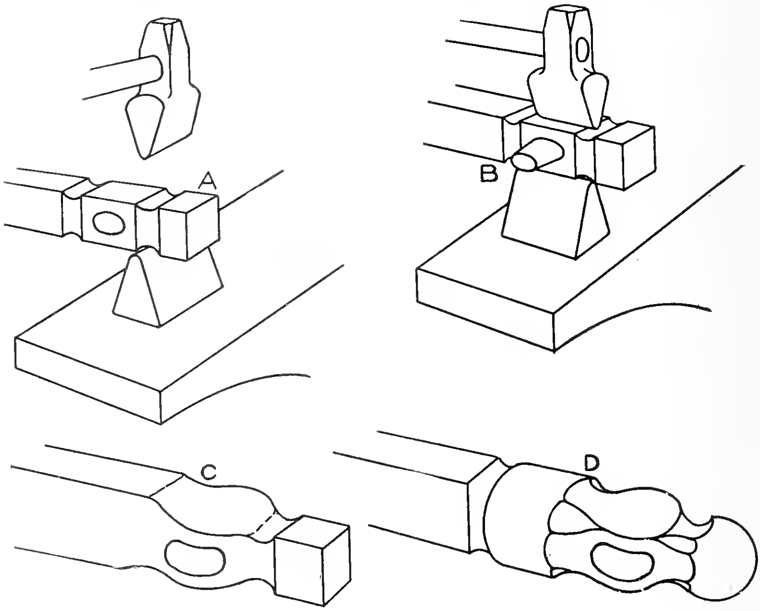

Fig. 133.

pene hammers may be made with a steam hammer in practically the same way as described above, excepting that round bars of steel should be substituted for the fullers.

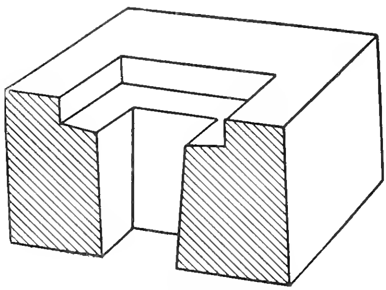

Fig. 134.

Blacksmith's Tools such as cold chisels, hot chisels, set hammers and flatters are made in much the same way as hammers. The wide face of the flatters may be upset by using a block such as is shown in Fig. 134. The heated end of the tool is dropped into the hole in the block and the face upset into the wide shallow opening. Swages may also be worked up in this way.

Self=hardening Steel is used to a large extent in modern practice for lathe tools, much being used in the shape of small square steel held in special holders. Such a tool is illustrated in Fig. 135. Self-hardening steel, as its name indicates, is almost self-hardening in nature, generally the only treatment that is required to harden the steel being to heat it red hot and allow it to cool. Sometimes the steel is cooled in an air blast or is dipped in oil. It is not necessary to "draw the temper". The self-hardening quality of steel is given to it by the addition of Chromium, Molybdenyum, Tungsten, or one of that group of elements, in addition to the carbon which ordinary tool steel contains. Self-hardening steel is comparatively expensive, costing from 40 cents and upwards per pound, some of the more expensive grades costing $1.00 or so. When in use, self-hardening steel will stand a much higher cutting speed than the ordinary so-called carbon steel. For this reason it is much more economical to use, although its first cost is higher. Self-hardening steel cannot be cut with a cold chisel and must be either cut hot or nicked with an emery wheel and snapped off. Great care must be used in forging it, as the range of temperature through which it may be forged is comparatively slight, running from a good red heat to a yellow heat. Some grades of self-hardening steel may be annealed by heating the steel to a high heat in the center of a good fire and allowing the fire and the steel to cool off together. Steel which has been annealed in this way may be hardened by heating to the hardening heat and cooling in oil.

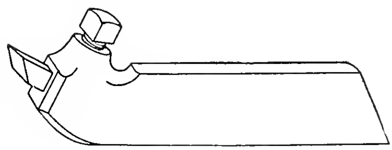

Fig. 135.

Taylor=White Process. This method of treating special grades of self-hardening steel was discovered some years ago by the men after whom it is named. It was found that if a piece of self-hardening steel be heated to a very high temperature (about the welding heat) and then suddenly cooled to about a low red heat, the steel would be in a condition to stand very much harder usage and take a much heavier cut. Steel treated in this way seemed to have the cutting edge of the tools almost burned or melted off and considerable grinding was necessary to bring them into shape. When put in use the edges would almost immediately be slightly rounded or crumble off, but after this slight breaking down of the cutting edge, the steel would stand up under excessively trying conditions of high speed and heavy cut. Tools of this character were of very little, or no, use for fine finishing, but were of great value for heavy and roughing cuts.

HEAVY FORGING.

Steam Hammer. An ordinary form of steam hammer is shown in Fig. 136. Its essential parts are an inverted steam cylinder, to whose piston rod the hammer head is attached, and the frame for carrying the whole. The hammer is raised by admitting steam

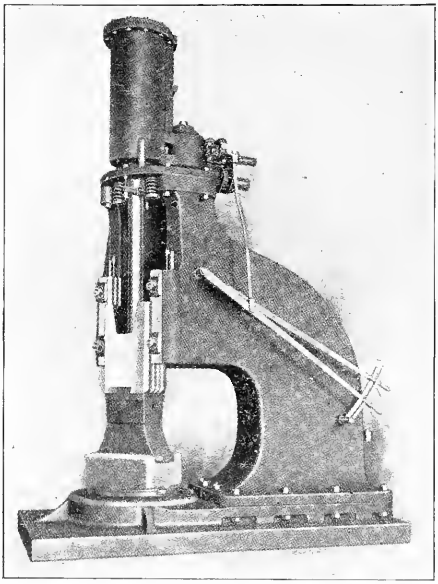

Fig. 136.

beneath the piston. The blow is dealt by exhausting the steam from beneath the piston and admitting it above the same. The head is thus accelerated by gravity and the pressure of steam above the piston. The valve gear is so arranged that the intensity of the blow may be varied by changing the amount of steam admitted to the piston on its downward stroke. The steam admitted below on the same stroke forms a cushion for the absorption of the momentum of the head. In this way the lightest of taps and the heaviest of blows can be delivered by the same hammer. These hammers are also made in a great variety of sizes. Steam hammers are rated by the weight of the falling parts, *i. e.*, the piston rod, ram or head, and hammer die. A hammer in which these parts weigh 400 lbs. would be called a 400 lb. hammer. Steam hammers are made in two distinct parts: the *frame*, carrying the hammer or ram, and the *anvil*, on which the hammer strikes.

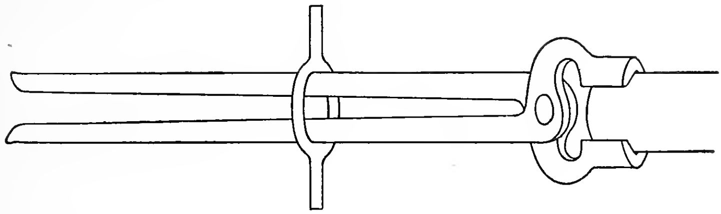

Fig. 137.

The frame is carried on a heavy foundation, and the heavy anvil, which is generally made of cast iron and fitted with a die block of tool steel, rests upon a heavier foundation of timber or masonry capped with a timber. The object of these separate foundations is to allow the anvil to give slightly under a blow without disturbing the frame. On very light power hammers the anvil and frame are sometimes made together.

Hammer Dies. The dies, as most commonly used with a steam

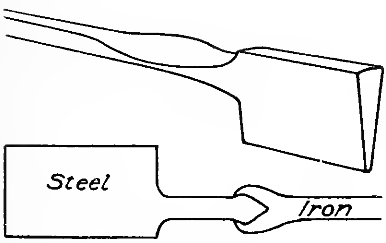

Fig. 138.

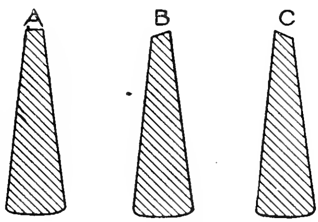

Fig. 139.

hammer, have flat faces. The best ones are made of tool steel. These dies may be made of tool steel and left unhardened, then when the dies become battered out of shape from use, they may be trued up and refaced without going to the trouble of annealing and hardening. Dies of gray cast iron and cast iron with a chilled face are also quite commonly used. Ordinary gray cast iron is used, particularly when special shaped dies are employed for welding and light bending.

Tongs for steam hammer work should always carefully be fitted and should grip the stock firmly on at least three sides. A quite common shape for tongs for heavy work is shown in Fig. 137. To hold the tongs securely on the work and to make it easier to handle them, a link is sometimes used of the shape shown. This is driven firmly

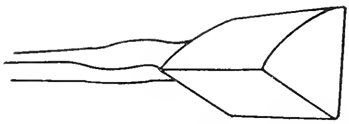

Fig. 140.

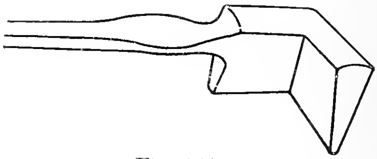

Fig. 141.

over the handles of the tongs and the projecting ends are used as handles for turning the work.

Hammer Chisels. The common shape for hot chisels for use under the steam hammer is given in Fig. 138. The handle and blade are sometimes made from one piece of tool steel. Sometimes the blade is made of tool steel and an iron handle welded on as shown in the sketch. The handle next to the blade should be flattened out to form sort of a spring which permits a little give when using the

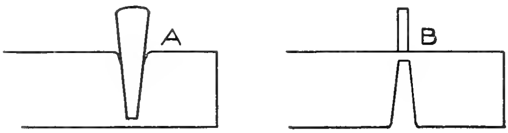

Fig. 142.

chisel. The edge of the chisel should be left square across and not rounding. The proper shape is shown at A, Fig. 139. Sometimes for special work the edge may be slightly beveled as at B or C. For cutting or nicking bars cold, a chisel similar in shape to Fig. 140 is sometimes used. This is made very flat and stumpy to resist the crushing effect of heavy blows. For cutting into corners a chisel similar in shape to Fig. 141 is sometimes used. For bent or irregular work the chisel may be formed accordingly. For cutting off hot stock the method used is about as illustrated in Fig. 142, *i. e.*, the work is cut nearly through as shown at A. The bar is then turned over and a thin strip of steel with square corners placed on top as shown at B.

A quick heavy blow of the hammer drives this steel bar through the work and carries away the thin fin shown, leaving both of the cut ends clean and smooth.

Tools. The tools used for steam hammer work are generally very simple. Swages for finishing work up to three or four inches in diameter are commonly made in the shape shown in Fig. 143.

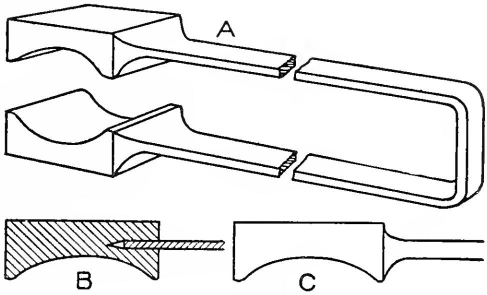

Fig. 143.

The handle is made in the shape of a spring and may be either made in one piece with the blocks and drawn out as shown at C, or may be inserted as shown at B. This sort of a tool is known as a spring tool. Another sort of swage sometimes used, is illustrated in Fig. 144, the

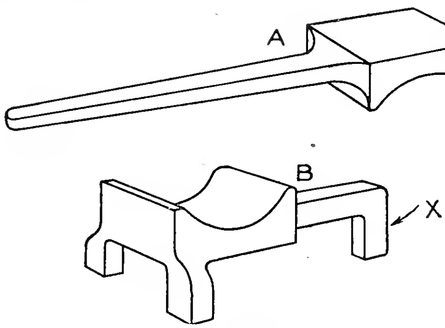

Fig. 144.

top swage at A, the bottom swage at B. This sort of a swage is used on a die block which has a square hole cut in its face similar to the hardy hole in an anvil. The short horn X, of the swage, fits into this hole, the other two projections coming over the side of the anvil block.

Tapering and Fullering Tool. The faces of the anvil and hammer dies are flat and parallel and it is, of course, impossible to finish tapering work smooth between the bare dies. This work may be done by using a tool similar to Fig. 145. Its method of use is shown in Fig. 146, the roughing being done with the round side down and the finish-

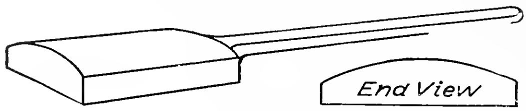

Fig. 145.

ing with the flat side. Fullers used for ordinary hand forgings are seldom employed in steam hammer work. Round bars are used in their place in the manner illustrated in Fig. 147. If a nick is wanted on one side only, simply one round bar is used. Care must always be taken to be sure that the work is in the proper position before

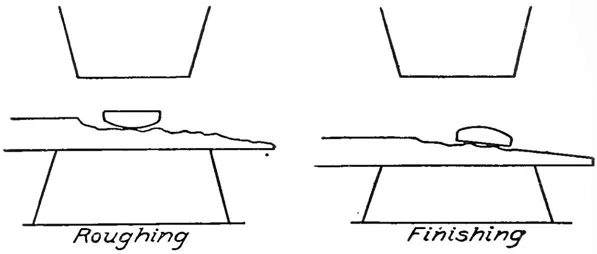

Fig. 146.

striking a heavy blow with the hammer. To do this the hammer should be brought down lightly on the work thus bringing the piece to a flat "bearing" for the first blow.

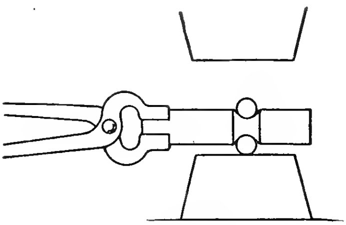

Fig. 147.

Squaring up Work. It frequently happens that work is knocked lopsided under the hammer, being worked up into some such shape as shown at A, Fig. 148. To correct this and bring the work up square, the bar should be put under the hammer and there knocked into shape B and then rolled in the direction indicated by the arrow until shaped as at C when it may then be worked down square and finished like D.

Crank Shafts. The crank shaft shown in Figs. 82 and 83 is quite a common example of steam hammer work. The stock is first worked as illustrated in Fig. 149, the cuts being on each side of the crank cheek. A special tool is used for this as illustrated. When the cuts are very deep, they should first be made with a hot chisel and then opened up with this spreading tool. With light cuts, however, both operations may be done with a spreading tool at the same time. Care must be taken, when flattening out the ends, to prevent any of the material from doubling over and forming a "cold shut". After the ends are hammered out, the corners next to the cheeks may be squared by using a block as shown in Fig. 85.

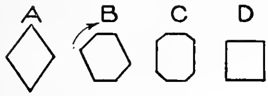

Fig. 148.

Connecting Rod: *Drawing out between the shoulders.* The forging illustrated in Fig. 80, while hardly the exact proportions of the connecting rod, is near enough the proper shape to give a good example of this kind of forging. The work is first started by making two cuts as illustrated in Fig. 150. The metal between the two cuts is then drawn out by using two steel blocks as shown in Fig. 151 until the metal is stretched long enough to allow the corners of the square ends to clear the edges of the hammer dies, when the work is done directly upon the bare die.

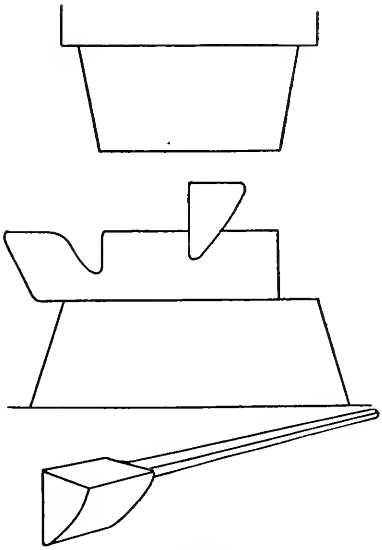
Fig. 149.

MISCELLANEOUS PROCESSES.

Shrinking. When iron is heated it expands and upon being cooled it contracts to about its original size. This property is utilized in doing what is known as *shrinking*. Fig. 152 shows a collar *shrunk* on a shaft. The collar and shaft are made separate, the hole through the collar being slightly less in diameter than the outside diameter of the shaft. The collar is then heated red hot and the heat causes the collar to expand, making the hole larger in diameter than the shaft. The collar, while still hot, is then placed on the shaft in proper position, and cooled as quickly as possible by pouring water on it. As the collar

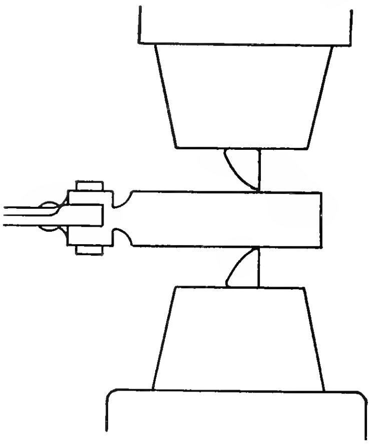

Fig. 150.

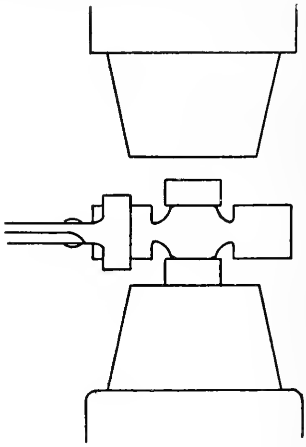

Fig. 151.

is cooled it contracts and squeezes, or locks, itself firmly in position. This principle of shrinking is used to a large extent where a firm, tight fit is wanted, the only objection being that it is rather difficult to take a piece off after it has once been shrunk into place.

Brazing. When two pieces of iron or steel are welded together,

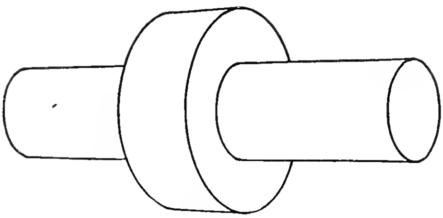

Fig. 152.

they are joined by making the pieces so hot that the particles of one piece will stick to those of the other, no medium being used to join them. In brazing, however, the brass acts in joining two pieces of metal together in somewhat the same manner that glue does in joining two pieces of wood. Briefly the process is as follows: The surfaces to be joined are cleaned, held together by a suitable clamp, heated to the temperature of melting brass, flux added, and the brass melted into the joint. The brass used is generally in the shape of "spelter". This is a finely granulated brass which melts at a comparatively low temperature. "Spelter" comes in several grades designated by hard,

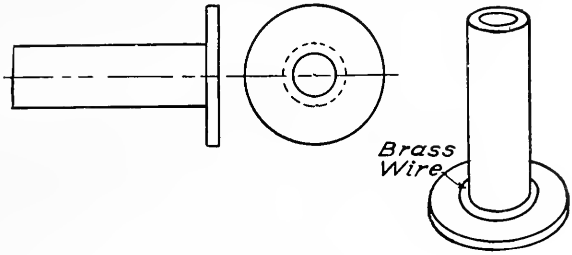

Fig. 153.

soft, etc., the harder spelters melting at higher heat but making a stronger joint. Brass wire or strips of rolled brass are sometimes used in place of spelter, brass wire in particular being very convenient in many places. A simple example of a brazed joint is shown in Fig. 153, where a flange is brazed to the end of a small pipe. It is not necessary in this case to use any clamps as the pieces will hold themselves together. The joint between the two should be made roughly. If a tight joint be used there will be no chance for the brass to run in. The joint should fit in spots but not all around. Before putting the two pieces together, the surfaces to be joined should be cleaned free from loose dirt and scale. When ready for brazing the joint is smeared with a flux (one part salammoniac, six or eight parts borax) which may be added dry or put on in the form of a paste mixed with water. The joint is then heated and the spelter mixed with flux sprinkled on and melted into place. Brass wire could be used in place of the spelter in the manner indicated, the wire being bent into a ring and laid round the joint as shown. Ordinary borax may be used as a flux, although not as good as the mixture used above. The heat should be gradu-

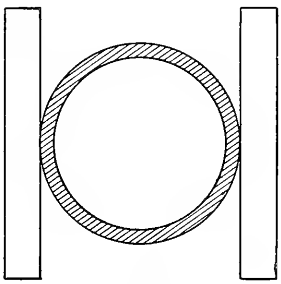

Fig. 154.

ally raised until the brass melts and runs all around and into the joint, when the piece should be lifted from the fire and thoroughly cleaned by scraping off the melted borax and scale. It is neces sary to remove the borax, as it leaves a hard glassy scale which is particularly disagreeable if any filing or finishing has to be done to the joint. This scale may be loosened by plunging the work while still red hot, into cold water. Almost any metal that will stand the heat, may be brazed. Great care must be used in brazing cast iron to have the surfaces in contact properly cleaned to start with, and then properly protected from the oxidizing influences of the air and fire while being heated.

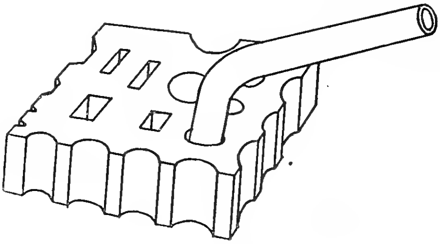

Fig. 155.

Annealing Copper and Brass may be done by heating the metals to a red heat and then cooling suddenly in cold water. When copper or brass is hammered to any extent, it becomes hard and springy and if it has to be further worked, it must be annealed or softened, otherwise it is almost sure to split.

Bending Cast Iron. It is sometimes necessary to straighten a casting which h s become warped or twisted. Cast iron may be twisted or bent to quite an extent if worked cautiously. The bending may generally be done at about the ordinary hardening heat of tool

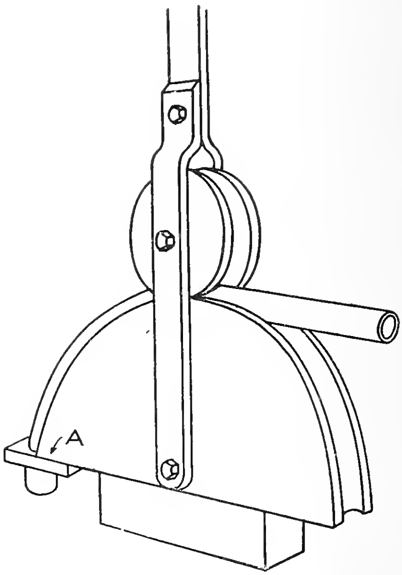

Fig. 156.

steel and should be done by a steadily applied pressure, not by blows. There is more danger of breaking the work by working it at too high a heat than by working at too low. As an example of how iron may be twisted, a bar of gray cast iron one inch square and a foot long may be twisted through about 90°, before it will break.

Case-Hardening. The essential difference between machine steel and tool steel is the amount of carbon that they contain. If carbon be added to machine steel it will be turned into tool steel. Sometimes articles are wanted very hard on the surface to resist wear and at the same time very tough to withstand shocks. If the piece be made of tool steel in order to be hard enough, it will be too brittle, and if made of machine steel in order to be tough enough, will be too soft. To overcome this difficulty the parts are made of machine steel and then the outside is carbonized or converted into tool steel to a slight depth, and this outside coating of tool steel then hardened. The process is known as *case-hardening*. The method used generally consists of heating the machine steel red hot in contact with something very rich in carbon, generally ground bone. The surface of the machine steel takes up or absorbs the carbon and is converted into tool steel. For more detailed information the reader is referred to "Tool Making".

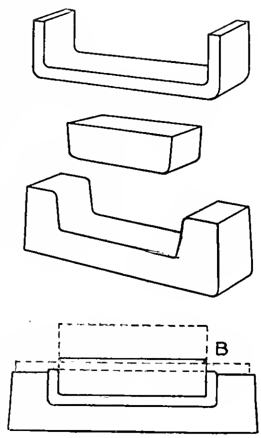

Fig. 157.

Pipe Bending. A piece of pipe when bent always has a tendency to collapse and if this collapsing can be prevented by keeping the sides of the pipe from spreading, a pipe may be successfully bent into almost any shape. One way of doing this would be to bend the pipe between two flat plates as shown in Fig. 154, the plates being the same distance apart as the outside diameter of the pipe. In bending large pipe, the sides are sometimes prevented from bulging by working in with a flatter. Where a single piece is to be bent, it may be done by heating the pipe and inserting one end in one of the holes in a swage block as shown in Fig. 155, the pipe being then bent by bearing down on the free end. As soon as a slight bend is made it is generally necessary to lay the pipe flat on the anvil and work down the bulge with a flatter. Where many pieces are to be bent, a grooved "jig" such as shown in Fig. 156 is sometimes used. The jig is of such a shape that the pipe is completely surrounded where it is being bent, thus not having any opportunity to collapse or bulge. Pipe is some-

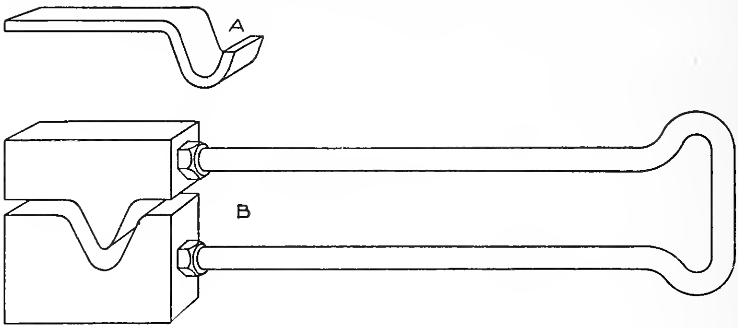

Fig. 158.

times filled full of sand for bending. This helps to some extent. Care must be taken to see that the pipe is *full* and that the ends are solidly plugged. For bending thin copper tubing, it may be filled with melted rosin. This gives very satisfactory results for this character of work. After bending, the rosin is removed by simply heating the pipe.

Duplicate Work. Where several pieces are to be exactly alike in a shop that is not equipped for special work, it is sometimes practical to use a "jig" for performing the operations. For simple bending the "jig" may consist of a set of cast-iron blocks. Fig. 157 illustrates a simple bend with the block used for doing the work. The work is done as shown at B. The piece to be bent is placed, as shown by the dotted lines, with the bending block on top. The bending is done by one or two strokes of the steam hammer. For convenience in handling, the bending blocks are sometimes held by a spring handle as shown in Fig. 158. The blocks in this case are for bending the hooks shown at A. The handle is simply a piece of

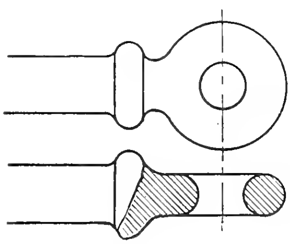

Fig. 159.

$\frac{1}{2}''$ round iron with the ends screwed into the cast-iron blocks and held firmly by the lock nuts shown. This makes a cheap arrangement for a variety of work, as the same handles may be used on various sets of

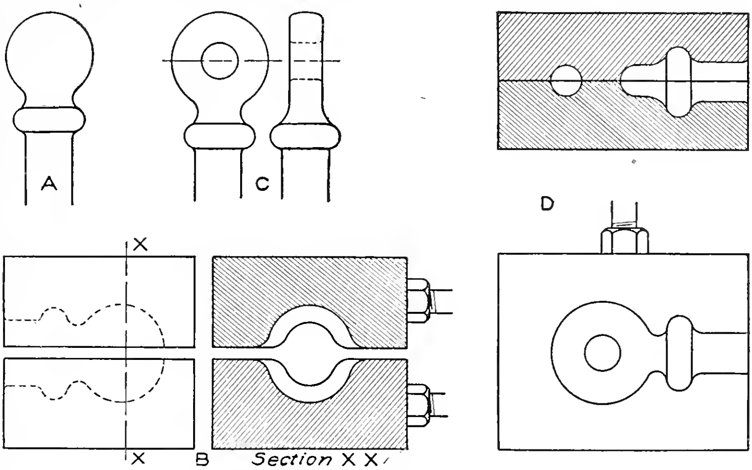

Fig. 160.

blocks. Where a great number of pieces are to be made, these blocks or bending dies may be made of such a shape that they can be keyed on the steam hammer in place of the regular flat dies.

Die Forging. Pieces are sometimes shaped between formed steel dies where many are to be made exactly alike. An example of this sort of work is the eye bolt, Fig. 159. Round stock is used and is first shaped like A, Fig. 160. The shaping is done in the dies shown at B, which are simply two small blocks of tool steel fastened together with a spring handle, the inside faces of the blocks being formed to shape the piece as shown. The end of the bar is heated, placed between the die blocks and hammered until it takes the required shape, being turned through about 90° between each two blows of the steam hammer, and the hammering continued until the die faces just touch.

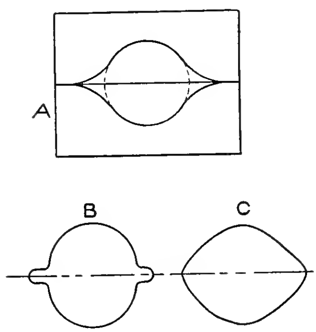

Fig. 161.

For the second step the ball is flattened to about the thickness of the finished eye and the hole punched under the steam hammer with an ordinary punch, leaving the work as shown at C. The final shaping is done with the finishing die D. This die is so shaped that when the two parts are together, the hole left is exactly the shape of the finished forging. In the first die it will be noticed that the holes do not conform exactly to the desired shape of the forging, being, instead of semi-

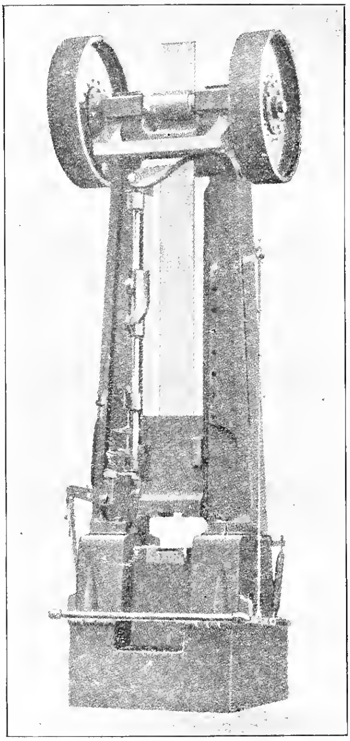

Fig. 162.

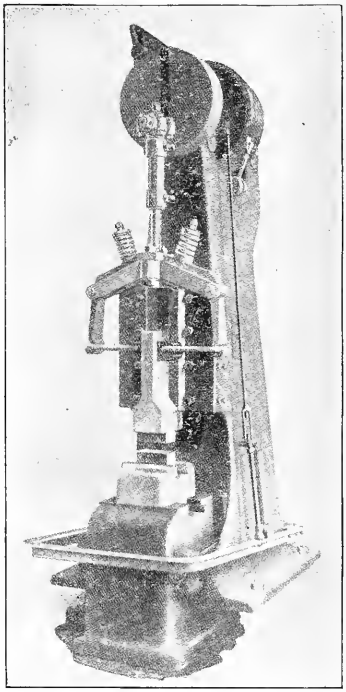

Fig. 163.

circular, considerably rounded off at the edges. This is shown more clearly in Fig. 161 at A, where the dotted lines show the shape of the forging, the solid lines the shape of the die. The object of the above is this: If the hole is semicircular in section, the stock, being larger than the smaller parts of the hole, after a blow will be left like B, the metal being forced out between the flat faces of the die and forming fins. When the bar is turned these fins are worked back and make a "cold shut". When the hole is a modified semicircle the stock will be formed like C, and may be turned and worked without danger of "cold shuts". Dies for this kind of work are sometimes made of cast iron. When made of tool steel it is sometimes possible to shape them hot. A "master" forging is first make of tool steel to exactly the shape of the required forging. The blocks for the dies are then forged with flat faces. These blocks are fastened to the handle and then

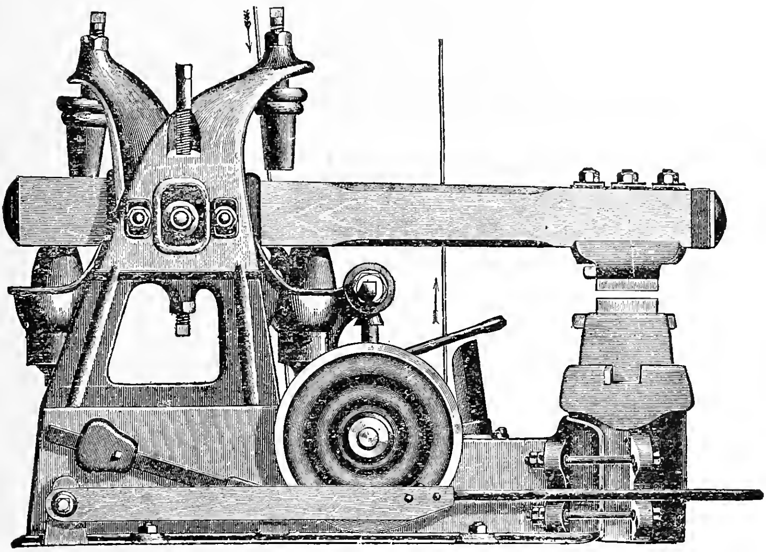

Fig. 164.

heated red hot. The master forging is then placed between the dies and the dies hammered down tight over the forging. This leaves a cavity just the shape for the required forging.

MANUFACTURING.

The manufacturing shop differs very essentially from the jobbing shop. In the latter shop very few forgings are made at the same time exactly alike, while in manufacturing, each forging is generally duplicated a large number of times and special machines are used for doing the work.

Drop Forges are used for quickly forming complicated shapes out of wrought iron or steel. They consist, as the name indicates, of a head that may be "dropped" from any desired height upon the piece to be shaped. The head of the drop and the anvil are in the form of dies. As they come together the metal is forced to flow so as to fill the interstices and thus take on the form desired. In drop forging the metal must be heated to a high temperature so as to be in a soft and plastic condition.

A common type of drop hammer used for this kind of work is is shown in Fig. 162. The hammer in this case is fastened to a board and is raised by the friction rollers at the top of the frame being pressed against the board. When the hammer reaches the top of the frame it is dropped by releasing the rollers from the board. This may

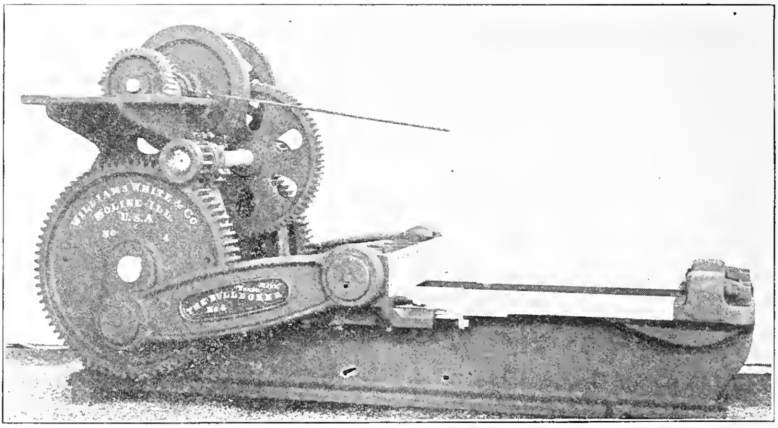

Fig. 165.

be done automatically or by a foot treadle. Drop hammers are also built in the same general way as steam hammers. Dies for drop forging generally consist of a roughing or breaking-down die where the rough stock is first given approximately the desired shape and a smoothing die when the finishing is done. These dies have in their faces, holes of the same shape as the required forging.

Power Hammers. Another tool which is used to quite a large extent in manufacturing as well as in the jobbing shop is the power hammer. This is made in several different types and is used where a quick, rapid blow is wanted. These hammers are run by belts. Two general types are shown in Figs. 163 and 164. The first is known as a justice hammer. The second is a Bradley. Shaped dies are frequently used on these hammers.

Bulldozer. This is a tool used for bending and consists of a heavy cast-iron bed with a block or bolster at one end, and a moving head which slides back and forth on the bed. A common type is shown in Fig. 165. Heavy dies are clamped against the bolster and on the moving head, of such a shape and in such a way that when the moving head is nearest the bolster, the shape left between the two dies is exactly the shape to which it is desired to bend the stock. In operation, the moving head slides back and forth on the bed. The bar to be bent is heated and placed between the dies when the head is farthest from the bolster. A clutch is then thrown in and the head moves forward to the bolster, bending the iron as it goes.

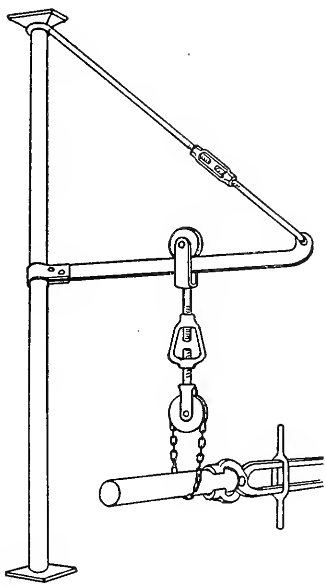

Fig. 166.

Presses serve the same purpose as drop hammers. They do the work more slowly, however. The class of work is, in some respects, the same. The principal difference lies in peculiarities of shape that require different time intervals for the flow of the metal. Where the shape is such that the metal must move slowly in order to acquire its new shape or fill the die, the press should be used.

Flanging Press. A particular type of forging press is the flanging press. This is used more particularly in boiler work and is generally a heavy hydraulic press. The flanging is done by placing the heated metal on the bed of the press and closing the dies together by hydraulic pressure.

Cranes. Where heavy work is to be handled, it is necessary to have some means of conveying the work from one part of the shop to another. This is done by means of cranes of two general types. The traveling crane and jib crane. The former type runs on an overhead track from one end of the shop to the other, generally. The latter type is used more commonly for handling work under the hammers, and is merely an arm or boom swinging around a post and having a suitable arrangement for raising and lowering the work. When handling heavy work, whenever possible, it is suspended from the crane by its center, in such a way that it nearly balances. The

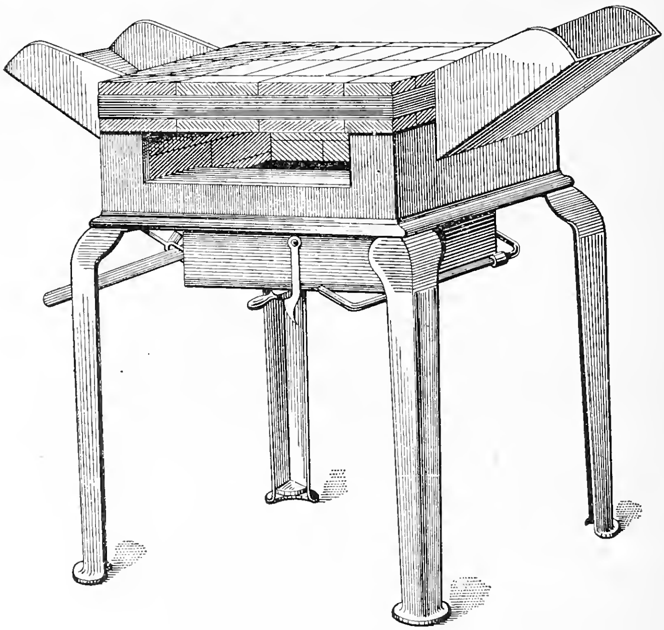

Fig. 167.

suspending is generally done by means of an endless chain such as illustrated in Fig. 166, and in this way it may be easily rolled and swung from side to side. For ease in handling large forgings, a bar, or handle is sometimes welded on. This is known as a porter bar.

Furnaces. In nearly all manufacturing work and in large work in the jobbing shop, the heating is done in furnaces. The heat is generally supplied by either hard coal, coke or oil, coke being more commonly employed in jobbing shops. Sometimes ordinary coal is used. A furnace used for heating small work for manufacturing is shown in Fig. 167. This may be used with either ordinary coal or coke.

Gas Furnaces are used when an even heat is wanted, particularly for hardening and tempering. For manufacturing work the furnaces are sometimes fixed to do the heating automatically. The pieces to be hardened are carried through the furnace on an endless chain which moves at a speed so timed that the pieces have just time enough

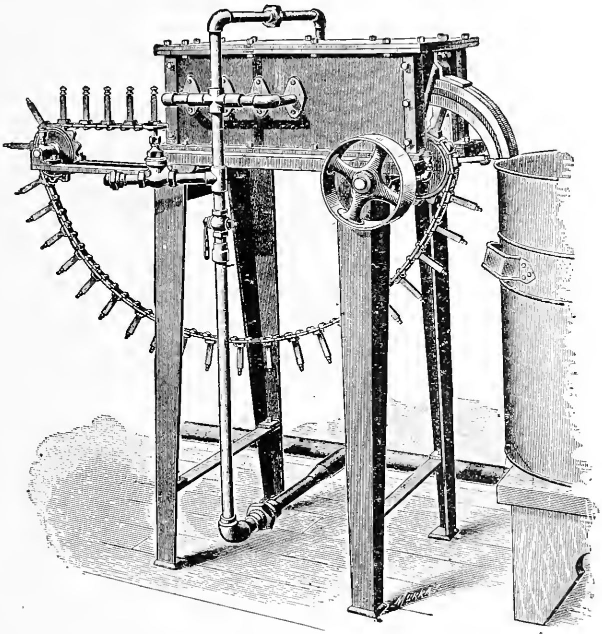

Fig. 168.

to be heated to the right temperature as they pass through the furnace. Such a furnace is shown in Fig. 168. A simple gas furnace for all around work is shown in Fig. 169.

Reverberatory Furnaces. A reverberatory or air furnace is a furnace in which ore, metal or other material is exposed to the action of flame, but not to the contact of burning fuel. The flame passes over a bridge and then downward upon the material spread upon the hearth. Such furnaces are extensively used in shops where heavy work is being executed. They are also used for melting iron or other metals. For this purpose, however, they are not economical since they require about twice as much fuel as that used in the cupola for the production of good hot iron. To be effective the flame must be made to *reverberate* from the low roof of the furnace down upon the hearth and work. The form of the roof and the velocity of the currents determines the hottest part of the furnace.

A common form of reverberatory furnace is shown in Fig. 170. The whole is lined with fire brick from the top of the grates to the top of the stack. The fuel is burned in a fire box separated from the heating portion of the furnace by a low bridge wall D. Access to the grate is obtained by suitable doors both above and below. When in service, both doors are tightly closed and a strong forced draft is admitted to the ash pit. Beyond the bridge wall is the furnace proper. This usually consists of a low chamber with a level floor. Like the fire box it is completely lined with a thick wall of fire brick. Access is obtained to this chamber through a vertically sliding door. These doors are also lined with fire brick and are usually suspended from chains. These pass over pulleys, and have counter balancing weights at the other end.

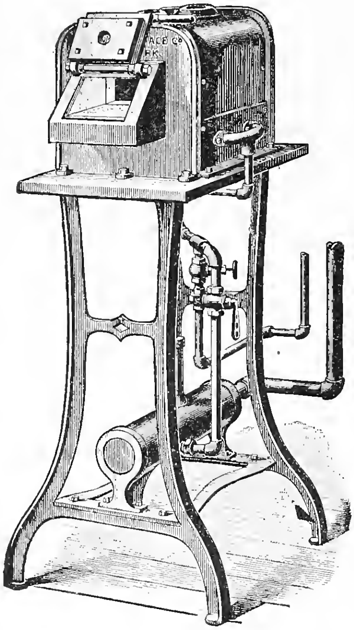

Fig. 169.

The operation of the furnace is exceedingly simple. After the fuel has been charged upon the grates, the ash pit and furnace doors are closed; the material to be heated is put upon the floor of the chamber; the doors are closed and the draft admitted to the ash pit. The thick walls which surround the furnace prevent radiation of its heat. The fire brick are, therefore, heated to incandescence and the hot gases sweep through the chamber. The flow of the gases is usually checked by a choke damper on top of the stack.

The outer form of these furnaces is usually rectangular. The brick walls are tied together by stay rods to prevent bulging and the corners are protected by angle irons.

The selection of the fuel is an important matter in the operation of these furnaces. Experiments have been made with almost every kind of fuel. That now universally used is a soft bituminous coal that will not cake.

Steam or power hammers are always used in connection with these furnaces. The work is too large and heavy for manipulation by hand hammers.

An ordinary class of work done with them is the welding of slabs from small pieces of scrap. To do this a rough pine board about 12 inches wide and from 15 to 18 inches long is used. On it

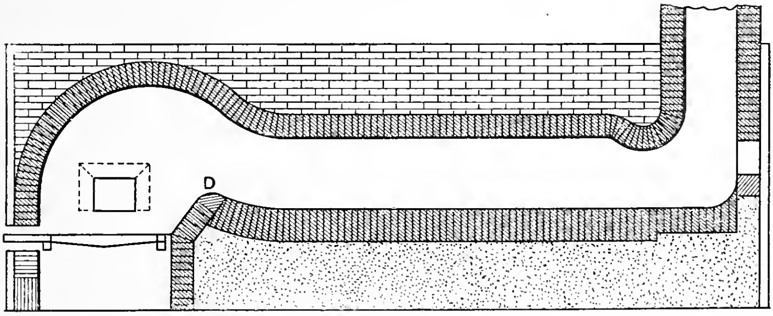

Fig. 170.

is neatly piled about 200 pounds of small scrap pieces. This material is then bound to the boards by wires, and the whole is placed upon the hearth of the furnace. It is allowed to remain until the whole mass is at a welding heat. When in this condition, the plastic surfaces of the pieces serve to stick them together, so that the whole mass can be handled as a single unit by the tongs. The board, of course, burns away, leaving the metal on the hearth. The metal is then lifted out and placed under the steam hammer. A few light blows serve to do the welding. After this heavier blows are struck and the mass is hammered into any shape that may be desired. Usually this first hammering gives it the form of a slab. Slabs thus made are cut up and again welded to form the metal for the final shape.

In the piling of the metal upon the board or *shingle,* as it is called, great care should be exercised. Iron and steel should not be piled together. Rusty metal should be cleaned before being put in the pile. Large air spaces between the pieces should be avoided.

The whole mass should be packed together as compactly as possible.

Bolt Headers are really upsetting machines that form the heads of bolts upon straight rods. Owing to the rapidity with which they do their work, they are invariably used for manufacturing bolts in quantities.

Miscellaneous Suggestions. In doing work in the blacksmith shop it must be constantly remembered that the work is larger at the time it is being manipulated than it will be when cool. Allowance must, therefore, always be made for shrinkage. As the pattern maker allows for the contraction of the molten metal to the cold casting, so the blacksmith must allow for the contraction of the hot iron or steel to the cold forging.

The temperatures of iron at the several colors, are as follows:

Lowest red visible in dark	878° F.
Lowest red visible in daylight	887° F.
Dull red	1100° F.
Full red	1370° F.
Light red, scaling heat	1550° F.
Orange	1650° F.
Light orange	1725° F.
Yellow	1825° F.
Light yellow	1950° F.

This table is based on temperatures given by Messrs. Taylor and White, Transactions Am. Soc. of Mech. Engs., Vol. XXI.

From the above it will be seen that the temperature at which forgings are finished under the hammer, should be at about 900° Fahr. When these same forgings are cold their temperature will be from 60° to 70° Fahr. There is, therefore, a difference of at least 840° between the working and the finished temperature. The expansion of iron may be taken to average about .00000662 of its length for each increase of one degree Fahrenheit in its temperature. If a bar of machine steel exactly 2 feet long when cold, be heated red hot and measured, it will be found to have increased nearly $\frac{1}{4}''$ in length. Taking the temperature of the red heat as 1370° F., and that of the cold bar as 70° F., the increase in length would be $1300 \times .00000662 \times 24$ (length in inches) $= .206''$. This expansion must be allowed for when measuring forgings red hot.

EXAMINATION PAPER

FORGING.

Read carefully: Place your name and full address at the head of the paper. Any cheap, light paper like the sample previously sent you may be used. Do not crowd your work, but arrange it neatly and legibly. *Do not copy the answers from the Instruction Paper; use your own words, so that we may be sure that you understand the subject.*

1. Make a sketch and show all dimensions of a hoisting hook for a load of 2,000 lbs.

2. What is the essential difference between tool steel and wrought iron?

3. What is shrinking?

4. What three materials are commonly used in forge work?

5. Give two methods of measuring the amount of stock required to make a scroll.

6. How much would the crank shaft shown in Fig. 82 weigh, before any machine work was done on it, if $\frac{1}{4}''$ be allowed for finish on all surfaces where called for?

7. How is a lead bath used, and what is the advantage in tempering?

8. What length of stock, $\frac{1}{2}''$ in diameter, is required to make a ring 3″ inside diameter? No allowance for welding.

9. What is meant by the term "allowance for finish"?

10. What is annealing?

11. How does brazing differ from welding?

12. What is the tuyere?

13. If two plates are to be riveted together as tightly as possible, should heavy or light blows be used?

14. What is meant by "the hardening heat?"

15. Make a sketch showing what dimensions the forging shown in Fig. 78 would have if $\frac{1}{4}''$ finish were allowed all over.

16. Of what does welding consist?

17. What precautions must be taken when forging a round bar to a point?

18. Three pieces of tool steel are heated to the hardening heat; the first is cooled in water, the second in oil, and the third is allowed to cool in the air. What will be the relative hardness? Why?

19. How are tongs fitted to work?

20. Make a sketch and show all dimensions of a hexagonal head bolt $\frac{3}{4}''$ x $8''$.

21. How is the final hardness of steel affected by the rate of cooling?

22. If a tap is broken off in a piece of work, the work is wanted in a hurry, and it is necessary to anneal the piece, how can the annealing be done?

23. What is brazing?

24. How much would an anvil marked 3 – 2 – 10 weigh?

25. Why are scarfs used in welding?

26. Why are springs hardened and tempered in oil?

27. Why is borax a better flux than sand?

28. What are the characteristics of a good forge coal?

29. What determines the size of the grain in hardened steel?

30. What is the down draft system?

31. What is meant by scarfing?

32. What is meant by clearance on lathe tools?

33. What is a flux, and why is it used in welding?

34. How are steam hammers rated?

35. Why should the ends of pieces to be welded, be upset?

36. (a) What do you understand to be meant by an oxidizing fire? (b) What do you understand to be meant by a reducing fire?

37. In making an S wrench, which is preferable; to forge the jaws separately and then weld on the handle, or to cut the jaws from a solid piece of metal and draw down the material between them to the proper size for the handle?

38. Explain the method of making a ladle shank in such a way that no welds are necessary in its construction.

39. Describe with sketches the so-called commercial method of forging a crank shaft.

After completing the work, add and sign the following statement:
I hereby certify that the above work is entirely my own.
(Signed)