FORGE-PRACTICE

AND

HEAT TREATMENT OF STEEL

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THIRD EDITION, REVISED AND ENLARGED

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To my Wife,

WITHOUT WHOSE ASSISTANCE IT WOULD NEVER HAVE BEEN WRITTEN, THIS LITTLE VOLUME IS DEDICATED.

PREFACE TO THE THIRD EDITION.

MODERN demands on the finished products of steel have necessitated rapid strides in the art of heat treatment of the metal. As the subjects of forging, hardening, tempering and annealing are so closely correlated it has seemed wise to add to "Forge Practice" a certain amount of material devoted to the other branches of the art.

The introduction of heat measuring and hardness testing instruments, together with various other modern appliances, and up to date systems of doing work have made necessary a broader knowledge of heat-treating methods than was formerly the case: for after all the most important factor is the man doing the work.

It is the earnest wish of the writers of this volume that it may be instrumental in helping men engaged in heat treating steel to be of greater value to themselves and others.

PREFACE TO THE SECOND EDITION.

The author believes that the text book should be used to explain principles and give examples, not to give minute explicit directions for making a set of exercises.

This necesitates an independent set of drawings for the work to be done.

It is for this purpose that the set of drawings is given.

The author has felt the need and lack of such drawings in the text-book as used before, and it is to remedy this defect that the addition has been made.

The exercises are such as have been found useful in the shop, and an effort has also been made to give drawings of such tools as are ordinarily used in the forge and machine shops.

J. L. B.

March, 1908.

PREFACE TO THE FIRST EDITION.

THIS little volume is the outgrowth of a series of notes given to the students at Lewis Institute from time to time in connection with shop work of the character described.

It is not the author's purpose to attempt to put forth anything which will in any way take the place of actual shop work, but rather to give some explanation which will aid in the production of work in an intelligent manner.

The examples cited are not necessarily given in the order in which they could most advantageously be made as a series of exercises, but are grouped under general headings in such a way as to be more convenient for reference.

The original drawings from which the engravings were made were drawn by L. S. B.

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CHAPTER X.

FORGE-PRACTICE.

CHAPTER I.

GENERAL DESCRIPTION OF FORGE AND TOOLS.

Forge.—The principal part of the forge as generally made now is simply a cast-iron hearth with a bowl, or depression, in the center for the fire. In the bottom of this bowl is an opening through which the blast is forced. This blast-opening is known as the tuyere. Tuyeres are made in various shapes; but the object is the same in all, that is, to provide an opening, or a number of openings, of such a shape as to easily allow the blast to pass through, and at the same time, as much as possible, to prevent the cinders from dropping into the blast-pipe.

There should be some means of opening the blast-pipe beneath the tuyere and cleaning out the cinders which work through the tuyere-openings, as some cinders are bound to do this no matter how carefully the tuyere is designed.

When a long fire is wanted, sometimes several tuyeres are placed in a line; and for some special work the tuyeres take the form of nozzles projecting inwardly from the side of the forge.

Coal.—The coal used for forge-work should be of the best quality bituminous, or soft, coal. It should coke easily; that is, when dampened and put on the fire it should cake up, form coke, and not break into small pieces. It should be as free from sulphur as possible, and make very little clinker when burned.

Good forge-coal should be of even structure through the lumps, and the lumps should crumble easily in the hand. The lumps should crumble rather than split up into layers, and the broken pieces should look bright and glossy on all faces, almost like black glass, and show no dull-looking streaks.

Ordinary soft coal, such as is used for "steaming-coal," makes a dirty fire with much clinker. "Steaming-coal" when broken is liable to split into layers, some of which are bright and glossy, while others are dull and slaty-looking.

Fire.—On the fire, to a very great extent, depends the success or failure of all forging operations, particularly work with tool-steel and welding.

In building a new fire the ashes, cinders, etc., should be cleaned away from the center of the forge down to the tuyere. Do not clean out the whole top of the forge, but only the part where the new fire is wanted, leaving, after the old material has been taken out, a clean hole in which to start the fresh fire.

The hearth of the forge is generally kept filled with cinders, etc., even with the top of the rim.

Shavings, oily waste, or some other easily lighted material should be placed on top of the tuyere and set on fire.

As soon as the shavings are well lighted, the blast should be turned on and coke (more or less of which is always left over from the last fire) put on top and outside of the burning shavings. Over this the "green coal" should be spread.

Green coal is fresh coal dampened with water. Before using the forge-coal it should be broken into small pieces and thoroughly wet with water. This is necessary, as it holds together better when coking, making better coke and keeping in the heat of the fire better. It is also easier to prevent the fire from spreading out too much, as this dampened coal can be packed down hard around the edges, keeping the blast from blowing through.

The fire should not be used until all the coal on top has been coked. As the fire burns out in the center, the coke, which has been forming around the edge, is pushed into the middle, and more green coal added around the outside.

We might say the fire is made up of three parts: the center where the coke is forming and the iron heating; a ring around and next to this center where coke is forming; and, outside of this, a ring of green coal.

This is the ordinary method of making a small fire.

This sort of fire is suitable for smaller kinds of work. It can be used for about an hour or two, at the end of which time it should be cleaned. When welding, the cleaning should be done much oftener.

Large Fires.—Larger fires are sometimes made as follows: Enough coke is first made to last for several hours by mounding up green coal over the newly started fire and letting it burn slowly to coke thoroughly. This coke is then shoveled to one side and the fire again started in the following way: A large block, the size of the intended fire, is placed on top of the tuyere and green coal is packed down hard on each side, forming two mounds of closely packed coal. The block is taken out and the fire started in the hole between the two mounds, coke being added as necessary. This sort of a fire is sometimes called a stock fire, and will last for some time. The mounds keep the fire together and help to hold in the heat.

For larger work, or where a great many pieces are to be heated at once, or when a very even or long-continued heat is wanted, a furnace is used. For furnace use, and often for large forge-fires, the coke is bought ready-made.

Banking Fires. — When a forge-fire is left it should always be banked. The coke should be well raked up together into a mound and then covered with green coal. This will keep the fire alive for some time and insure plenty of good coke for starting anew when it does die out. A still better method to follow, when it is desired to keep the fire for some time, is to bury a block of wood in the center of the fire when banking it.

Oxidizing Fire.—When the blast is supplied from a power fan, or blower, the beginner generally tries to use too much air and blow the fire too hard. Coal requires a certain amount of air to burn properly, and as it burns it consumes the oxygen from the air. When too much blast is used the oxygen is not all burned out of the air and will affect the heated iron in the fire. Whenever a piece of hot iron comes in contact with the air the oxygen of the air attacks the iron and forms oxide. This oxide is the scale which is seen on the outside of iron. The higher the temperature to which the iron is heated, the more easily the oxide is formed. When welding, particularly, there should be as little scale, or oxide, as possible, and to prevent its formation the iron should not be heated in contact with any more air than necessary. Even on an ordinary forging this scale is a disadvantage, to say the least, as it must be cleaned off, and even then is liable to leave the surface of the work pitted and rough. If it were possible to keep air away from the iron entirely, no trace of scale would be formed, even at a high heat.

If just enough air is blown into the fire to make it burn properly, all the oxygen will be burned out, and very little, if any, scale will be formed while heating. On the other hand, if too much air is used, the oxygen will not all be consumed and this unburned oxygen will attack the iron and form scale. This is known as "oxidizing";

that is, when too much air is admitted to the fire the surplus oxygen will attack the iron, forming "oxide," or scale. This sort of a fire is known as an "oxidizing" fire and has a tendency to "oxidize" anything heated in it.

Anvil.—The ordinary anvil, Fig. 1, has a body of cast iron, wrought iron, or soft steel, with a tool-steel face welded on and hardened. The hardened steel covers just the top face, leaving the horn and the small block next the horn of the softer material.

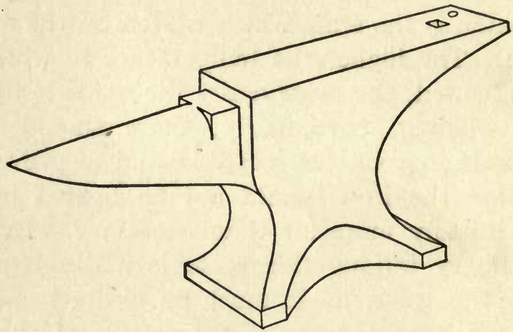


FIG. 1.

The anvil should be so placed that as the workman faces it the horn will point toward his left. The square hardie-hole in the right-hand end of the face is to receive and hold the stems of hardies, swages, etc.

For small work the anvil should weigh about 150 lbs.

Hot and Cold Chisels.—Two kinds of chisels are commonly used in the forge-shop: one for cutting cold stock, and the other for cutting red-hot metal. These are called cold and hot chisels.

The cold chisel is generally made a little thicker in the blade than the hot chisel, which is forged down to a thin edge.

Fig. 2 shows common shapes for cold and hot chisels, as well as a hardie, another tool used for cutting.

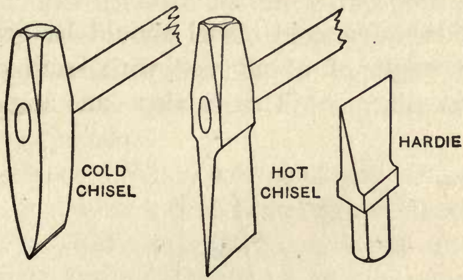


FIG. 2.

Both chisels should be tempered alike when made.

The cold chisel holds its temper; but, from contact with hot metal, the hot chisel soon has its edge softened. For these reasons the two chisels should never be used in place of each other, for by using the cold chisel on hot work the temper is drawn and the edge left too soft for cutting cold metal, while the hot chisel soon becomes so soft that if used in place of the cold it will have its edge turned and ruined.

It would seem that it is useless to temper a hot chisel, as the heated work, with which the chisel comes in contact, so soon draws the temper. When the chisel is tempered, however, the steel is left in a much better condition even after being affected by hot metal on which it is used than it would be if the chisel were made untempered.

Grinding Chisels.—It is very important to have the chisels, particularly cold chisels, ground correctly, and the following directions should be carefully followed.

The sides of a cold chisel should be ground to form an angle of about 60° with each other, as shown in Fig. 3. This makes an angle blunt

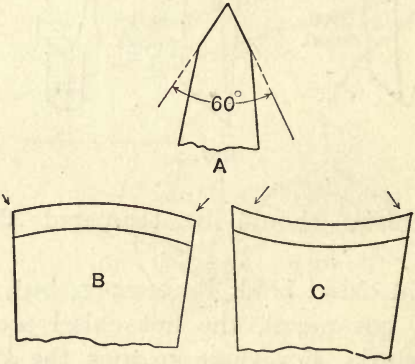


FIG. 3.

enough to wear well, and also sharp enough to cut well.

The cutting edge should be ground convex, or curving outward, as at *B*. This prevents the corners from breaking off. When the edge of the chisel is in this shape, the strain of cutting tends to force the corners back against the solid metal in the central part of the tool. If the edge were made concave, like *C*, the strain would tend to force the corners outward and snap them off. The arrows on *B* and *C* indicate the direction of these forces.

Hot chisels should be ground sharper. The sides should be ground at an angle of about 30° instead of 60°.

Another tool used for cutting is the hardie. This takes the place of the cold or hot chisel. It has a stem fitted to the square hole in the right-hand end of the anvil face, this stem holding the hardie in place when in use.

Cutting Stock.—When soft steel and wrought-iron bars are cut with a cold chisel the method should be about as follows: First cut about one-fourth of the way through the bar on one side; then make a cut across each edge at the ends of the first cut; turn the bar over and cut across the second side about one-fourth the way through; tilt the bar slightly, with the cut resting on the outside corner of the anvil, and by striking a sharp blow with the sledge on the projecting end, the piece can generally be easily broken off.

Chisels should always be kept carefully ground and sharp.

A much easier way of cutting stock is to use bar shears, but these are not always at hand.

The edge of a chisel should never under any circumstances be driven clear through the stock and allowed to come in contact with the hard face of the anvil.

Sometimes when trimming thin stock it is convenient to cut clear through the piece; in this case the cutting should be done either on the horn, the soft block next the horn, or the stock to be cut should be backed up with some soft metal. An easy way to do this is to cut a wide strip of stock about two inches longer than the width of the face of the anvil, and bend the ends down to fit over the sides of the anvil. The cutting may be done on this without injury to the edge of the chisel. It is very convenient to have one of these strips always at hand for use when trimming thin work with a hot chisel.

The author has seen a copper block used for this same purpose. The block was formed like Fig. 4, the stem being shaped to fit into the hardie-hole of the anvil. This block was designed for use principally when trimming thin parts of heated work with a hot chisel.

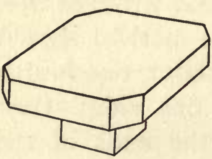


FIG. 4.

Care should always be taken to see that the work rests flat on the anvil or block when cutting. The work should be supported directly underneath the point where the cutting is to be done; and the solider the support, the easier the cutting.

Hammers.—Various shapes and sizes of hammers are used, but the commonest, and most convenient for ordinary use, is the ball pene-hammer shown in Fig. 5.

The large end is used for ordinary work, and the small ball end, or pene, for riveting, scarfing, etc. These hammers vary in weight from a few ounces up to several pounds. For ordinary use about a $1\frac{1}{2}$- or 2-pound hammer is used.

Several other types in ordinary use are illustrated

FIG. 5.

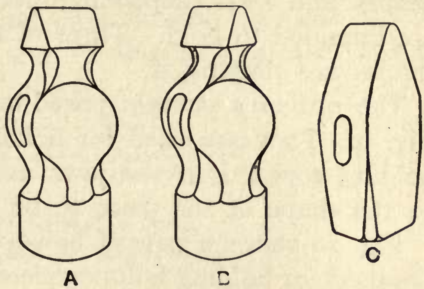


FIG. 6.

in Fig. 6. *A* is a straight-pene; *B*, a cross-pene; and *C*, a riveting-hammer.

Sledges.—Very light sledges are sometimes made the same shape as ball-pene hammers. They are used for light tool-work and boiler-work.

Fig. 7 illustrates a common shape for sledges. This is a double-faced sledge.

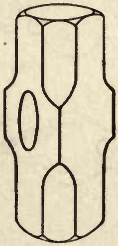


FIG. 7.

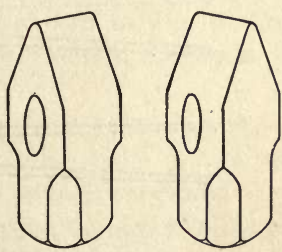


FIG. 8.

Sledges are also made with a cross-pene or straight-pene, as shown in Fig. 8.

For ordinary work a sledge should weigh about 10 or 12 lbs.; for heavy work, from 16 to 20.

Sledges for light work weigh about 5 or 6 lbs.

Tongs.—Tongs are made in a wide variety of shapes and sizes, depending upon the work they are intended to hold. Three of the more ordinary shapes are illustrated.

The ordinary straight-jawed tongs are shown in Fig. 9. They are used for holding flat iron. For holding round iron the jaws are grooved or bent to the shape of the piece to be held.

Fig. 10 shows a pair of bolt-tongs. These tongs are used for holding bolts or pieces which are larger on the end than through the body, and are so shaped that the tongs do not touch the enlarged end when the jaws grip the body of the work.

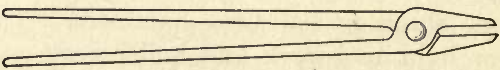


FIG. 9.

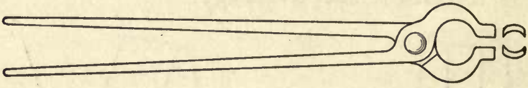


FIG. 10.

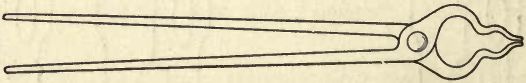


FIG. 11.

Pick-up tongs, Fig. 11, are used for handling small pieces, tempering, etc., but are very seldom used for holding work while forging.

Fitting Tongs to Work.—Tongs should always be carefully fitted to the work they are intended to hold.

Tongs which fit the work in the manner shown in Fig. 12 should not be used until more carefully fitted. In the first case shown, the jaws are too close together; and in the second case, too far apart.

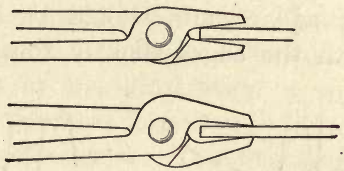


FIG. 12.

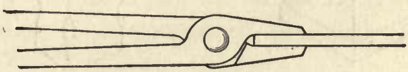


FIG. 13.

When properly fitted, the jaws should touch the work the entire length, as illustrated in Fig. 13. With properly fitted tongs the work may be held firmly, but if fitted as shown in Fig. 12 there is always a very "wobbly" action between the jaws and the work.

To fit a pair of tongs to a piece of work, the jaws should be heated red-hot, the piece to be held placed between them, and the jaws closed down tight around the piece with a hammer. To prevent the handles from being brought too close together while the tongs are being fitted, a short piece of stock should be held between them just back of the jaws. If the handles are too far apart, a few blows just back of the eye will close them up.

Flatter—Set-hammer—Swage—Fuller—Swage-block.—Among the commonest tools used in forge-work are the ones mentioned above.

The flatter, Fig. 14, as its name implies, is used for flattening and smoothing straight surfaces.

The face of the flatter is generally from 2 inches to 3 inches square, and should be kept perfectly smooth with the edges slightly rounding.

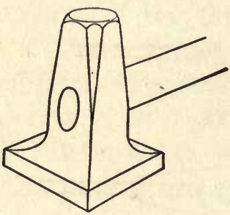


FIG. 14.

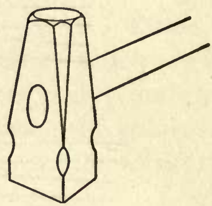


FIG. 15.

Fig. 15 shows a set-hammer. This is used for finishing parts which cannot be reached with the flatter, up into corners, and work of that character. The face of this tool also should be smooth and flat, with the corners more or less rounded, depending on the work it is intended to do.

Set-hammers for small work should be about 1 or 1¼ inches square on the face.

"Set-hammer" is a name which is sometimes given to almost any tool provided with a handle, which tool in use is held in place and struck with another hammer. Thus, flatters, swages, fullers, etc., are sometimes classed under the general name of set-hammers.

Fullers, Fig. 16, are used for finishing up filleted corners, forming grooves, and for numerous purposes which will be given more in detail later.

They are made in a variety of sizes, the size being determined by the shape of the edge *A*. On a $\frac{1}{2}$ inch fuller this edge would be a half-circle $\frac{1}{2}$ inch in diameter; on a $\frac{3}{4}$ inch it would be $\frac{3}{4}$ inch in diameter, etc.

Fullers are made "top" and "bottom." The one shown with a handle is a "top" fuller, and the lower one in the illustration is a "bottom" fuller and has the stem forged to fit into the square hardie-hole of the anvil. This stem should be a loose fit in the hardie-hole. Tools of this character should never be used on an anvil where they fit so tightly that it is necessary to drive them into place.

A top and bottom swage is shown in Fig. 17. The swages shown here are for finishing round

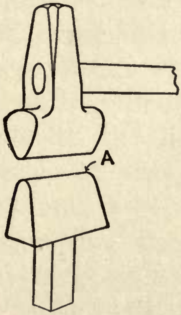


FIG. 16.

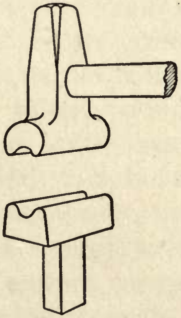


FIG. 17.

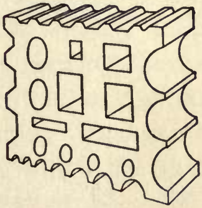


FIG. 18.

work; but swages are made to be used for other shapes as well.

Swages are sized according to the shape they are made to fit. A 1-inch round swage, for instance, is made to fit a circle 1 inch in diameter, and would be used for finishing work of that size.

All of the above tools are made of low-carbon tool steel.

A swage-block is shown in Fig. 18. These blocks are made in a variety of shapes; the illustration showing a common form for general use. This block is made of cast iron and is about 3½ inches thick. It has a wide range of uses and is very convenient for general work, where it takes the place of a good many special tools.

CHAPTER II.

WELDING.

Welding-heat.—A piece of wrought iron or mild steel, when heated, as the temperature increases becomes softer and softer until at last a heat is reached at which the iron is so soft that if another piece of iron heated to the same point touches it, the two will stick together. The heat at which the two pieces will stick together is known as the welding-heat. If the iron is heated much beyond this point, it will burn. All metals cannot be welded (in the sense in which the term is ordinarily used). Some, when heated, remain very dense and retain almost their initial hardness until a certain heat is reached, when a very slight rise of temperature will cause them to either crumble or melt. Only those metals which, as the temperature is increased, become gradually softer, passing slowly from the solid to the liquid state, can be welded easily. Metals of this kind just before melting become soft and more or less pasty, and it is in this condition that they are most weldable. The greater the range of temperature through which the metal remains pasty the more easily may it be welded.

In nearly all welding the greatest trouble is in heating the metal properly. The fire must be clean and bright or the result will be a "dirty" heat; that is, small pieces of cinder and other dirt will stick to the metal, get in between the two pieces, and make a bad weld.

Too much care cannot be used in welding; if the pieces are too cold they will not stick, and no amount of hammering will weld them. On the other hand, if they are kept in the fire too long and heated to too high a temperature they will be burned, and burned iron is absolutely worthless.

The heating must be done slowly enough to insure the work heating evenly all the way through. If heated too rapidly, the outside may be at the proper heat while the interior metal is much colder; and, as soon as taken from the fire, this cooler metal on the inside and the air almost instantly cool the surface to be welded below the welding temperature, and it will be too cold to weld by the time any work can be done on it.

If the pieces are properly heated (when welding wrought iron or mild steel), they will feel sticky when brought in contact.

When welding, it is best to be sure that everything is ready before the iron is taken from the fire. All the tools should be so placed that they may be picked up without looking to see where they are. The face of the anvil should be perfectly clean, and the hammer in such a position that it will not be knocked out of the way when the work is placed on the anvil for welding.

All the tools being in place, and the iron brought to the proper heat, the tongs should be held in such a way that the pieces can be easily placed in position for welding without changing the grip or letting go of them; then, when everything is ready, the blast should be shut off, the pieces taken from the fire, placed together on the anvil, and welded together with rapid blows of the hammer, welding (after the pieces are once stuck together) the thin parts first, as these are the parts which naturally cool the quickest.

Burning Iron or Steel.—The statement that iron can be burned seems to the beginner to be rather exaggerated. The truth of this can, however, be very easily shown. If a bar of iron be heated in the forge and considerable blast turned on, the bar will grow hotter and hotter, until at last sparks will be seen coming from the fire. These sparks, which are quite unlike the ordinary ones from the fire, are white and seem to explode and form little white stars.

These sparks are small particles of burning iron which have been blown upward out of the fire.

The same sparks may be made by dropping fine iron-filings into a gas-flame, or by burning a piece of oily waste which has been used for wiping up iron-filings.

If the bar of iron be taken from the fire at the time these sparks appear, the end of the bar will seem white and sparkling, with sparks, like stars similar to those in the fire, coming from it. If the heating be continued long enough, the end of the bar will be partly consumed, forming lumps similar to the "clinkers" taken from a coal fire.

To burn iron two things are necessary: a high enough heat, and the presence of oxygen.

As noted before, when welding, care must be taken not to have too much air going through the fire; in other words, not to have an oxidizing fire.

If the fire is not an oxidizing one, there is not so much danger of injury to the iron by burning and the forming of scale.

Iron which has been overheated and partially burned has a rough, spongy appearance and is brittle and crumbly.

Use of Fluxes in Welding.—When a piece of iron or steel is heated for welding under ordinary conditions the outside is oxidized; that is, a thin film of iron oxide is formed. This oxide is the black scale which is continually falling from heated iron and is formed when heated iron is brought in contact with the air. This oxide of iron is not fluid except at a very high heat, and, if allowed to stay on the iron, will prevent a good weld.

When welding without a flux the iron is brought to a high enough heat to melt the oxide, which is forced from between the welding pieces by the blows of the hammer.

This heat may easily be taken when welding ordinary iron; but when working with some machine-steel, and particularly tool-steel, the metal cannot be heated to a high enough temperature to melt the oxide without burning the steel.

From the above it would seem impossible to weld steel, as it cannot be heated under ordinary conditions without oxidizing, but by the use of a flux this difficulty may be overcome and the oxide melted at a lower temperature.

The flux (sand and borax are the most common) should be sprinkled on the part of the piece to be welded when it has reached about a yellow heat, and the heating continued until the metal is at a proper temperature to be soft enough to weld, but care should be taken to see that the flux covers the parts to be welded together.

The flux has a double action; in the first place, as it melts it flows over the piece and forms a protecting covering which prevents oxidation, and also when raised to the proper heat dissolves the oxide that has already formed.

The oxide melts at a much lower heat when combined with the flux than without it, and to melt the oxide is the principal use of the flux. The metal when heated in contact with the flux becomes soft and "weldable" at a lower temperature than when without it.

Ordinary borax contains water which causes it to bubble up when heated. If the heating is continued at a high temperature, the borax melts and runs like water; this melted borax, when cooled, is called borax-glass.

Borax for welding is sometimes fused as above and then powdered for use.

Sal ammoniac mixed with borax seems to clean the surface better than borax alone. A flux made of one part of sal ammoniac and four parts borax works well, particularly when welding tool-steel, and is a little better than borax alone.

Most patented welding compounds have borax as a basis, and are very little, if any, better than the ordinary mixture given above.

The flux does not in any way stick the pieces together or act as a cement or glue. Its use is principally to help melt the oxide already formed and to prevent the formation of more.

Iron filings are sometimes mixed with borax and used as a flux.

When using a flux the work should always be scarfed the same as when no flux is used. The pieces can be welded, however, at a lower heat.

Fagot or Pile Welding.—When a large forging is to be made of wrought iron, small pieces of "scrap" iron (old horseshoes, bolts, nuts, etc.) are placed together in a square or rectangular pile on a board, bound together with wire, heated to welding heat in a furnace, and welded together into one solid lump, and the forging made from this. If there is not enough metal in one lump, several are made in this way and afterward welded to each other—making one large piece. This is known as fagot or pile welding.

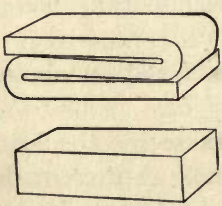


FIG. 19.

Sand is used for fluxing to a large extent on work of this kind.

Sometimes a small fagot weld is made by laying two or more pieces together and welding them their entire length, or one piece may be doubled together several times and welded into a lump. Such a weld is shown in Fig. 19, which shows the piece before welding and also after being welded and shaped.

Scarfing.—In a fagot weld the pieces are not prepared or shaped for each other, being simply laid together and welded, but for most welding the ends of the pieces to be joined should be so shaped that they will fit together and form a smooth joint when welded. This is called scarfing. It is very important that the scarfing be properly done, as a badly shaped scarf will probably spoil the weld. For instance, if an attempt be made to weld two bars together simply by overlapping their ends, as in Fig. 20, the weld when finished would be something like Fig. 21. Each bar would

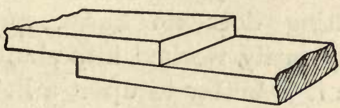


FIG. 20.

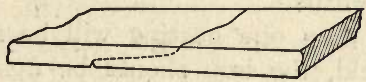


FIG. 21.

be forged into the other and leave a small crack where the end came. On the other hand, if the ends of the bars were properly scarfed or pointed, they could be welded together and leave no mark—making a smooth joint.

Lap-welds are sometimes made without scarfing when manufacturing many pieces alike, but this should not be attempted in ordinary work.

Lap-weld Scarf.—In preparing for the lap-weld, the ends of the pieces to be welded should be first upset until they are considerably thicker than the rest of the bar. This is done to allow for the iron which burns off, or is lost by scaling, and also to allow for the hammering which must be done when welding the pieces together. To make a proper weld the joint should be well hammered together, and as this reduces the size of the iron at that point the pieces must be upset to allow for this reduction in size in order to have the weld the same size as the bar.

If the ends are not upset enough in the first place, it requires considerable hard work to upset the weld after they are joined together. Too much upsetting does no harm, and the extra metal is very easily worked into shape. To be on the safe side it is better to upset a little more than is absolutely necessary—it may save considerable work afterwards.

If more than one heating will be necessary to make a weld, the iron should be upset just that much more to allow for the extra waste due to the second or third heating.

Flat Lap-weld.—The lap-weld is the weld ordinarily used to join flat or round bars of iron together end to end.

Following is a description of a flat lap-weld: The ends of the pieces to be joined must be first upset. When heating for upsetting heat only the end as shown in Fig. 22, where the shaded part indicates the hotter metal. To heat this way place only the extreme *end* of the bar in the fire, so the heat will not run back too far. The end should be upset until it looks about like Fig. 23.

FIG. 22.

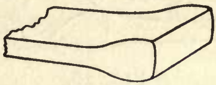


FIG. 23.

When starting to shape the scarf use the round or pene end of the hammer. Do not strike directly *down* on the work, but let the blows come at an angle of about 45 degrees and in such a way as to force the metal back toward the base as shown in Fig.

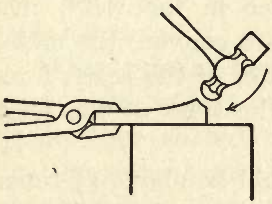


FIG. 24.

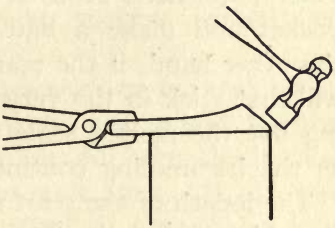


FIG. 25.

24. This drives the metal back and makes a sort of thick ridge at the beginning of the scarf. In finishing the scarf, use the flat face of the hammer, and bring the piece to the very edge of the anvil, as in this way a hard blow may be struck without danger of hitting the anvil instead of the work. The proper position is shown in Fig. 25.

The scarfs should be shaped as in Fig. 26, leaving them slightly convex and not concave, as shown in Fig. 27.

The reason for this is that if the scarfed ends be concave when the two pieces are put together, a

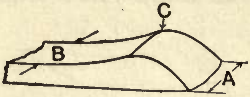


FIG. 26.

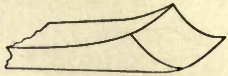


FIG. 27.

small pocket or hollow will be left between them, the scarfs touching only the edges. When the weld is hammered together, these edges being in contact will naturally weld first, closing up all outlet to the pocket. As the surface of the scarf is more or less covered with melted scale and other impurities, some of this will be held in the pocket and make a bad place in the weld. On the other hand, if the scarfs are convex, the metal will first stick in the very center of the scarf, forcing out the melted scale at the sides of the joint as the hammering continues.

The length of the scarf should be about 1½ times the thickness of the bar; thus on a bar ½″ thick the scarf should be about ¾″ long.

The width of the end *A* should be slightly less than the width *B* of the bar. In welding the two pieces together, the first piece should be placed scarf side up on the anvil, and the second piece laid on top, scarf side down, in such a way that the thin edges of the second piece will lap over the thick ridge *C* on the first piece as shown in Fig. 28. The piece which is laid on top should be held by the smith doing the welding, the other may be handled by the helper.

The helper should place his piece in position on the anvil first. As it is rather hard to lay the other piece directly on top of this and place it exactly in the right position, it is better to rest the second piece on the corner of the anvil as

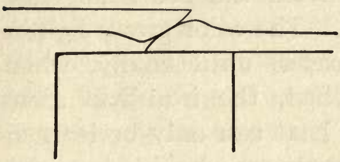


FIG. 28.

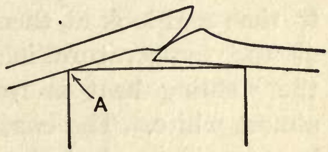


FIG. 29.

shown at *A*, Fig. 29, and thus guide it into position. In this way the piece may be steadied and placed on the other in the right position without any loss of time.

When heating for a lap-weld, or for that matter any weld where two pieces are joined together, great care should be taken to bring both pieces to the same heat at the same time. If one piece heats faster than the other, it should be taken from the fire and allowed to cool until the other piece "catches up" with it. It requires some practice to so place the pieces in the fire that they will be heated uniformly and equally. The tips particularly must be watched, and it may be necessary to cool them from time to time in the water-bucket to prevent the extreme ends from burning off.

The fire *must* be clean, and the heating should be done slowly in order to insure its being done evenly.

Just before taking the pieces from the fire they should be turned scarf side down for a short time, to be sure that the surfaces to be joined will be hot.

More blast should be used at the last moment than when starting to heat.

The only way to know how this heating is going on is to take the pieces from the fire from time to time and look at them. The color grows lighter as the temperature increases, until finally, when the welding heat is reached, the iron will seem almost white. The exact heat can only be learned by experience; but the workman should recognize it after a little practice as soon as he sees it.

To get an indication of the heat, which will help sometimes, watch the sparks that come from the fire. When the little, white, explosive sparks come they show that some of the iron has been heated hot enough to be melted off in small particles and is burning. This serves as a rough indication that the iron is somewhere near the welding heat. This should never be relied on entirely, as the condition of the fire has much to do with their appearance.

Round Lap-weld.—The round lap-weld—the weld used to join round bars end to end—is made in much the same way as the ordinary or flat lap-weld. The directions given for making the flat weld apply to the round lap as well, excepting that the scarf is slightly different in shape. The proper shape of scarf is shown in Fig. 30, which gives the top and side views of the piece. One side is

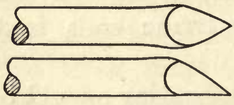


FIG. 30.

left straight, the other three sides tapering in to meet it in a point. The length of the scarf should be about one and one-half times the diameter of the bar. Always be sure, particularly in small work, that the pieces are scarfed to a *point*, and not merely flattened out. The greatest difficulty with this weld is to have the points of the pieces well welded, as they cool very rapidly after leaving the fire. The first blows, after sticking the pieces together, should cover the points. The weld should be made *square* at first and then rounded. The weld is not so apt to split while being hammered if welded square and then worked round, as it would be if hammered round at first.

If the scarf were made wide on the end like the ordinary lap-weld, it would be necessary to hammer clear around the bar in order to close down the weld; but with the pointed scarf, one blow on each point will stick the work in place, making it much more quickly handled.

Ring Weld, Round Stock. A ring formed from round stock may be made in two ways; that is, by scarfing before or after bending into shape. When scarfed *before* bending, the length of stock should be carefully calculated, a small amount

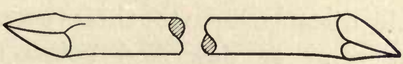


Fig. 31.

being added for welding, and the ends upset and scarfed exactly the same as for a round lap-weld.

Care should be taken to see that the scarfs come on opposite sides of the piece.

Fig. 31 shows a piece of stock scarfed ready for bending.

After scarfing, the piece should be bent into a ring and welded, care being taken when bending to see that the points of the scarf lie as indicated at *A*, Fig. 32, and not as shown at *B*.

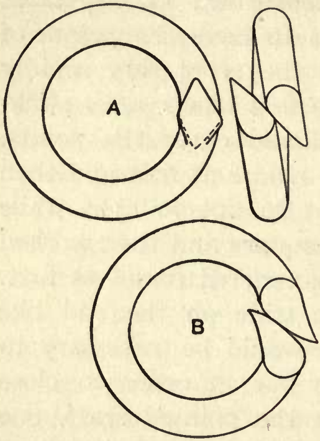


FIG. 32.

When the points of the scarfs are lapped as shown at *A*, most of the welding may be done while the ring lies flat on the anvil, the shaping being finished over the horn. If the points are lapped the other way, *B*, the welding also must be done over the horn, making it much more awkward to handle.

The second way of welding the ring is practically the same as that of making a chain link, and the same description of scarfing will answer for both, the stock being cut and bent into a ring, with the ends a little distance apart; these ends are then scarfed the same as described below for a link scarf and welded in exactly the same manner as described for making the other ring.

Chain-making.—The first step in making a link is to bend the iron into a U-shaped piece, being careful to keep the legs of the U exactly even in length. The piece should be gripped at the lower end of the U, the two ends brought to a high heat, scarfed, bent into shape together, reheated, and welded.

To scarf the piece place one end of the U on the anvil, as shown in Fig. 33, and strike one blow on it; move it a short distance in the direction shown by the arrow and strike another blow. This should be continued until the edge or corner of the piece is reached, moving it after each blow.

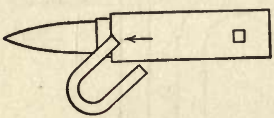


FIG. 33.

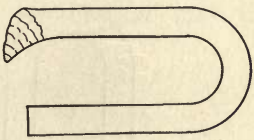


FIG. 34.

This operation leaves a series of little steps on the end of the piece, and works it out in a more or less pointed shape, as shown in Fig. 34.

This scarf may be finished by being brought more to a point by a few blows over the horn of the anvil. The ends should then be bent together and welded. Fig. 35 shows the steps in making the link and two views of the finished link. The link is sometimes left slightly thicker through the weld. A second link is made—all but welding—spread open, and the first link put on it, closed up again, and welded. A third is joined to this etc.

When made on a commercial scale, the links are not scarfed but bent together and welded in one heat.

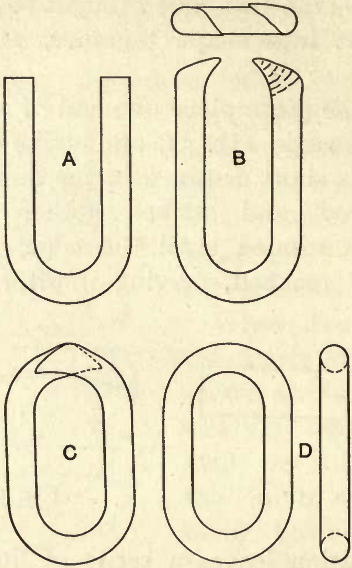


FIG. 35.

Ring, or Band.—A method of making a ring from

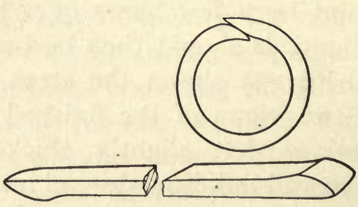


FIG. 36.

flat iron is shown in Fig. 36, which shows the stock before and after bending into shape.

The stock is cut to the correct length, upset, and scarfed exactly the same as for a flat lap-weld. The piece is bent into shape and welded over the horn of the anvil. The ring must be heated for welding very carefully or the outside lap will burn before the inside is hot enough to weld.

In scarfing this—as in making other rings—care must be taken to have the scarfs come on opposite sides of the tock.

Washer, or Flat Ring.—In this weld flat stock is used bent edgewise into a ring without any preparation. The corners of the ends are trimmed off parallel after the stock is bent as shown in Fig. 37.

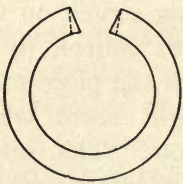


FIG. 37.

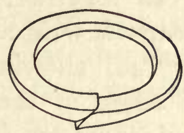


FIG. 38.

After trimming the ends are scarfed with a fuller or pene end of a hammer and lapped ready for welding (Fig. 38).

When heating for welding, the ring should be turned over several times to insure uniformity in heating.

If the work is particular, the ends of the stock should be upset somewhat before bending into shape.

Butt-weld. — This is a weld where the pieces are butted together without any slanting scarfs, leaving a square joint through the weld.

When two pieces are so welded the ends should be slightly rounded, simillar to Fig. 39, which shows two pieces ready for welding. If the ends are convex as shown, the scale and other impurity sticking to the metal is forced out of the joint. If the ends were concave this matter would be

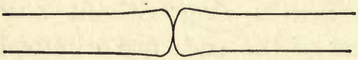


FIG. 39.

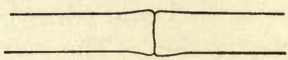


FIG. 40.

held between the pieces and make a poor weld. The pieces are welded by being struck on the ends and driven together. This, of course, upsets the metal near the weld and leaves the piece something like Fig. 40, showing a slight seam where the rounded edges of the ends join. This upset part is worked down to size at a welding heat, leaving the bar smooth.

A butt-weld is not as safe or as strong as a lap-weld.

When the pieces are long enough they may be welded right in the fire. This is done by placing the pieces in the fire in the proper position for welding; a heavy weight is held against the projecting end of one piece—to "back it up"—and the weld is made by driving the pieces together by hammering on the projecting end of the second piece. As soon as the work is "stuck," the weld is taken from the fire and finished on the anvil.

Jump Weld.—Another form of butt-weld, Fig. 41, is the "jump" weld, which, however, is a form which should be avoided as much as possible, as it is very liable to be weak. When making a weld like this, the piece which is to be "jumped," or "butted," on to the other piece should have its end upset in such a way as to flare out and form a sort of flange the wider the better. When the weld is made, this flange—indicated by the arrow—can be welded down with a hammer, or set-hammers, and make a fairly strong weld.

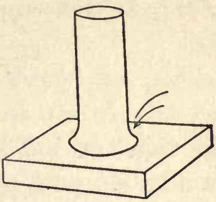


FIG. 41.

Split Weld; Weld for very Thin Steel.—Very thin stock is sometimes difficult to join with the ordinary lap-weld for the reason that the stock is so thin that if the pieces are taken from the fire at the proper heat they will be too cold to weld before they can be properly placed together on the anvil.

This difficulty is somewhat overcome by scarfing the ends, similar to Fig. 42. The ends are tapered

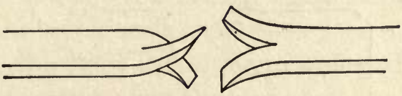


FIG. 42.

to a blunt edge and split down the center for half an inch or so, depending on the thickness of stock. One half of each split end is bent up, the other down; the ends are pushed tightly together and the split parts closed down on each other, as shown

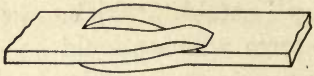


FIG. 43.

in Fig. 43. The joint may then be heated and welded.

This is a weld sometimes used for welding spring steel, or iron to steel.

Split Weld; Heavier Stock.—A *split weld* for heavier stock is shown ready for welding in Fig.

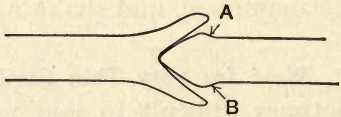


FIG. 44.

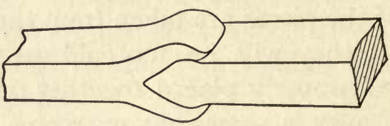


FIG. 45.

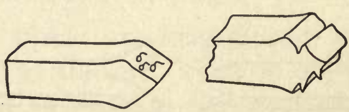


FIG. 46.

45, Fig. 44 showing the two pieces before they are put together. In this weld the ends of the pieces are first upset and then scarfed, one piece being split and shaped into a Y, while the other has its end brought to a point with the sides of the bar just back of the point bulging out slightly as shown at *A* and *B*. This bulge is to prevent the two pieces from slipping apart.

When properly shaped the two pieces are driven together and the sides, or lips, of the Y-shaped scarf closed down over the pointed end of the other piece. The lips of the Y should be long enough to lap over the bulge on the end of the other piece and thus prevent the two pieces from slipping apart. The pieces are then heated and welded. Care must be taken to heat slowly, that the pointed part may be brought to a welding heat without burning the outside piece. Borax, sand, or some other flux should be used. (Sometimes the faces of the scarfs are roughened or notched with a chisel, as shown in Fig. 46, to prevent the pieces from slipping apart.)

This is the weld that is often used when welding tool-steel to iron or mild steel.

Sometimes the pieces are heated separately to a welding heat before being placed together. Good results may be obtained this way when tool-steel is welded to iron or mild steel, as the tool-steel welds at a much lower temperature than either wrought iron or mild steel, and if the two pieces are heated separately, the other metal may be raised to a much higher temperature than the tool-steel.

Angle Weld.—In all welding it should be remembered that the object of 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 weld, and it should be remembered that the method given here is not necessarily the only way in which the particular weld can be made.

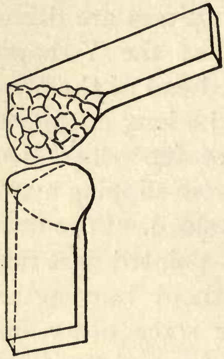


FIG. 47.

Fig. 47 shows one way of scarfing for a right-angle weld made of flat iron. Both pieces are scarfed exactly alike. The scarfing is done with the pene end of the hammer. If necessary the ends of the pieces may be upset before scarfing.

As in all other welds, care must be taken to so shape the scarfs that when they are placed together they will touch in the center, and not around the edges, thus leaving an opening for forcing out the impurities which collect on the surfaces to be welded.

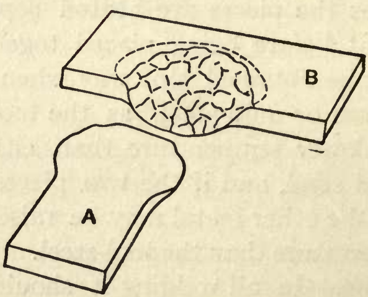


FIG. 48.

"T" Weld.—A method of scarfing for a "T" weld is illustrated in Fig. 48.

The stem, *A*, should be placed on the bar, *B*, when welding in about the position shown by the dotted line on *B*.

"T" Weld, Round Stock.—Two methods of scarfing for a "T" weld made from round stock are shown in Fig. 49.

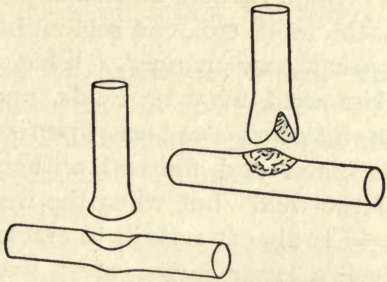


FIG. 49.

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 when tool-steel is to be welded, either to itself or to wrought iron or mild steel, more care must be used in the heating than when working with the softer metals alone.

The proper heat for welding tool-steel—about a bright yellow—can only be learned by experiment. If the tool-steel is heated until the sparks fly, a light blow of the hammer will cause it to crumble and fall to pieces.

When welding mild steel or wrought iron to tool-steel, the tool-steel should be at a lower heat than the other metal, which should be heated to its regular welding heat.

The flux used should be a mixture of about one part sal ammoniac and four parts borax.

Tool-steel of high carbon, and such as is used for files, small lathe tools, etc., can seldom be welded to itself in a satisfactory manner. What appears to be a first-class weld may be made, and the steel may work up into shape and seem perfect—may, in fact, be machined and finished without showing any signs of the weld—but when the work is hardened, the weld is almost certain to crack open.

Spring steel, a lower carbon steel, may be satisfactorily welded if great care be used.

CHAPTER III.

CALCULATION OF STOCK FOR BENT SHAPES.

Calculating for Angles and Simple Bends. — It is often necessary to cut the stock for a forging as nearly as possible to the exact length needed. This length can generally be easily obtained by meas-ment or calculation.

About the simplest case for calculation is a plain right-angle bend, of which the piece in Fig. 50 will serve as an example.

This piece as shown is a simple right-angle bend made from stock 1″ through, 8″ long on the outside of each leg.

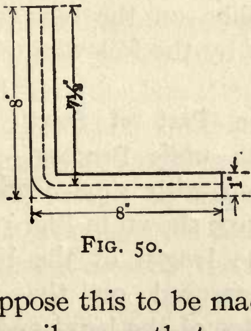


FIG. 50.

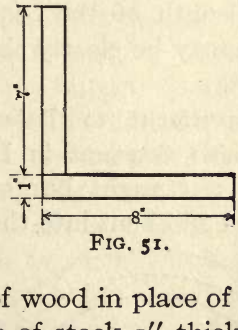


FIG. 51.

Suppose this to be made of wood in place of iron. It is easily seen that a piece of stock 1″ thick and 15″ long would make the angle by cutting off 7″

from one end and fastening this piece to the end of the 8″ piece, as shown in Fig. 51.

This is practically what is done when the angle is made of iron—only, in place of cutting and fastening, the bar is bent and hammered into shape.

In other words, any method which will give the length of stock required to make a shape of uniform section in wood, if no allowance is made for cutting or waste, will also give the length required to make the same shape with iron.

An easier way—which will serve for calculating lengths of all bent shapes—is to measure the length of an imaginary line drawn through the center of the stock. Thus, if a dotted line should be drawn through the center of stock in Fig. 50, the length of each leg of this line would be $7\frac{1}{2}''$, and the length of stock required 15″, as found before.

No matter what the shape when the stock is left of uniform width through its length, this length of straight stock may always be found by measuring the length of the center line on the bent shape. This may be clearly shown by the following experiment.

Experiment to Determine Part of Stock which Remains Constant in Length while Bending.—Suppose a straight bar of iron with square ends be taken and bent into the shape shown in Fig. 52. If the length of the bar be measured on the inside edge of the bend and then on the outside, it will be found that the inside length is considerably shorter

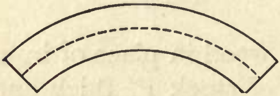


Fig. 52.

than the outside; and not only this, but the inside will be shorter than the original bar, while the outside will be longer. The metal must therefore squeeze together or upset on the inside and stretch or draw out on the outside. If this is the case, as it is, there must be some part of the bar which when it is bent neither squeezes together nor draws out, but retains its original length, and this part of the bar lies almost exactly in the center, as shown by the dotted line. It is on this line of the bent bar that the measuring must be done in order to determine the original length of the straight stock, for this is the only part of the stock which remains unaltered in length when the bar is bent.

To make the explanation a little clearer, suppose a bar of iron is taken, polished on one side, and lines scratched upon the surface, as shown in the lower drawing of Fig. 53, and this bar then bent into the shape shown in the upper drawing. Now if the length of each one of these lines be measured and the measurements compared with the length of the same lines before the bar was bent, it would be found that the line *AA*, on the outside of the bar, had lengthened considerably; the line *BB* would be somewhat lengthened, but not as much as *AA*; and *CC* would be lengthened less than *BB*. The line *OO*, through the center of the bar, would measure almost exactly the same as when the bar was straight. The line *DD* would be found to be shorter than *OO* and *FF* shorter than any other. The line *OO*, at the center of the bar, does not change its length when the bar is bent; consequently, to determine the length of straight stock required to bend into any shape, measure the

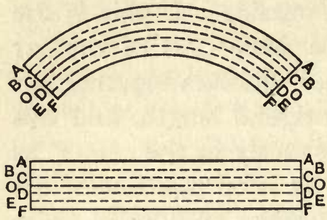


FIG. 53.

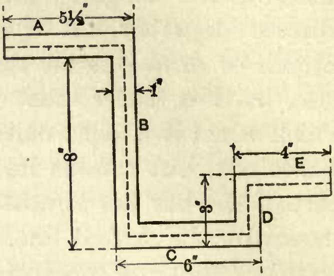


FIG. 54.

length of the line following the center of the stock of the bent shape.

As another example Fig. 54 will serve.

Suppose a center line be drawn, as shown by the dotted line. As the stock is 1″ thick, the length of the center line of the part *A* will be 5″, at *B* 8″, *C* 5″, *D* 2″, *E* $3\frac{1}{2}''$, and the total length of stock required $21\frac{1}{2}''$.

A convenient form for making calculations is as follows:

$$A = 5''$$
$$B = 8''$$
$$C = 5''$$
$$E = 3\tfrac{1}{2}''$$

Total . ∴ $21\frac{1}{2}''$ = length of stock required.

Curves. Circles. Methods of Measuring.—On circles and curves there are several different methods which may be employed in determining the length of stock, but the same principle must be followed in any case—the length must be measured along the center line of the stock.

One way of measuring is to lay off the work full size. On this full-size drawing lay a string or thin, easily bent wire in such a way that it follows the shape of the bend through its entire length, being careful that the string is laid along the center of the stock.

The string or wire may then be straightened and the length measured directly.

Irregular shapes or scrolls are easily measured in this way.

Another method of measuring stock for scrolls, etc., is to step around a scroll with a pair of dividers with the points a short distance apart, and then lay off the same number of spaces in a straight line and measure the length of that line. This is of more use in the drawing-room than in the shop.

Measuring-wheel.—Still another way of measuring directly from the drawing is to use a light measuring-wheel, similar to the one shown in Fig. 55, mounted in some sort of a handle. This is a thin light wheel generally made with a circumference of about 24″. The side of the rim is sometimes graduated in inches by eighths. 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

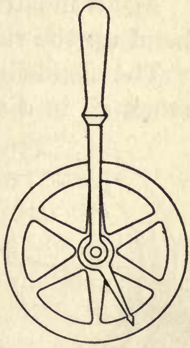


FIG. 55.

pushed along the surface following the line to be measured, with just pressure enough to make it revolve. By counting the revolutions made and setting the pointer or making a mark on the wheel to correspond to the end of the line when it is reached, it is an easy matter to push the wheel over a straight line for the same number of revolutions and part of a revolution as shown by the pointer and measure the length. If the wheel is graduated, the length run over can of course be read directly from the figures on the side of the wheel.

Calculating Stock for Circles.—On circles and parts of circles, the length may be calculated mathematically, and in the majority of cases this is probably the easiest and most accurate method. This is done in the following way: The circumference, or distance around a circle, is equal to the diameter multiplied by $3\frac{1}{7}$ (or more accurately, 3.1416).

As an illustration, the length of stock required to bend up the ring in Fig. 56 is calculated as follows:

The inside diameter of the ring is 6″ and the stock 1″ in diameter. The length must, of course, be measured along the center of the stock, as shown by the dotted line. It is the diameter of this circle, made by the dotted line, that is used for calculating the length of stock; and for convenience this may be called the "calculating" diameter, shown by C in Fig. 56.

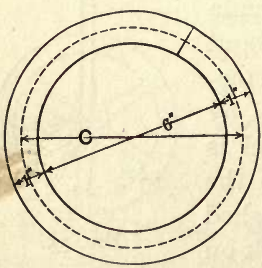


Fig. 56.

The length of this calculating diameter is equal to the inside diameter of the ring with one-half the thickness of stock added at each end, and in this case would be $\frac{1}{2}'' + 6'' + \frac{1}{2}'' = 7''$.

The length of stock required to make the ring would be $7'' \times 3\frac{1}{7} = 22''$; or, in other words, to find the length of stock required to make a ring, multiply the diameter of the ring, measured from center to center of the stock, by $3\frac{1}{7}$.

Calculating Stock for "U's."—Some shapes may be divided up into straight lines and parts of circles and then easily calculated. Thus the U shape in Fig. 57 may be divided into two straight sides and a half-circle end. The end is half of a circle having an outside diameter of $3\frac{1}{2}''$. The calculating diameter of this circle would be $3''$, and the length of stock required for an entire circle this size $3 \times 3\frac{1}{7} = 9\frac{3}{7}$, which for convenience we may call $9\frac{3}{8}''$, as this is near enough for ordinary work. As the forging calls for only half a circle, the length needed would be $9\frac{3}{8}'' \div \frac{1}{2} = 4\frac{1}{16}''$.

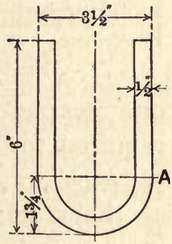


Fig. 57.

As the circle is $3\frac{1}{2}''$ outside diameter, half of this diameter, or $1\frac{3}{4}''$, must be taken from the total length of the U to give the length of the straight part of the sides; in other words, the distance from the line *A* to the extreme end of the U is half the diameter of the circle, or $1\frac{3}{4}''$. This leaves the straight sides each $4\frac{1}{4}''$ long, or a total length for both of $8\frac{1}{2}''$. The total stock required for the forging would be:

	Length stock for sides.........	$8\frac{1}{2}''$
	" " " end...........	$4\frac{11}{16}''$
Total	" " " forging.......	$13\frac{3}{16}''$.

Link.—As another example, take the link shown in Fig. 58. This may be divided into the two semicircles at the ends and the two straight sides. Calculating as always through the center of the stock, there are the two straight sides 2″ long, or 4″, and the two semicircular ends, or one complete circle for the two ends. The length required for these two ends would be $1\frac{1}{2}'' \times 3\frac{1}{7}'' = \frac{66}{14}'' = 4^{1}''$, or, nearly enough, $4\frac{11}{16}''$. The total length of the stock would be $4'' + 4\frac{11}{16}'' = 8\frac{11}{16}''$, to which must be added a slight amount for the weld.

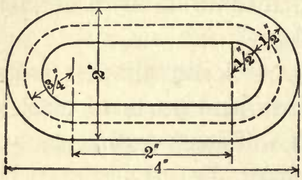


FIG. 58.

Double Link.—The double link in Fig. 59 is another example of stock calculation. Here there are two complete circles each having an inside diameter of $\frac{3}{4}''$, and, as they are made of $\frac{1}{4}''$ stock, a "calculating" diameter of 1″. The length of stock required for one side would be $3.1416'' \times 1'' = 3.1416''$, and the total length for complete links $3.1416'' \times 2'' = 6.2832''$, which is about $6\frac{1}{4}''$.

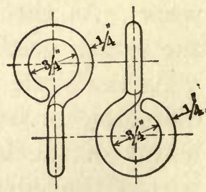


FIG. 59.

As a general rule it is much easier to make the calculations with decimals as above and then reduce these decimals to eighths, sixteenths, etc.

Use of Tables.—To aid in reduction a table of decimal equivalents is given on p. 249. By using this table it is only necessary to find the decimal result and select the nearest sixteenth in the table. It is generally sufficiently accurate to take the nearest sixteenth.

A table of circumferences of circles is also given; and by looking up the diameter of any circle the circumference may be found opposite.

To illustrate, suppose it is necessary to find the amount of stock required to make a ring 6″ inside diameter out of $\frac{3}{4}''$ round stock. This would make the calculating diameter of the ring $6\frac{3}{4}$.

In the table of circumferences and areas of circles opposite a diameter $6\frac{3}{4}$ is found the circumference 21.206. In the table of decimal equivalents it will be seen that $\frac{3}{16}$ is the nearest sixteenth to the decimal .206; thus the amount of stock required is $21\frac{3}{16}''$. This of course makes no allowance for welding.

Allowance for Welding.—Some allowance must always be made for welding, but the exact amount is very hard to determine, as it depends on how carefully the iron is heated and how many heats are taken to make the weld.

The only stock which is really lost in welding, and consequently the only waste which has to be allowed for, is the amount which is burned off or lost in scale when heating the iron.

Of course when preparing for the weld the ends of the piece are upset and the work consequently shortened, and the pieces are still farther shortened by overlapping the ends in making the weld; but all this material is afterward hammered back into shape so that no loss occurs here at all, except of course the loss from scaling.

A skilled workman requires a very small allowance for waste in welding, in fact sometimes none at all; but by the beginners an allowance should always be made.

No rules can be given; but as a rough guide on small work, a length of stock equal to from one-fourth to three-fourths the thickness of the bar will probably be about right for waste on rings, etc. When making straight welds, when possible it is better to allow a little more than is necessary and trim off the extra stock from the end of the finished piece.

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 in welding. In this way an accurate knowledge is soon obtained of the proper allowance for waste.

CHAPTER IV.

UPSETTING, DRAWING OUT, AND BENDING.

Drawing Out.—When a piece of metal is worked out, either by pounding or otherwise, in such a way that the length is increased, and either the width or thickness reduced, we say that the metal is being "drawn out," and the operation is known as "drawing out."

It is always best when drawing out to heat the metal to as high a heat as it 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 iron is laid flat on the anvil face and hit a blow with the hammer, it flattens out and spreads both lengthwise and crosswise, making the piece longer and wider. The piece is not wanted wider, however, but only longer, so it is necessary to turn it on edge and strike it in this position, when it will again increase in length and also in thickness, and will have to be thinned out again. A good deal of work thus goes to either increasing the width or thickness, which is not wanted increased; consequently this work and the work required to again thin the forging are lost. In other words, when drawing out iron on the face of the anvil the force of the blow is expended in forcing the iron sidewise as well as lengthwise, and the work used in forcing the iron sidewise is lost. Thus only about one half the force of the blow is really used to do the work wanted.

Suppose the iron be placed on the horn of the

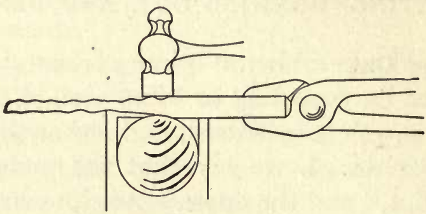


FIG. 60.

anvil, as shown in Fig. 60, and hit with the hammer as before. The iron will still spread out sidewise a little, but not nearly as much as before and will lengthen out very much more. The horn in this case acts as sort of a blunt wedge, forcing out the metal in the direction of the arrow, and the force of the blow is used almost entirely in lengthening the work.

Fullers may be used for the same purpose, and the work held either on the horn or the face of the anvil.

Drawing Out and Pointing Round Stock.—When drawing out or pointing round stock it should always be first forged down *square* to the required size and then, in as few blows as possible, rounded up.

Fig. 61 illustrates the different steps in drawing out round iron to a smaller size. *A* is the original bar, *B* is the first step, *C* is the next, when the iron is forged octagonal, and the last step is shown at *D*,

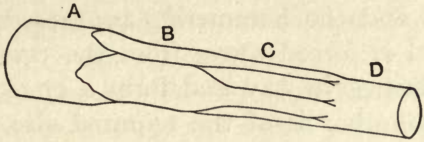


FIG. 61.

where the iron is finished up round. In drawing out a piece of round iron it should first be forged like *B*, then like *C*, and lastly finished like *D*.

As an example: Suppose part of a bar of $\frac{3}{4}''$ round stock is to be drawn down to $\frac{3}{8}''$ in diameter. Instead of pounding it down round and round until the $\frac{3}{8}''$ diameter is reached, the part to be drawn out should be forged perfectly square and this drawn down to $\frac{3}{8}''$, keeping it as nearly square as possible all the time.

The corners of the square are forged off, making an octagon, and, last of all, the work is rounded up. This prevents the metal from splitting, as it is very liable to do if worked round and round.

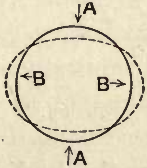


FIG. 62.

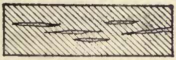


FIG. 63.

The reason for the above is as follows: Suppose Fig. 62 represents the cross-section of a round bar as it is being hit on the upper side. The arrows indicate the flow of the metal—that is, it is forged together at *AA* and apart at *BB*. Now, as the bar is turned and the hammering continued, the outside metal is forced away from the center, which may, at last, give way and form a crack; and by the time the bar is of the required size, if cut, it would probably look something like Fig. 63.

The same precaution must be taken when forging any shaped stock down to a round or conical point. The point must first be made square and then rounded up by the method given above. If this is not done the point is almost *sure* to split.

Squaring Up Work.—A common difficulty met with in all drawing out, or in fact in all work which must be hammered up square, is the liability of the bar to forge into a diamond shape, or to have one corner projecting out too far. If a section be cut through a bar misshaped in this way, at right angles to its length, instead of being a square or rectangle, the shape will appear something like one of the outlines in Fig. 64.

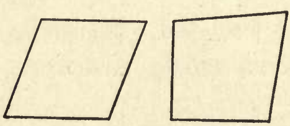


FIG. 64.

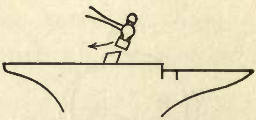


FIG. 65.

To remedy this and square up the bad corners, lay the bar across the anvil and strike upon the projecting corners as shown in Fig. 65, striking in such a way as to force the extra metal back into the body of the bar, gradually squaring it off. Just as the hammer strikes the metal it should be given a sort of a sliding motion, as indicated by the arrow.

No attempt should be made to square up a corner of this kind by simply 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 corner.

Upsetting.—When a piece of metal 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 ways of upsetting, the method depending mostly on the shape the work is in. With short pieces the work is generally stood on end on the anvil and the blow struck directly on the upper end. The work should always be kept straight; after a few blows it will probably start to bend and must then be straightened before more upsetting is done.

If one part only of a piece is to be upset, then the heat must be confined to that part, as the part of the work which is hottest will be upset the most.

When upsetting a short piece for its entire length, it will sometimes work up like Fig. 66. This may be due to two causes: either the ends were hotter than the center or the blows of the hammer were too light. To bring a piece of this sort to uniform size throughout, it should be heated to a higher heat in the center and upset with heavy blows. If the work is very short it is not always convenient to confine the heat to the central part; in such a case, the piece may be heated all over, seized by the tongs in the middle and the ends cooled, one at a time, in the water-bucket.

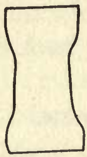


FIG. 66.

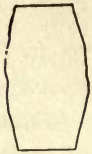


FIG. 67.

When light blows are used the effect of the blow does not reach the middle of the work, and consequently the upsetting is only done on the ends.

The effect of good heating and heavy blows is shown in Fig. 67. With a heavy blow the work is upset more in the middle and less on the ends.

To bring a piece of this kind to uniform size throughout, one end should be heated and upset and then the other end treated in the same way, confining the heat each time as much as possible to the ends.

Long work may be upset by laying it across the face of the anvil, letting the heated end extend two or three inches over the edge, the upsetting being done by striking against this end with the hammer or sledge. If the work is heavy the weight will offer enough resistance to the blow to prevent the piece from sliding back too far at each blow; but with lighter pieces it may be necessary to "back up" the work by holding a sledge against the unheated end.

Another way of upsetting the ends of a heavy piece is to "ram" the heated end against the side of the anvil by swinging the work back and forth horizontally and striking it against the side of the anvil. The weight of the piece in this case takes the place of the hammer and does the upsetting.

Heavy pieces are sometimes upset by lifting them up and dropping or driving them down on the face of the anvil or against a heavy block of iron resting on the floor. Heavy cast-iron plates are sometimes set in the floor for this purpose, and are called "upsetting-plates."

Fig. 68 shows the effect of the blows when upsetting the end of a bar. The lower piece has been properly heated and upset with heavy blows, while the other piece shows the effect of light blows. This last shape may also be caused by having the extreme end at a higher heat than the rest of the part to be upset.

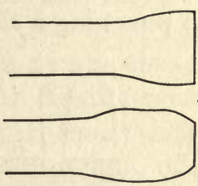


FIG. 68.

Punching.—There are two kinds of punches used for making holes in hot metal—the straight hand-punch, used with a hand-hammer, and the punch made from heavier stock and provided with a handle, 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 simply a bar of round or octagonal steel, eight or ten inches long, with the end forged down tapering, and the extreme end the same shape, but slightly smaller than the hole which is to be punched. Such a punch is shown in Fig. 69. The punch should taper uniformly, and the extreme end should be perfectly square across, not in the least rounding.

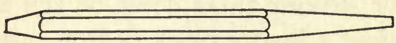


FIG. 69.

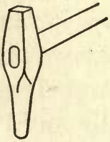


FIG. 70.

For heavier and faster work with a helper, a punch like Fig. 70 is used. This is driven into the work with a sledge-hammer.

A, *B*, and *C*, in Fig. 71, show the different steps in punching a clean hole through a piece of hot iron.

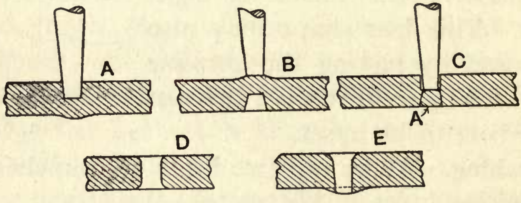


FIG. 71.

The punch is first driven about half-way through the bar while the work is lying flat on the anvil; this compresses the metal directly underneath the punch and raises a slight bulge on the opposite side of the bar by which the hole can be readily located. The piece is then turned over and the punching completed from this side, the small piece, "*A*", being driven completely through. This leaves a clean hole; while if the punching were all done from one side, a burr, or projection, would be raised on the side where the punch came through.

D and *E* (Fig. 71) illustrate the effects of proper and improper punching. If started from one side and finished from the other the hole will be clean and sharp on both sides of the work; but if the punching is done from one side only a burr will be raised, as shown at *E*, on the side opposite to that from which the punching is done.

If the piece is thick the punch should be started, then a little powdered coal put in the hole, and the punching continued. The coal prevents the punch from sticking as much as it would without it.

Bending.—Bends may be roughly divided into two classes—curves and angles.

Angles. — In bending angles it is nearly always necessary to make the bend at some definite point on the stock. As the measurements are much easier made while the stock is cold than when hot, it is best to "lay off" the stock before heating.

The point at which the bend is to be made should be marked with a center punch—generally on the edge of the stock, in preference to the side.

Marking with a cold chisel should not be done unless done very lightly on the *edge* of stock. If a slight nick be made on the side of a piece of stock to be bent, and the stockbent at this point with the nick outside, the small nick will expand and leave quite a crack. If the nick be on the inside, it is apt to start a bad cold shut which may extend nearly through the stock before the bending is finished.

Whenever convenient, it is generally easier to bend in a vise, as the piece may be gripped at the exact point where the bend is wanted.

When making a bend over the anvil the stock should be laid flat on the face, with the point at

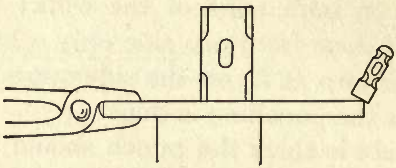


FIG. 72.

which the bend is wanted almost, but not quite, up to the outside edge of the anvil.

The bar should be held down firmly on the anvil by bearing down on it with a sledge, so placed that the outside edge of the sledge is about in line with the outside edge of the anvil.

This makes it possible to make a short bend with less hammering than when the sledge is not used.

The bar will pull over the edge of the anvil slightly when bending.

Bend with Forged Corner. — Brackets and other forgings are sometimes made with the outside corner of the bend forged up square, as shown in Fig. 73.

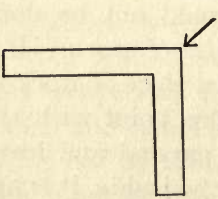


FIG. 73.

There are several ways of bending a piece to finish in this shape.

One way is to take stock of the required finished size and bend the angle, forging the corner square as it is bent; another is to start with stock considerably thicker than the finished forging and draw down both ends to the required finished thickness, leaving a thin-pointed ridge across the bar at the point where the bend will come, this ridge forming the outside or square corner of the angle where the piece is bent; or this ridge may be formed by upsetting before bending.

The process in detail of the first method mentioned is as follows: The first step is to bend the bar so that it forms nearly a right angle, keeping the bend as sharp as possible, as shown at *A* (Fig. 74).

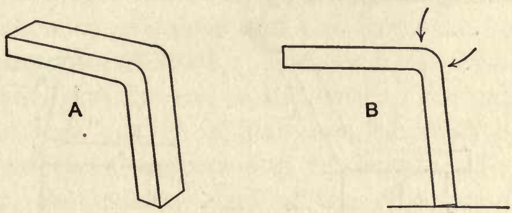


FIG. 74.

This should be done at a high heat, as the higher the heat the easier it is to bend the iron and consequently the sharper the bend.

Working the iron at a good high heat, as before, the outside of the bend should be forged into a sharp corner, letting the blows come in such a way as to force the metal out where it is wanted, being careful not to let the angle bend so that it becomes less than a right angle or even equal to one. Fig.

74, *B*, shows the proper way to strike. The arrows indicate the direction of the blows.

The work should rest on top of the anvil while this is being done, not over one corner. If worked over the corner, the stock will be hammered too thin.

The object in keeping the angle obtuse is this: The metal at the corner of the bend is really being upset, and the action is somewhat as follows: In Fig. 75 is shown the bent piece on the anvil. We will suppose the blows come on the part *A* in the direction indicated by the heavy arrow. The metal, being heated to a high soft heat at *C*, upsets, part of it forming the sharp outside corner and part flowing as shown by the small arrow at *C* and

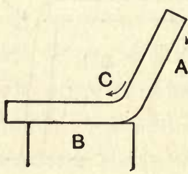


FIG. 75.

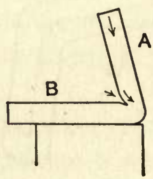


FIG. 76

making a sort of fillet on the inside corner. If in place of having the angle greater than 90 degrees it had been an acute angle (Fig. 76), the metal forced downward by the blows on *A* would carry with it part of the metal on the inside of the piece *B*, and a cold shut or crack would be formed on the inside of the angle. To form a sound bend the corner must be forged at an angle greater than a right angle. When the piece has been brought to a sharp corner the last step is to square up the bend over the corner, or edge, of the anvil.

The second way of making the above is to forge a piece as shown in Fig. 77, where the dotted lines indicate the size of the original piece. This piece is then bent in such a way that the ridge, *C*, forms the outside sharp corner of the angle.

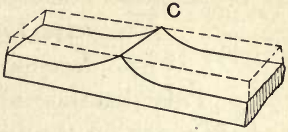


FIG. 77.

This ridge is sometimes upset in place of being drawn out.

The first method described is the most satisfactory.

Ring-bending.—In making a ring the first step of course is to calculate and cut from the bar the proper amount of stock. The bend should always be started from the end of the piece. For ordinary rings up to 4″ or 5″ in diameter the stock should be heated for about one-half its length. To start bending, the extreme end of the piece should be first bent over the horn of the anvil, and the bar should be fed across the horn of the anvil and bent down as it is pushed forward. Do not strike directly on top of the horn, but let the blows fall a little way from it, as in Fig. 78. This bends the iron and does not pound it out of shape. One-half of the ring is bent in this way and then the part left straight is heated. This half is bent up the same as the other, starting from the end exactly as before.

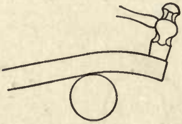


FIG. 78.

Eye-bending.—The first step in making an eye like Fig. 79 is to calculate the amount of stock required for the bend. The amount required in this case, found by looking up the circumference of a 2″ circle in the table, is $7\frac{1}{2}''$. This distance should be laid off by making a chalk-mark on the face of the anvil $7\frac{1}{2}''$ from the left-hand end.

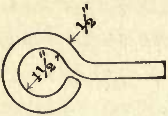


Fig. 79.

A piece of iron is heated and laid on the anvil with the heated end on the chalk-mark, the rest of the bar extending to the left. A hand-hammer is held on the bar with the edge of the hammer directly in line with the end of the anvil. This measures off $7\frac{1}{2}''$ from the edge of the hammer to the end of the bar. The bar is then laid across the anvil bringing the edge of the hammer exactly in line with the outside edge of the anvil, thus leaving $7\frac{1}{2}''$ projecting over the edge. This projecting end is bent down until it forms a right angle. The extreme end of this bent part is then bent over the horn into

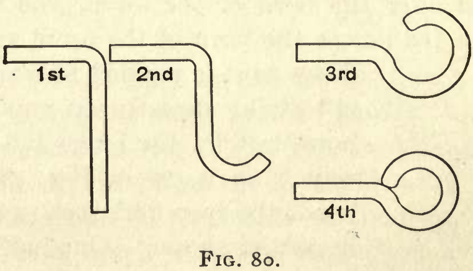


Fig. 80.

the circular shape and the bending continued until the eye is formed.

The same general method as described for bending rings should be followed. The different steps are shown in Fig. 80.

If an eye is too small to close up around the horn, it may be closed as far as possible in this way, and then completely closed over the corner or on the face of the anvil, as shown in Fig. 81.

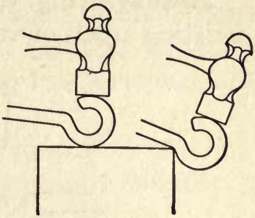


FIG. 81.

Double Link.—Another good example of this sort of bending is the double link, shown in Fig. 59.

The link is started by bending the stock in the *exact center*, the first step being to bend a right angle. This step, with the succeeding ones, is shown in Fig. 82.

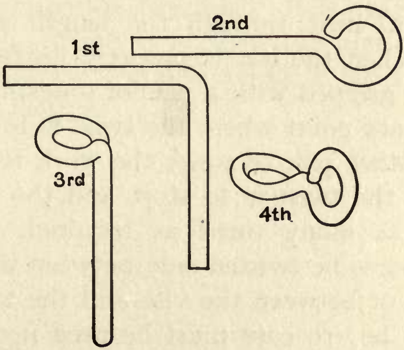


FIG. 82.

After this piece has been bent into a right angle, the ring on the end should be bent in the same way as an ordinary ring; excepting that all the bending is done from one end of the piece, starting from the extreme end as usual.

Twisting.—Fig. 83 shows the effects produced by twisting stock of various shapes—square, octagonal,

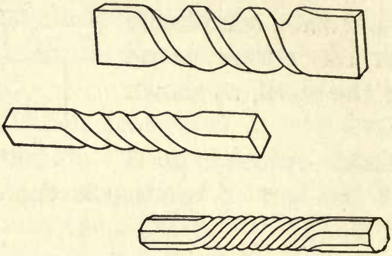


FIG. 83.

and flat, the shapes being shown by the cuts in each case.

To twist work in this way it should be brought to a uniform heat through the length intended to twist. When the bar is properly heated it should be firmly gripped with a pair of tongs, or in a vise, at the exact point where the twist is to commence. With another pair of tongs the work is taken hold of where the twist is to stop, and the bar twisted through as many turns as required. The metal will of course be twisted only between the two pairs of tongs, or between the vise and the tongs, as the case may be; so care must be used in taking hold of the bar or the twist will be made at the wrong points.

The heat must be the same throughout the part to be twisted. If one part is hotter than another, this hotter part, being softer, will twist more easily, and the twist will not be uniform. If one end of the bar is wanted more tightly twisted than the other, the heat should be so regulated that the part is heated hottest that is wanted tightest twisted; the heat gradually shading off into the parts wanted more loosely twisted.

Reverse Twisting. — The effect shown in Fig. 84 is produced by reversing the direction of twisting.

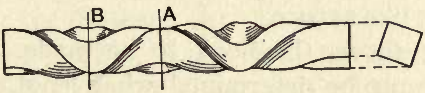


FIG. 84.

A square bar is heated and twisted enough to give the desired angle. It is then cooled, in as sharp a line as possible, as far as *B*, and twisted back in the opposite direction. It is again heated, cooled up to *A*, and twisted in the first direction; and this operation is continued until the twist is of the desired length.

CHAPTER V.

SIMPLE FORGED WORK.

Twisted Gate-hook.—This description answers, of course, not only for this particular piece, but for others of a like nature.

Fig. 85 shows the hook to be made. To start with, it must be determined what length of stock,

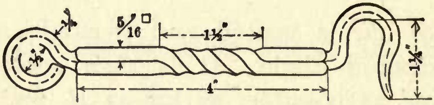


FIG. 85.

after it is forged to proper size, will be required to bend up the ends.

The length of straight stock necessary should, of course, be measured through the center of the stock on the dotted lines in the figure. To do this lay out the work full size, and lay a string or thin piece of soft wire upon the lines to be measured. It is then a very easy matter to straighten out the wire or string, and measure the exact length required. If the drawing is not made full size, an accurate sketch may be made on a board, or other flat surface, and the length measured from this.

The hook as above will require about $2\frac{7}{8}''$ length for stock; the eye, about $2\frac{5}{8}''$.

The first step would be like Fig. 86.

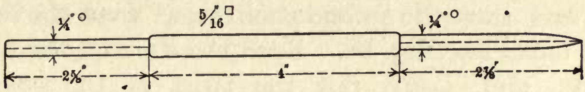


FIG. 86.

After cutting the piece of $\frac{5}{16}''$ square stock, start the forging by drawing out the end, starting from the end and working back into the stock until a piece is forged out $2\frac{5}{8}''$ long and $\frac{1}{4}''$ in diameter. Now work in the shoulder with the set-hammer in the following way:

Forming Shoulders: Both Sides—One Side.—Place the piece on the anvil in such a position that the point where the shoulder is wanted comes exactly on the nearest edge of the anvil. Place the set-hammer on top of the piece in such a way that its edge comes directly in line with the edge of the anvil (Fig. 87). Do *not* place the piece like

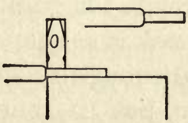


FIG 87.

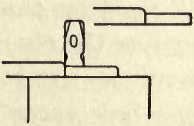


FIG 88.

Fig. 88, or the result will be as shown—a shoulder on one side only. As the shoulder is worked in the piece should be turned continually, or the shoulder will work in faster on one side than on the other. Always be careful to keep the shoulder exactly even with the edge of the anvil.

When the piece is formed in the proper shape on one end, start the second shoulder 4″ from the first, and finish like Fig. 86. Bend the eye and then the hook; and, *lastly*, put the twist in the center. Make the twist as follows:

First make a chalk-mark on the jaws of the vise, so that when the end of the hook is even with the mark the edge of the vise will be where one end of the twist should come. Heat the part to be twisted to an even yellow heat (be sure that it is heated evenly); place it in a vise quickly, with the end even with the mark; grasp the piece with the tongs, leaving the distance between the tongs and vise equal to the length of twist (Fig. 89); and twist it around one complete turn.

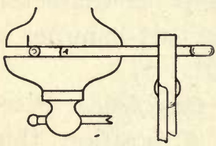


FIG. 89.

The eye should be bent as described before, and the hook bent in the same general way as the eye.

Grab-hooks.—This is the name given to a kind of hooks used on chains, and made for grabbing or hooking over the chain. The hook is so shaped that the throat, or opening, is large enough to slip easily over a link turned edgewise, but too narrow to slip down off this link on to the next one, which, of course, passes through the first link at right angles to it.

Grab-hooks are made in a variety of ways, one of which is given below in detail.

Fig. 90 will serve as an example. To forge this, use a bar of round iron large enough in section to form the heavy part of the hook. This bar should first be slightly upset, either by ramming or hammering, for a short distance from the end, and then flattened out like Fig. 91.

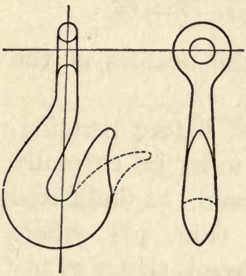


FIG. 90.

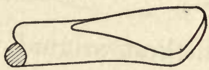


FIG. 91.


FIG. 92.

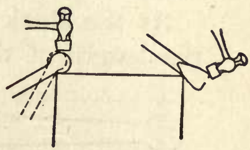


FIG. 93.

The next step is to round up the part for the eye, as shown in Fig. 92, by forming it over the corner of the anvil as indicated in Fig. 93. The eye should be forged as nearly round as possible, and then punched.

Particular attention should be paid to this point. If the eye is not properly rounded before punching, it is difficult to correct the shape afterward.

After punching, the inside corners of the hole are rounded off over the horn of the anvil in the manner shown in Fig. 94. Fig. 95 shows the appearance of a section of the eye as left by the punch. When the eye is finished it should appear as though bent up from round iron—that is, all the square corners should be rounded off as shown in Fig. 96.

When the eye is completed the body of the hook should be drawn out straight, forged to size, and then bent into shape. Care should be taken to

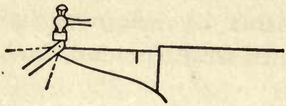


FIG. 94.

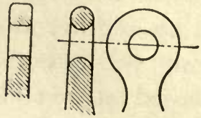


FIG. 95. FIG. 96.

keep the hook thickest around the bottom of the bend.

As the stock is entirely formed before bending, the length of the straight piece must be carefully measured, as indicated at *A* (Fig. 97), where the piece is shown ready for bending. To determine the required length the drawing or sample should be measured with a string or piece of flexible wire, measuring along the center of the stock, from the extreme point to the center of the eye.

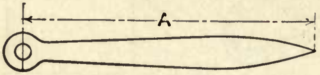


FIG. 97.

The weakest point of almost any hook is in the bottom bend. When the hook is strained there is a tendency for it to straighten out and take the shape shown by the dotted lines in Fig. 90. To avoid this the bottom of the hook must be kept as thick as possible along the line of strain, which is shown by the line drawn through the eye. A good shape for this lower bend is shown in the sketch, where it will be noticed that the bar has been hammered a little thinner in order to increase the thickness of the metal in the direction of the line of strain.

The part of the hook most liable to bend under a load is the part lying between the points marked *I* and *J* in Fig. 102.

Another style of grab-hook is shown in Fig. 98,

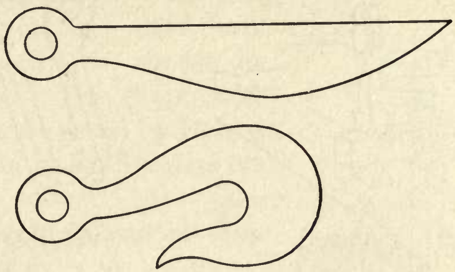


FIG. 98.

which shows the finished hook and also the straight piece ready for bending.

The forming will need no particular description. The hook shown is forged about $\frac{3}{8}''$ thick; the outside edge around the curve being thinned out to about $\frac{1}{8}''$, in order to give greater stiffness in the direction of the strain.

Stock about $\frac{3}{8}'' \times 1''$ is used.

A very convenient way to start the eye for a hook of this kind, or in fact almost any forged eye, is shown in Fig. 99. Two fullers, top and bottom, are used, and the work shaped as shown. The bar should be turned, edge for edge, between every few blows, if the grooves are wanted of the same depth. After cutting the grooves the edge is shaped the same as described above.

A grab-hook, sometimes used on logging-chains, is shown in Fig. 100. This is forged from square stock by flattening and forming one end into an eye and pointing the other end; after which the hook is bent into shape.

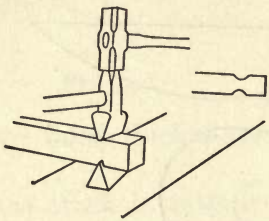


FIG. 99.

FIG. 100.

Welded Eye-hooks.—Hooks sometimes have the eye made by welding instead of forging from the solid stock. Such a hook is shown in Fig. 101,

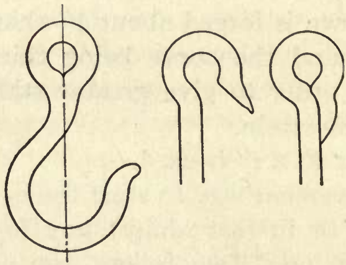


FIG. 101.

which also shows the stock scarfed and bent into shape ready for closing up the eye for the weld, and also the eye ready for welding. Before heating for the weld, the eye should be closed, and stock at the end be bent close together. The scarf should be pointed the same as for any other round weld.

This sort of eye is not as strong as a forged eye of the same size; but is usually as strong as the rest of the hook, as the eye is generally considerably stronger than any other part.

Hoisting-hooks. — A widely accepted shape for hoisting-hooks, used on cranes, etc., is shown in Fig. 102. The shape and formula are given by Henry R. Town, in his Treatise on Cranes.

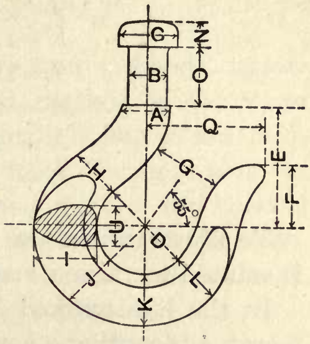


FIG. 102.

T = working load in tons of 2000 lbs.

A = diameter of round stock used to form hook.

The size of stock to use for a hook to carry any particular load is given below. The capacity of the hook, in tons, is given in the upper line—the figures in the lower line, directly under any particular load in the upper line, giving the size of bar required to form a hook to be used at that load.

$T=$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	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 formula, all the dimensions being in inches:

$$D = .5T + 1.25$$
$$E = .64T + 1.6$$
$$F = .33T + .85$$

$$
\begin{aligned}
G &= .75D \\
O &= .363T+.66 \\
Q &= .64T+1.6 \\
H &= 1.08A \\
I &= 1.33A \\
J &= 1.2A \\
K &= 1.13A \\
L &= 1.05A \\
M &= .5A \\
N &= .85B-.16 \\
U &= .866A
\end{aligned}
$$

To illustrate the use of the table, suppose a hook is wanted to raise a load of 500 lbs.

In the line marked T in the table are found the figures $\frac{1}{4}$, denoting a load of one-quarter of a ton, or 500 lbs. Under this are the figures $\frac{11}{16}$, giving the size stock required to shape the hook.

The different dimensions of the hook would be found as follows:

$$D=.5\times{}^{1}/_{4}+1{}^{1}/_{4}''=1{}^{3}/_{8}''.$$
$$E=.64\times{}^{1}/_{4}+1.6''=1.76=1{}^{3}/_{4}'' \text{ about.}$$

. . . .

$$H=1.08A=1.08\times{}^{11}/_{13}=.74=\,{}^{3}/_{4} \text{ about.}$$
$$I=1.33A=1.33\times{}^{11}/_{16}=.915={}^{29}/_{32} \text{ about.}$$

When reducing the decimals, the dimensions which have to do only with the bending of the hook, that is, the opening, the length, the length of point, etc., may be taken as the nearest 16th, but these dimensions for flattening should be reduced to the nearest 32d on small hooks.

The complete dimensions for the hook in question, 1000 lbs. capacity, would be as follows:

$D=1\,{}^3/_8''$	$G=1''$	$H={}^3/_4''$	$L={}^{23}/_{32}''$
$E=1\,{}^3/_4''$	$O={}^3/_4''$	$I={}^{29}/_{32}''$	$M={}^{11}/_{32}''$
$F={}^{15}/_{16}''$	$Q=1\,{}^3/_4''$	$J={}^{13}/_{16}''$	
		$K={}^{25}/_{32}''$	$U={}^9/_{16}''$

Bolts.—Bolts are made by two methods, upsetting and welding. The first method is the more common, particularly on small bolts, where it is nearly always used, the stock being upset to form the head. In the second method the head is formed by welding a ring of stock around the stem.

An upset head is stronger than a welded head, provided they are both equally well made.

The size of the bolt is always given as the diameter and length of the shank, or stem. Thus, a $\frac{1}{2}''$ bolt, $6''$ long, means a bolt having a shank $\frac{1}{2}''$ in diameter, and $6''$ long from the under side of the head to the end.

Dimensions of bolt-heads are determined from the diameter of the shank, and should always be the same size for the same diameter, being independent of the length.

The diameter and thickness of the head are measured as shown in Fig. 103.

The dimensions of both square and hexagonal heads are as follows:

D = diameter of head across the flats (short diameter).

T = thickness of head.

S = diameter of shank of bolt.

$D = 1\frac{1}{2} \times S + \frac{1}{8}''$.

$T = S$.

For a 2″ bolt the dimensions would be calculated as follows:

Diameter of head would equal $1\frac{1}{2}'' \times 2'' + \frac{1}{8}'' = 3^1/_8''$.

Thickness of head would be 2″.

These are dimensions for rough or unfinished heads; each dimension of a finished head is $^1/_{16}''$ less than the same dimension of the rough head.

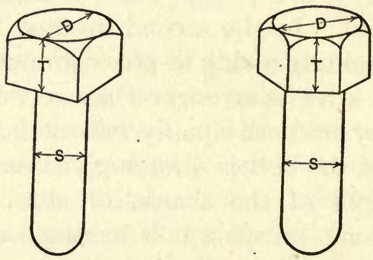


FIG. 103.

Bolts generally have the top corners of the head rounded or chamfered off (Fig. 103). This can be done with a hand-hammer, or with a cupping-

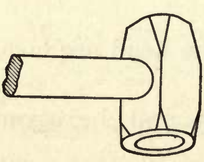


FIG. 104.

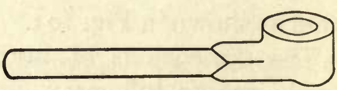


FIG. 105.

tool (Fig. 104), which is simply a set-hammer with the bottom face hollowed out into a bowl or cup shape.

For making bolts one special tool is required, the heading-tool. This is commonly made something the shape of Fig. 105, although for a "hurry-up" bolt sometimes any flat strip of iron with a hole punched the proper size to admit the stem of the bolt can be used.

When in use this tool is placed on the anvil directly over the square hardie-hole, the stem of the bolt projecting down through the heading-tool and hardie-hole while the head is being forged on the bolt.

This heading-tool is made with one side of the head flush with the handle, the other side projecting a quarter of an inch or so above it. The tool should always be used with the *flat side on the anvil.*

Upset-head Bolt.—An upset head is made as follows: The stock is first heated to a high heat for a short distance at the end, and upset as shown at Fig. 106. The bolt is then dropped through the heading tool, the upset portion projecting above. This upset part is then flattened down on the tool as shown at *B*, and forged square or hexagonal on the anvil.

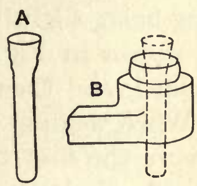


FIG. 106.

The hole in the heading-tool should be large enough to allow the stock to slip through it nearly up to the upset portion.

Welded-head Bolts.—A welded-head bolt is made by welding a ring of square iron around the shank to form the head, which is then shaped in a heading-tool the same as an upset head. A piece of square iron of the proper size is bent into a ring, but not welded. About the easiest way to do this is to take a bar several feet long, bend the ring on the end, and then cut it off as shown in Fig. 107.

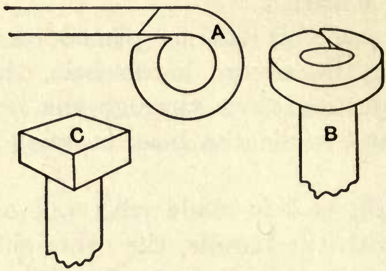


FIG. 107.

This ring is just large enough, when the ends are slightly separated, to slip easily over the shank.

The shank is heated to about a welding heat, the ring being slightly cooler, and the two put together as shown in Fig. 107, *B*. The head is heated and welded, and then shaped as described above.

When welding on the head it should be hammered *square* the first thing, and *not* pounded round and round. It is much easier to make a sound weld by forging square.

Care must be used when taking the welding heat to heat slowly, otherwise the outside of the ring will be burned before the shank is hot enough to stick.

It is sometimes necessary when heating the bolt-head for welding to cool the outside ring to prevent its burning before the shank has been heated sufficiently to weld; to do this put the bolt in the water sideways just far enough to cool the outside edge of the ring and leave the central part, or shank, hot.

Tongs.—Tongs are made in a great variety of ways, several of which are given below.

Common flat-jaw tongs, such as are used for holding stock up to about $\frac{3}{4}$ inch thick, may be made as follows: Stock about $\frac{3}{4}$ inch square should be used. This is first bent like *A*, Fig. 108. To form the eye the bent stock is laid

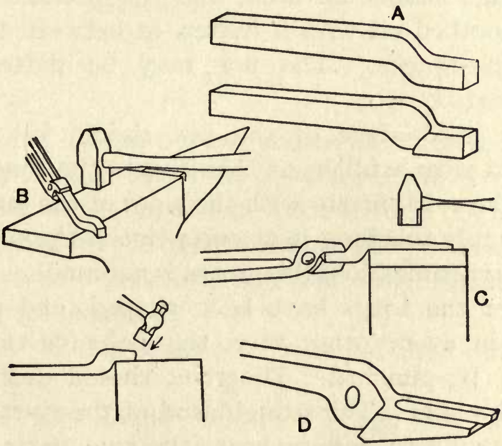


FIG. 108.

across the anvil in the position shown at *B*, and flattened by striking with a sledge the edge of the anvil, forming the shoulder for the jaw. A set-hammer may be used to do this by placing the piece with the other side up, flat on the face of the anvil, and holding the set-hammer in such a way as to form the shoulder with the edge of the hammer, the face of the hammer flattening the eye.

The long handle is drawn out with a sledge, working as shown at *C*. When drawing out work this way the forging should always be held with the straight side up, the corner of the anvil forming the sharp corner up against the shoulder on the piece. If the piece be turned the other side up, there is danger of striking the projecting shoulder with the sledge and knocking the work out of shape.

For finishing up into the shoulder a set-hammer or swage should be used, and the handles should be smoothed off with a flatter, or between top and bottom swages. The jaw may be flattened as shown at *D*.

The inside face of the jaw should be slightly creased with a fuller, as this insures the tongs gripping the work firmly with the sides of the jaws, and not simply touching it at one point in the center, as they sometimes do if this crease is not made.

After the tongs have been shaped, and are finished in every other way, the hole for the rivet should be punched. The rivet should drop easily into the hole. The straight end of the rivet should be brought to a high heat, the two parts of the tongs placed together with the holes in line, the rivet inserted, and the end "headed up." Most of the heading should be done with the pene end of the hammer. After riveting the tongs will probably be rather "stiff"; opening and shutting them several times, while the rivet is still red-hot, will leave them loose. The tongs should be finished by fitting to a piece of stock of the size on which they are to be used.

Light Tongs.—Tongs may be made from flat stock in the following way: A cut is made with a narrow fuller at the right distance from the end of the bar to leave enough stock to form the jaw between the cut and the end, as shown at *A*, Fig. 109.

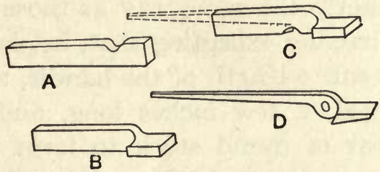


FIG. 109.

This end is bent over as shown at *B* and a second fuller cut made, shown at *C*, to form the eye. The other end of the bar is drawn out to form the handle, as indicated by the dotted lines. The jaw is shaped, the rivet-hole punched, and the tongs finished, as at *D*, in the usual way.

Tongs of this character may be used on light work.

Tongs for Round Stock. — Tongs for holding round stock may be made by either of the above methods, the operations in making being the same, with the exception of shaping the jaws, which may be done in this way: A top fuller and bottom swage are used, the swage being of the size to which it is wished to finish the outside of the jaws, the fuller

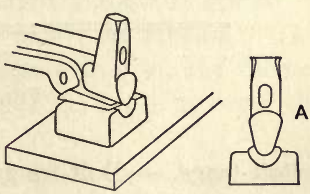


FIG. 110.

the size of the inside. The jaw is held on the swage, and the fuller placed on top and driven down on it, Fig. 110, forcing the jaw to take the desired shape, shown at *A*. The final fitting is done as usual, after the jaws are riveted together.

Welded Tongs.—Tongs with welded handles are made in exactly the same way as those with solid, drawn-out handles excepting that, in place of drawing out the entire length of the handle, a short stub only is forged, a few inches long, and to this is welded a bar of round stock to form the handle. Fig. 111 shows one ready for welding.

FIG. 111.

Pick-up Tongs. — No particular description is necessary for making pick-up tongs. The tongs may be drawn out of a flat piece and bent as shown in Fig. 112.

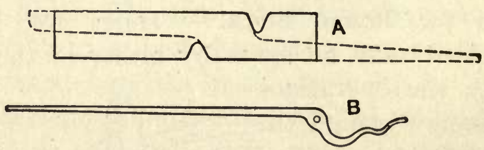


FIG. 112.

Bolt-tongs. — Bolt-tongs are easily made from round stock, although square may be used to advantage.

The first operation is to bend the bar in the shape shown in Fig. 113. This may be done with a fuller over the edge of the anvil, as shown at *A*. When bending the extreme end of the jaw the bar should be held almost level at first, and gradually swung down, as shown by the arrow, until the end is properly bent.

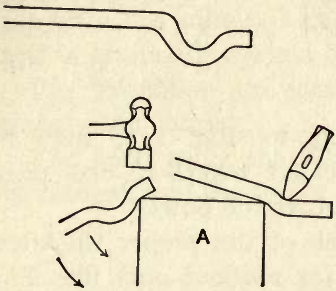


Fig. 113.

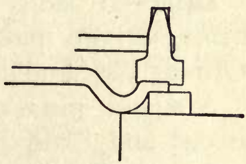


Fig. 114.

The eye may be flattened with the set-hammer, and the part between the jaw proper and the eye worked down to shape over the horn and on the anvil with the same tool.

The jaw proper is rounded and finished with a fuller and swage, as shown in Fig. 114.

There is generally a tendency for the spring of the jaw to open up too much in forging. This may be bent back into shape either on the face of the anvil, as shown at *A* (Fig. 115), or over the horn, as at *B*.

Another method of making the first bend, when starting the tongs, is shown in Fig. 116. A swage-block and fuller are here used; a swage of the proper size could of course be used in place of the block.

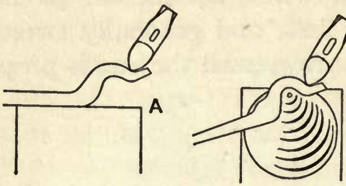


FIG. 115.

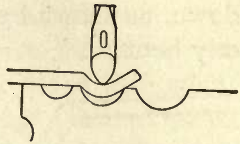


FIG. 116.

Ladle.—A ladle, similar to Fig. 117, may be made of two pieces welded together, one piece forming the handle, the other the bowl.

A square piece of stock of the proper thickness is cut and "laid out" (or marked out) like Fig. 118; the center of the piece being first found by drawing the diagonals.

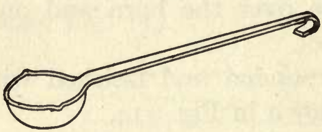


FIG. 117.

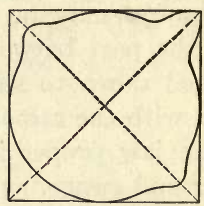


FIG. 118.

A circle is drawn as large as possible, with its center on the intersection of the diagonals; the piece is cut out with a cold chisel to the circle, excepting at the points where projections are left for lips and for a place to weld on the handle. This latter projection is scarfed and welded to the strip forming the handle.

The bowl is formed from the circular part by heating it carefully to an *even* yellow heat and placing it over a round hole in a swage-block or other object. The pene end of the hammer is used, and the pounding done over the hole in the swage-block. As the metal in the center is forced downward by the blow of the hammer, the swage-block prevents the material at the sides from following and is gradually worked into a bowl shape.

Fig. 119 shows the position of the block and the piece when forging.

The bowl being shaped properly, the lips should be formed, and the top of the bowl ground off true.

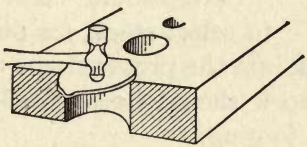


FIG. 119.

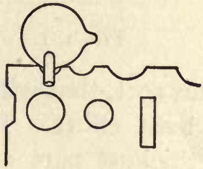


FIG. 120.

The lips may be formed by holding the part where the lips are to be against one of the smaller grooves in the side of the swage-block, and driving it into the groove by placing a small piece of round iron on the inside of the bowl as shown in Fig. 120.

For a ladle with a bowl $3\frac{1}{2}''$ in diameter, the diameter of the circle, cut from the flat stock, should be about $4''$, as the edges of the piece draw in somewhat. Stock for other sizes should be in about the same proportion. Stock should be about $\frac{1}{8}''$ thick.

Machine-steel should be used for making the bowl. If ordinary wrought iron is used, the metal is liable to split.

Bowls.—Bowls, and objects of similar shape, may be made in the manner described above, but care must be used not to do too much hammering in the center of the stock, as that is the part most liable to be worked too thin.

Chain-stop.—The chain-stop, shown in Fig. 121, will serve as an example of a very numerous class of forgings; that is, forgings having a comparatively large projection on one side.

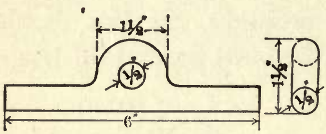


FIG. 121.

Care should be taken to select stock, for pieces of this sort, that will work into the proper shape with the least effort. The stock should be as thick as the thickest part of the forging, and as wide as the widest part. Stock, in this particular case, should be $\frac{1}{2}'' \times 1\frac{1}{2}''$.

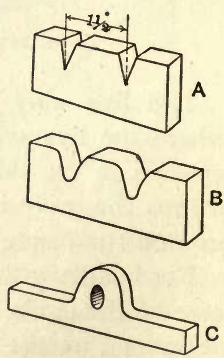


FIG. 122.

The different steps in making the forging are shown in Fig. 122. First two cuts are made $1\frac{1}{2}''$ apart, as shown at *A*; then these cuts are widened out with a fuller, *B*. The ends are then forged out square, as at *C*. To finish the piece the hole is punched and rounded and the ends finished round.

When the fuller is used it should be held slightly slanting, as shown in Fig. 123.

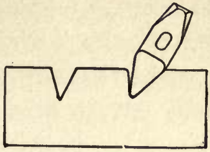


FIG. 123.

This forces the metal toward the central part and leaves a more nearly square shoulder, in place of the slanting shoulder that would be left were the fuller to be held exactly upright.

CHAPTER VI.

CALCULATION OF STOCK; AND MAKING OF GENERAL FORGINGS.

Stock Calculations for Forged Work.—When calculating the amount of stock required to make a forging, when the stock has its original shape altered, there is one simple rule to follow: Calculate the volume of the forging, add an allowance for stock lost in forging, and cut a length of stock having the total volume. In other words, the forging contains the same amount, or volume, of metal, no matter in what shape it may be, as the original stock; an allowance of course being made

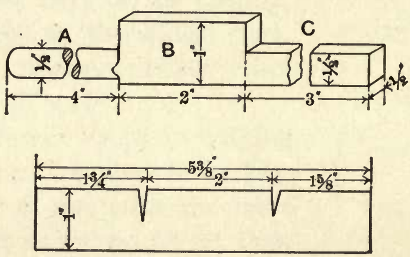


FIG. 124.

for the slight loss by scaling, and for the parts cut off in making.

Take as an example the forging shown in Fig. 124, to determine the amount of stock required to make the piece. This forging could be made in much the same way as the chain-stop. A piece of straight stock would be used and two cuts made and widened with a fuller, in the manner shown in Fig. 125. The ends on either side of the cuts

FIG. 125.

are then drawn down to size, as shown by the dotted lines, the center being left the size of the original bar. The stock should be $\frac{1}{2}'' \times 1''$, as these are the dimensions of the largest parts of the forging. For convenience in calculating the forging may be divided into three parts: the round end *A*, the central rectangular block *B*, and the square end *C*.

The block *B* will of course require just 2″ of stock.

The end *C* has a volume of $\frac{1}{2}'' \times \frac{1}{2}'' \times 3'' = \frac{3}{4}$ of a cubic inch.

The stock ($\frac{1}{2}'' \times 1''$) has a volume of $\frac{1}{2}'' \times 1'' \times 1'' = \frac{1}{2}$ of a cubic inch for each inch of length.

To find the number of inches of stock required to make the end *C*, the volume of this end ($\frac{3}{4}$ cubic inch) should be divided by the volume of one inch of stock (or $\frac{1}{2}$ cubic inch). Thus, $\frac{3}{4} \div \frac{1}{2} = 1\frac{1}{2}''$.

It will therefore require $1\frac{1}{2}''$ of stock to make the end *C*; with allowance for scaling, $1\frac{5}{8}''$.

The end *A* is really a round shaft, or cylinder, 4″ long and $\frac{1}{2}''$ in diameter. To find the volume of a cylinder, multiply the square of half the diameter by $3\,^1/_7$, and then multiply this result by the length of the cylinder.

The volume of A would be $^1/_4 \times {}^1/_4 \times 3\,^1/_7 \times 4 = {}^{11}/_{14}$. And the amount of stock required to make A would be $^{11}/_{14} \div {}^1/_2 = 1\,^4/_7''$ in length, which is practically equal to $1\,^5/_8$. To the above amount of stock must be added a small amount for scaling, allowing altogether about $1\,^3/_4''$.

The stock needed for the different parts of the forging is as follows:

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

First taking a piece of stock $\frac{1}{2}'' \times 1'' \times 5\frac{3}{8}''$, the cuts would be made for drawing out the ends as shown in Fig. 125.

In such a case as the above it is not always necessary to know the *exact* amount of stock to cut. What is known to be more than enough stock to make the forging could be taken, the central block made the proper dimensions, the extra metal worked down into the ends, and then trimmed off to the proper length. There are frequently times, however, when the amount of material required must be calculated accurately.

Take a case like the forging shown in Fig. 126. Here is what amounts to two blocks, each $2'' \times 4'' \times 6''$, connected by a round shaft, $2''$ in diameter.

To make this, stock 2″ thick and 4″ wide should be used, starting by making cuts as shown in Fig.

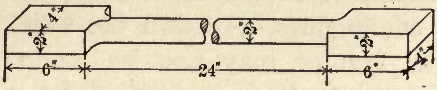


FIG. 126.

127, and drawing down the center to 2″ round. It is of course necessary to know how far apart to

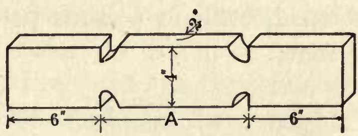


FIG. 127.

make the cuts when starting to draw down the center.

The volume of a cylinder 2″ in diameter and 24″ long would be $1'' \times 1'' \times 3^1/_7{}'' \times 24'' = 75^3/_7$ cubic inches, which may be taken as $75^1/_2$ cubic inches. For each inch in length the stock would have a volume of $4'' \times 2'' \times 1'' = 8$ cubic inches. Therefore it would require $75^1/_2 \div 8 = 9^7/_{16}$ inches of stock to form the central piece; consequently the distance between cuts, shown at *A* in Fig. 127, would have to be $9^7/_{16}{}''$. Each end would require 6″ of stock, so the total stock necessary would be $6'' + 6'' + 9^7/_{16}{}'' = 21^7/_{16}{}''$.

Any forging can generally be separated into several simple parts of uniform shape, as was done above, and in this form the calculation can be easily made, if it is always remembered that the *amount of metal* remains the same, and in forging, merely the shape, and not the volume, is altered.

Weight of Forgings.—To find the weight of any forging, the volume may first be found in cubic inches, and this volume multiplied by .2779, the weight of wrought iron per cubic inch. (If the forging is made of steel, multiply by .2836 in place of .2779.) This will give the weight in pounds.

Below is given the weight of both wrought and cast iron and steel, both in pounds per cubic inch and per cubic foot.

	Lbs. per Cu. Ft.	Lbs. per Cu. In.
Cast iron weighs........	450	.2604
Wrought iron weighs. .	480	.2779
Steel weighs............	490	.2936

Suppose it is required to find the weight of the forging shown in Fig. 124. We had a volume in A of $^{11}/_{14}$ cubic inch, in C of $^{3}/_{4}$ cubic inch, and in B of 1 cubic inch, making a total of $2\,^{15}/_{28}$ cubic inches. If the forging were made of wrought iron, it would weight $2\,^{15}/_{28} \times .2779 = .7$ of a pound.

The forging shown in Fig. 126 has a volume in each end of 48 cubic inches, and in the center of $75\frac{3}{7}$ cubic inches, making a total of $171\frac{3}{7}$ cubic inches, and would weigh, if made of wrought iron, 47.64 pounds.

A much quicker way to calculate weights is to use a table such as is given on page 250. As steel is now commonly used for making forgings, this table is figured for steel. The weight given in the table is for a bar of steel of the dimensions named and one foot long. Thus a bar 1″ square weighs 3.402 lbs. per foot, a bar $3\frac{1}{2}'' \times 1''$ weighs 11.9 lbs. per foot, etc.

To calculate the weight of the forging shown in Fig. 126, proceed as follows: Each end is $2'' \times 4''$ and 6″ long, so, as far as weight is concerned, equal to a bar $4'' \times 2''$ and 12″ long. From the table, a bar $4'' \times 1''$ weighs 13.6 lbs. for each foot in length; so a bar $4'' \times 2''$, being twice as thick, would weigh twice as much, or 27.2 lbs., and as the combined length of the two ends of the forging is one foot, this would be their weight. The table shows that a bar 2″ in diameter weighs 10.69 lbs. for every foot in length; consequently the central part of the forging, being 2 ft. long, would weigh 10.69×2, or 21.38 lbs. The total weight of the entire forging would be 48.58 lbs. (This seems to show a difference between this weight and the weight as calculated before, but it must be remembered that before the weight was calculated for wrought iron; while this calculation was made for steel.)

Finish.—Some forgings are machined, or "finished," after leaving the forge-shop. As the drawings are always made to represent the finished work, and give the finished dimensions, it is necessary to make an allowance for this finishing when making the forging, and all parts which have to be "finished," or "machined," must 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 FINISH marked on them; sometimes the finishing is shown simply by the symbol *f*, as used in Fig. 128, showing that the shafts and pin only of the crank are to be finished.

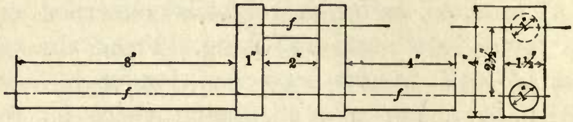


FIG. 128.

When all surfaces of a piece are to be finished the words FINISH-ALL-OVER are sometimes marked on the drawing.

The allowance for finish on small forgings is generally about $^1/_{16}''$ on each surface; thus if a block were wanted to finish $4'' \times 2'' \times 1''$, and $^1/_{16}''$ were allowed for finishing, the dimensions of the forging should be $4\frac{1}{8}'' \times 2\frac{1}{8}'' \times 1\frac{1}{8}''$.

On a forging like Fig. 126, about $\frac{1}{8}''$ allowance should be made for finish, 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. If it is necessary to finish by filing the forging should be made as nearly to size as possible, and having a very slight amount for finish, $^1/_{32}''$, or even $^1/_{64}''$, being enough in some cases.

It is of course necessary to take this into account when calculating stock, and the calculation made for the forging with the allowance for finish added to the drawing dimensions and not simply for the finished piece.

Crank-shafts. — There are several methods of forging crank-shafts, but only the common commercial method will be given here.

When forgings were mostly made of wrought iron, cranks were welded up of several pieces. One piece was used for each of the end shafts, one piece for each cheek, or side, and another piece for the crank-pin. Mild-steel cranks are now more universally used and forged from one solid piece of stock. The drawing for such a crank is given in Fig. 128; finish to be allowed only as shown, that is, only on crank-pin and shafts. The forgings, as made, will appear like the outlines in Fig. 129. The metal in the throat of the crank is generally removed by drilling a line of holes and then sawing slots where the sides of the crank cheeks should come, as shown by the dotted lines in Fig. 129.

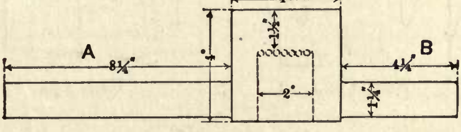


FIG. 129.

The central block is then easily knocked out. This drilling and sawing are done in the machine-shop. This throat can be formed by chopping out the surplus metal with a hot chisel, but on small cranks, such as here shown, it is generally cheaper in a well-equipped shop to use the first method.

The first step is to calculate the amount of stock required. Stock $1\frac{1}{2}'' \times 4''$ should be used. The ends, *A* and *B*, should be left $1\frac{1}{4}''$ in diameter to allow for finishing. The end *A* contains 10.13 cubic inches. Each inch of stock contains 6 cubic inches. It would therefore require 1.7″ of stock to form this end provided there were no waste from scale in heating. This waste does take place, and must be allowed for, so it will be safe to take about 2″ of stock for this end. *B* contains 5.22 cubic inches, and would require .87″ of stock without allowance for scale. About $1\frac{1}{8}''$ should be taken. The stock should then be $7\frac{1}{4}''$ long. The first step is to make cuts $1\frac{1}{8}''$ from one end and 2″ from the other, and widen out these cuts with a fuller, as shown in Fig. 130.

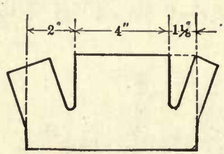


FIG. 130.

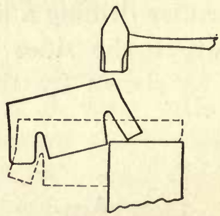


FIG. 131.

These ends are then forged out round in the manner illustrated in Fig. 131. The forging should be placed over the corner of the anvil in the position shown, the blows striking upon the corner of the piece as indicated. As the end gradually straightens out, the other end of the piece is slowly raised into the position shown by the dotted lines and the shaft hammered down round and finished up between swages.

Care must be taken to spread the cuts properly before drawing down the ends, otherwise a bad cold-shut will be formed. If the cuts are left without spreading, the metal will act somewhat after the manner shown in Fig. 132. The top part of the bar, as it is worked down, will gradually fold over, leaving, when hammered down to size, a bad cold-shut, or crack, such as illustrated in Fig. 132. When the metal starts to act this way, as shown by the upper sketch in 132, the fault may be remedied by trimming off the corner along the dotted line. This must always be done as soon as any tendency to double over is detected.

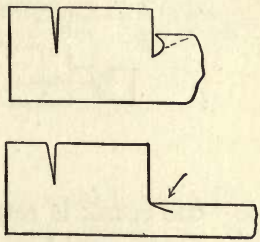


FIG. 132.

Double-throw Cranks.—Multiple-throw cranks are first forged flat, rough turned, then heated and twisted into shape.

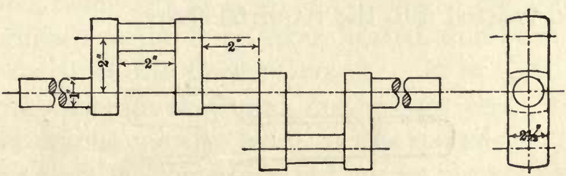


FIG. 133

The double-throw crank, shown in Fig. 133, would be first forged as shown in Fig. 134; the parts shown dotted would then be cut out with the drill and saw, as described above.

After the pins and shafts have been rough turned —that is, turned round, but left as large as possible—the crank is returned to the forge-shop, where it is heated red-hot and twisted into the finished shape.

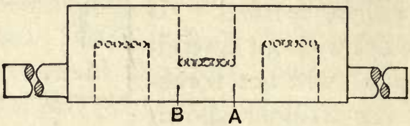


FIG. 134.

When twisting, the crank is gripped just to one side of the central bearing, as shown by the dotted line *A*. This may be done with a vise or wrench, if the crank is small, or the crank may be placed on the anvil of a steam-hammer and the hammer lowered down on it to hold it in place.

The other end of the crank is gripped on the line *B* and twisted into the required shape.

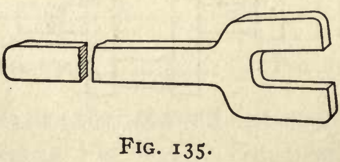


FIG. 135.

A wrench of the shape shown in Fig. 135 is very convenient for doing work of this character. It may be formed by bending a U out of flat stock, bent edgewise, and welding on a handle.

Three-throw Crank.—Fig. 136 shows what is known as a "three-throw" crank. The forging for

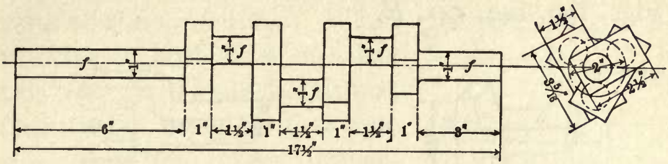


FIG. 136.

this is first made as shown by the solid lines in Fig. 137. The forging is drilled and sawed in the

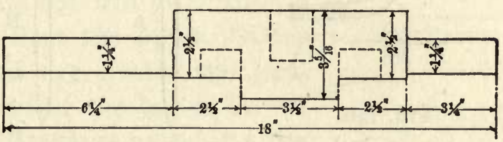


FIG. 137.

machine-shop to the dotted lines, and pins rough turned, being left as large as possible. The forging is returned to the forge-shop, heated, and bent into the shape of the finished crank. It is then sent to the machine-shop and finished to size. Four-throw cranks are also made in this manner.

The slots are sometimes cut out in the forge-shop with a hot chisel, but, particularly on small work, it is generally more economical to have them sawed out in the machine-shop. This is especially so of multiple-throw cranks, which must be twisted.

Knuckles.—There is a large variety of forgings which can be classed under one head—such forgings as the forked end of a marine connecting-rod, the knuckle-joints sometimes used in valve-rods, and others of this character, such as illustrated in Figs. 139, 140, 141, *E*.

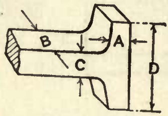


FIG. 138.

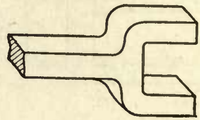


FIG. 139.

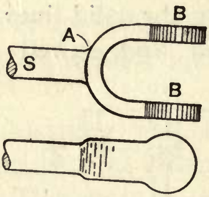


FIG. 140.

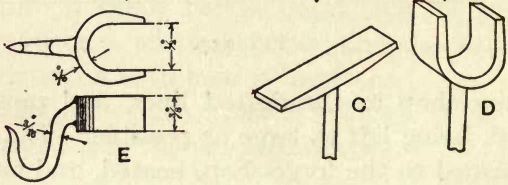


FIG. 141.

Connecting-rod End.—Fig. 138 shows the shaped end often used on the crank end of connecting-rods. The method of forming this is the same as the first step in forging the other pieces above mentioned.

The stock used for making this should be as wide as *B* and somewhat more than twice as thick as *A*. The first step is to make two fuller cuts as shown at *A*, Fig. 142, using a top and bottom fuller and working in both sides at the same time. When working in both sides of a bar this way, it should be turned frequently, bringing first one side, then the other, uppermost. In this way the cuts will be worked to the same depth on both sides, while if the work is held in one position, one cut will generally be deeper than the other. After the cuts are made, the left-hand end of the bar is drawn out to the proper size and the right-hand end punched and split like *B*. Sometimes when the length *D*, Fig. 138, is comparatively short and the stock wide, instead of being punched and split, the end of the bar is cut out, as shown at *C*, Fig. 142, with a right angle or curved cutter.

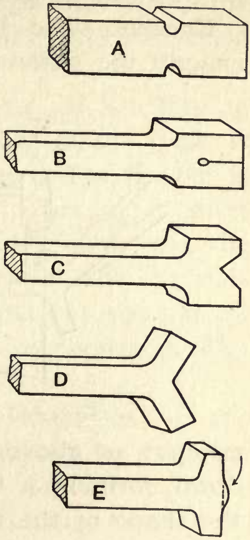


FIG. 142.

The split ends are spread out into the position shown at *D*, and drawn down to size over the corner of the anvil, in the manner illustrated in Fig. 143. These ends are then bent back into the proper position for the finished forging. Generally when the ends are worked out and bent back in this manner, a bump is left like that indicated by the arrow-point at *E*, Fig. 142. This should be trimmed off along the dotted line.

Knuckle.—The knuckle, Fig. 139, is started in exactly the same way, but after being forged out

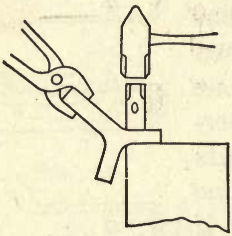


FIG. 143.

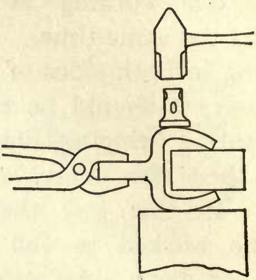


FIG. 144.

straight, as above, the tips of these ends are bent down, forming a U-shaped loop of approximately the shape of the finished knuckle. A bar of iron of the same dimension at the inside of the finished knuckle is then inserted between the sides of the loop and the sides closed down flat over it, Fig. 144.

Forked-end Connecting-rod.—Fig. 140 is made in the same manner. The shaft *S* should be drawn down into shape and rounded up before the other end is split. After the split ends have been bent back straight, the shoulder *A* should be finished up with a fuller in the manner shown in Fig. 145. The rounded

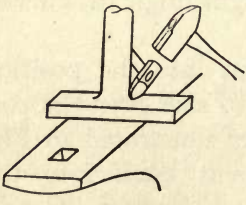


FIG. 145.

ends *B–B* should be formed before the piece is bent into shape. The final bending can be done over a cast-iron block of the right shape and size if the forging is a large one and several of the same kind are wanted.

Hook with Forked End.—Fig. 141, *E* is a forging which also comes in this general class. This is made from $\frac{3}{8}''$ square stock. The end of the bar is first drawn down to $^3/_{16}''$ round. This round end is put through the hole of a heading-tool, and the square part is split with a hot chisel, the cut widened out, and the sides hammered out straight on the tool. The different steps are shown in Fig. 141.

Wrench, Open-end.—Open-end wrenches of the general class shown in Fig. 146 may be made in

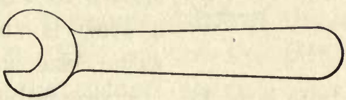


FIG. 146.

several different ways. It would be possible to make this by the same general method followed for making the forked end of the connecting-rod described above. Ordinary size wrenches are more easily made in the way illustrated in Fig. 147.

A piece of stock is used, wide enough and thick enough to form the head of the wrench. This is worked in on both sides with a fuller and the head rounded up as shown. A hole is then punched through the head and the piece cut out to form the opening, as shown by the dotted lines at *B*.

This wrench could also be made by bending up a U from the proper size flat stock and welding on a handle.

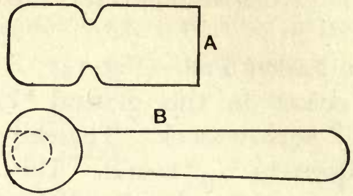


FIG. 147.

The solid-forged wrench is the more satisfactory.

Socket-wrench. — The socket-wrench, shown in Fig. 148, may be made in several ways. About the easiest, on "hurry-up" work, is the method shown in Fig. 149. Here a stub is shaped up the same size and shape as the finished hole is to be. A ring is bent up of thin flat iron and this ring welded around the stub.

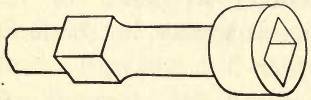


FIG. 148.

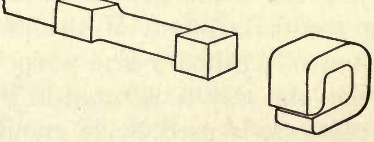


FIG. 149.

The width of the ring should of course be equal to the length of the hole plus the lap of the weld.

When finishing the socket, a nut or bolt-head the size the wrench is intended to fit should be placed in the hole and the socket finished over this between swages.

A better way of making wrenches of this sort is to make a forging having the same dimensions as the finished wrench, but with the socket end forged solid. The socket end should then be drilled to a depth slightly greater than the socket is wanted. The diameter of the drill should be, as shown in Fig. 150, equal to the shortest diameter of the hole.

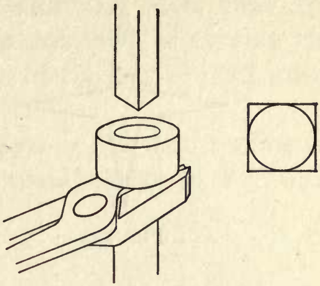


FIG. 150.

After drilling, the socket end is heated red-hot and a punch of the same shape as the intended hole driven into it. The end of the punch should be square, with the corners sharp. As the punch is driven in, the corners will shave off some of the metal around the hole and force it to the bottom of the hole, thus making it necessary to have the drilled hole slightly deeper than the socket hole is intended to finish.

While punching, the wrench may be held in a heading tool, or if the wrench be double-ended, in a pair of special tongs, as shown in Fig. 150.

Split Work.—There is a great variety of thin forgings, formed by splitting a bar and bending the split parts into shape. For convenience, these can be called split forgings.

Fig. 151 is a fair sample of this kind of work.

This piece could be made by taking two flat strips and welding them across each other, but, particu-

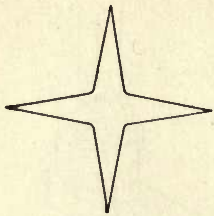


FIG. 151.

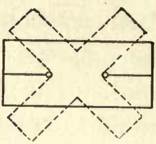


FIG. 152.

larly if the work is very thin, this is rather a difficult weld to make.

An easier way is to take a flat piece of stock of the proper thickness and cut it with a hot chisel, as shown by the solid lines in Fig. 152. The four ends formed by the splits are then bent at right angles to each other as shown by the dotted lines, and hammered out pointed as required.

If machine steel stock is used, it is not generally necessary to take any particular precautions when

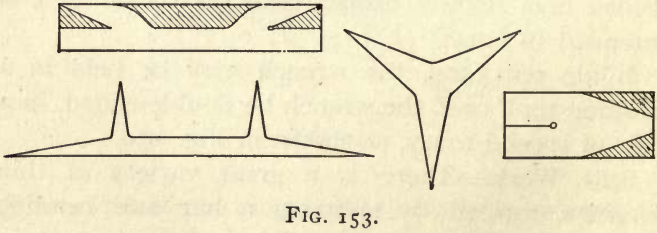


FIG. 153.

splitting the bar, but if the material used is wrought iron, it is necessary to punch a small hole through the bar where the end of the cut comes, to prevent the split from extending back too far.

Fig. 153 shows several examples of this kind of work. The illustrations show in each case the finished piece, and also the method of cutting the bar. The shaded portions of the bar are cut away completely.

Expanded or Weldless Eye. — Another forging of the same nature is the expanded eye in Fig. 154.

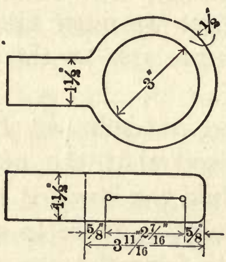


FIG. 154.

FIG. 155.

To make this, a flat bar is forged rounding on the end, punched and split as shown. The split is widened out by driving a punch, or other tapering tool into it, and the forging finished by working over the horn of the anvil, as shown in Fig. 155.

If the dimensions of the eye are to be very accurate, it will be necessary to make a calculation for the length of the cut. This can be done as follows: Suppose the forging, for the sake of convenience in calculating, to be made up of a ring 3″ inside diameter and sides ½″ wide, placed on the end of a bar 1½″ wide. The first thing is to determine the area of this ring. To do this find the area of the outside circle and subtract from it the area of the inside circle. (Areas may be found in table, page 243.)

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

The stock, being $1\frac{1}{2}''$ wide, has an area of $1\frac{1}{2}$ sq. in. for every inch in length, and it will take $3\frac{2}{3}''$ of this stock to form the ring, as we must take an amount of stock having the same area as the ring. This will be practically $3^{11}/_{16}''$.

The stock should be punched and split, as shown in Fig. 154. It will be noticed that the punch-holes are $\frac{5}{8}''$ from the end, while the stock is to be drawn to $\frac{1}{2}''$. The extra amount is given to allow for the hammering necessary to form the eye.

Weldless Rings.—Weldless rings can be made in the above way by splitting a piece of flat stock and expanding it into a ring, or they can be made as follows: The necessary volume of stock is first forged into a round flat disc and a hole is punched through the center. The hole should be large enough to admit the end of the horn of the anvil. The forging is then placed on the horn and worked to the desired size in the manner indicated in Fig. 155. Fig. 156 shows the different steps in the process—the disc, the punched disc, and the finished ring.

Rings of this sort are made very rapidly under the steam-hammer by a slight modification of this method. The discs are shaped and punched and then forged to size over a "mandril." A U-

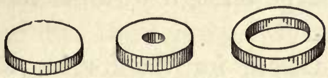


FIG. 156.

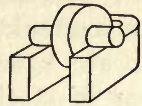


FIG. 157.

shaped rest is placed on the anvil of the steam-hammer, the mandril is slipped through the hole in the disc and placed on the rest, as shown in Fig. 157. The blows come directly down upon the top side of the ring, it being turned between each two blows. The ring of course rests only upon the mandril. As the hole increases in size, larger and larger mandrils are used, keeping the mandril as nearly as possible the same size as the hole.

Forging a Hub, or Boss.—Fig. 158 is an example of a shape very often met with in machine forging: a lever, or some flat bar or shank, with a "boss"

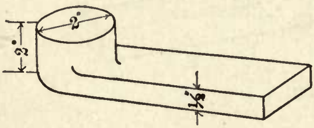


FIG. 158.

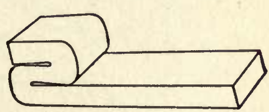


FIG. 159.

formed on one end. This may be made in two ways—either by doubling over the end of the bar, as shown in Fig. 159, and making a fagot-weld of sufficient thickness to form the boss, or by taking a bar large enough to form the boss and drawing down the shank. The second method will be described, as no particular directions are necessary for the weld, and after welding up the end, the boss is rounded up in the same way in either case. The stock should be large enough to form the boss without any upsetting.

A bar of stock is taken, for the forging shown above, 2″ wide and 2″ thick. The first step is to make a cut about 2″ from the end, with a fuller, like *A*, Fig. 160.

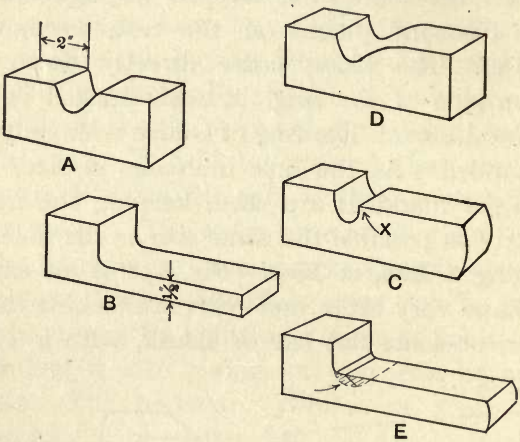


FIG. 160.

The stock, to the right of the cut, is then flattened down and drawn out to size, as shown at *B*. In drawing out the stock, certain precautions must be taken or a "cold-shut" will be formed close to the boss. If the metal is allowed to flatten down into shape like Fig. *C*, the corner at *X* will overlap, and work into the metal, making a crack in the work which will look like Fig. *E*. This is quite a common fault, and whenever a crack appears in a forging close to a shoulder, it is generally caused by something of this sort—that is, by some corner or part of the metal lapping over and cutting into the forging. When one of these cracks appears, the only way to remedy the evil is to cut it out as shown by the dotted lines in *E*. For this purpose a hot-chisel is sometimes used, with a blade formed like a gouge.

Fig. *D* shows the proper way to draw out the stock; the corner in question should be forged away from the boss in such a manner as to gradually widen the cut. The bar should now be rounded up by placing the work over the corner of the anvil, as shown in Fig. 161. First forge off the

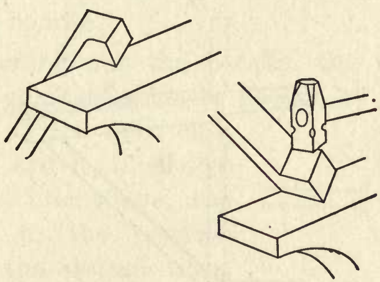


FIG. 161.

corners and then round up the boss in this way. To finish around the corner formed between the boss and the flat shank, a set-hammer should be used. Sometimes the shank is bent away from the boss to give room to work, and a set-hammer, or swage, used for rounding the boss as shown.

After the boss is finished, the shank is straightened. The boss should be smoothed up with a swage.

Ladle Shank.—The ladle shank, shown in Fig. 162, may be made in several ways. It is possible to make it solid without any welds, or the handle may be welded on a flat bar and the bar bent into a ring and welded, or the ring and handle may be forged in one piece and the ring closed together by welding. The last-mentioned method is as follows: The stock should be about 1″ square. It is necessary to make a

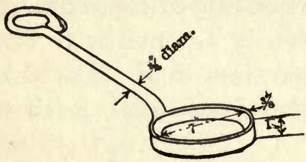


FIG. 162.

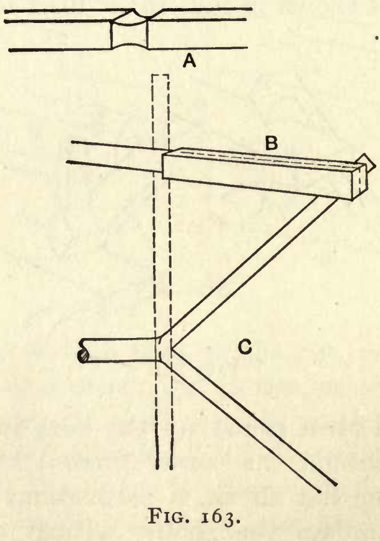


FIG. 163.

rough calculation of the amount of this size stock required to form the ring of the shank. If the ring were made of $\frac{3}{8}'' \times 1''$ stock, about $23\frac{1}{4}''$ would be required; now as $1'' \times 1''$ stock is the same width and about two and one-half times as thick as $\frac{3}{8}'' \times 1''$ stock, every inch of the $1'' \times 1''$ will make about $2\frac{1}{2}''$ of $\frac{3}{8}'' \times 1''$, consequently about $9\frac{1}{2}''$ of the $1''$ square will be required to form the ring.

A fuller cut is made around the bar, as shown at *A*, Fig. 163. This should be made about $9\frac{1}{2}''$ from the end of the bar. The left-hand end of the bar is drawn down to $\frac{3}{4}''$ in diameter to form the handle. If the work is being done under a steam or power hammer, enough stock may be drawn out to form the entire handle, but if working on the anvil, it will probably be more satisfactory to draw out only enough stock to make a "stub" 4″ or 5″ long. To this stub may be welded a round bar to form the handle.

After drawing out the handle, the $9\frac{1}{2}''$ square end of the stock is split, as shown by the dotted lines at *B*. These split ends are spread apart, as shown at *C*, forged into shape, and bent back to the position shown by the dotted lines. The ring is completed by cutting the ends to the proper length, scarfing, bending into shape, and welding, as indicated in Fig. 164.

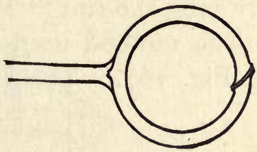


FIG. 164.

If for any reason it is necessary to make a forging of this kind without a weld in the ring, it may be done by the method shown in Fig. 165. The split in this case should not extend to the end of the bar. About $\frac{5}{8}''$ or $\frac{3}{4}''$ of stock should be left uncut at the end. This split is widened out and the

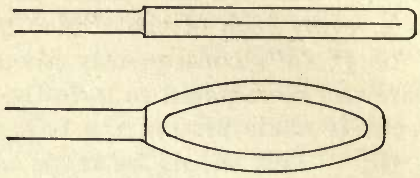


FIG. 165.

sides drawn down and shaped into a ring as desired.

Starting-lever.—The lever shown in Fig. 166 is a

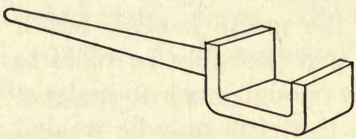


FIG. 166

shape sometimes used for levers used to turn the fly-wheels of engines or other heavy wheels by gripping the rim.

The method used in making the lever is shown in Fig. 167. The end is first drawn down round and the handle formed. The other end is then split, forged down to size, and bent at right angles to the handle. After trimming to the proper length, the flat ends are bent into shape.

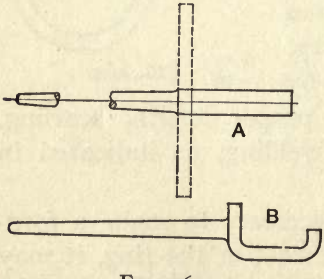


FIG. 167.

If this shaped end is very heavy, it may be necessary to forge it in the shape of a solid block, as shown in Fig. 168, and then either work in the depression shown by the dotted lines, with a fuller and set-hammers, or the dotted line may be cut out with a hot-chisel.

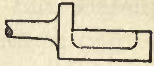


FIG. 168.

Moulder's Trowel.—The moulder's trowel shown in Fig. 169 gives an example of the method used in

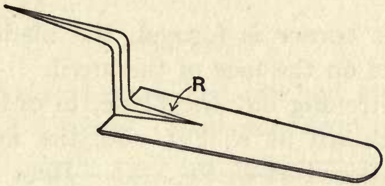


FIG. 169.

making forgings of a large class, forgings having a wide thin face with a stem, comparatively small, forged at one end.

The stock to be used for the trowel shown should be about $\frac{1}{4}'' \times 1''$. This is thick enough to allow for the formation of the ridge at *R*.

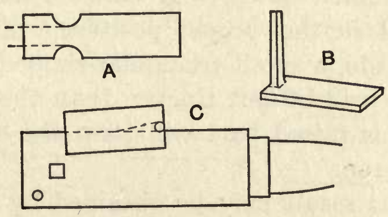


FIG. 170.

Fig. 170 shows the general method employed. The forging is started by making nicks like *A*, with the top and bottom fuller. One end is drawn down to form the tang for the handle. This should not be forged down pointed, as required when completed, but the entire length of handle should be forged square and about the size the largest part is required to finish to. The handle is then bent up at right angles, as at *B*, and the corner forged square in the same manner that the corner of a bracket is shaped up sharp and square on the outside.

After this corner is formed, the blade is drawn down to size on the face of the anvil.

When flattening out the blade, in order to leave the ridge shown at *R*, Fig. 169, the work should be held as shown at *C*, Fig. 170. Here the handle is held pointing down and against the side of the anvil. By striking directly down on the work, and covering the part directly over the edge of the anvil with the blows, all of the metal on the anvil will be flattened down, leaving the metal not resting on the anvil unworked. By swinging the piece around into a reverse position the other edge of the blade may be thinned down. If care be taken to hold the trowel in the proper position while thinning out the blade, a small triangular-shaped piece next the handle will be left thicker than the rest of the blade. This raised part will form the ridge shown at *R*, Fig. 169.

The same result may be obtained by placing the trowel, other side up, on the face of the anvil and using a set-hammer, or flatter, to thin out the blade.

Welded Brace.—Fig. 171 shows a form of brace, or bracket, sometimes used for holding swinging signs and for various other purposes.

The bracket in this case is made of round stock; but the same method may be followed in making one of flat or square material.

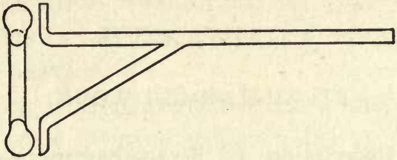


FIG. 171.

The stock is first scarfed on one end and this end doubled over, forming a loop, as shown in Fig. 172.

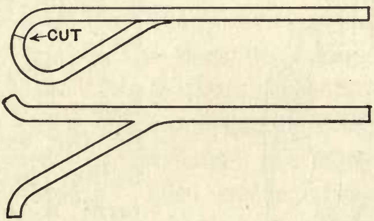


FIG. 172.

The loop is welded and then split, the ends straightened out and flattened into the desired shape as illustrated.

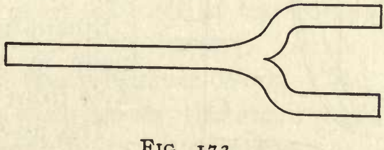


FIG. 173.

Welded Fork.—The welded fork, shown in Fig. 173, is made in the same way as the brace described above.

CHAPTER VII.

STEAM-HAMMER WORK.

General Description of Steam-hammer.—The general shape of small and medium steam-hammers is shown in Fig. 174. This type is known as a single-frame hammer.

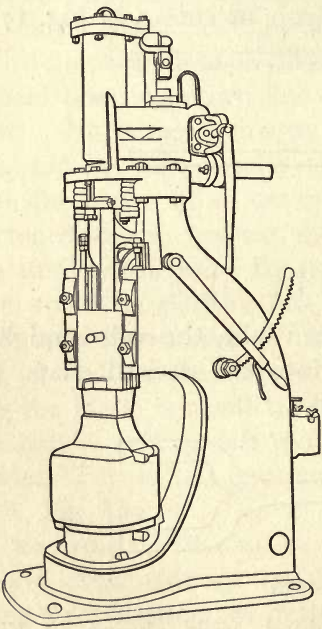


FIG. 174.

The size of a steam-hammer is determined by the weight of its falling parts; thus the term a 400-lb. hammer would mean that the total weight of the ram, hammer-die, and piston-rod was 400 lbs.

Steam-hammers are made in this general style from 200 lbs. up.

The anvil is entirely separate from the frame of the hammer, and each rests on a separate foundation.

The foundation for the frame generally takes the shape of two blocks of timber or masonry capped with timber—one in front and one behind the anvil block. The anvil foundation is placed between the two blocks of the frame foundation, and is larger and heavier.

The object of separating the anvil and frame is to allow the anvil to give under a heavy blow without disturbing the frame or its foundation.

Hammer-dies.—The dies most commonly used on steam-hammers have flat faces; the upper or hammer die being the same width, but sometimes shorter in length than the lower or anvil die.

Tool-steel makes the best dies, but chilled iron is also used to a very large extent. Sometimes, for forming work, even gray iron castings are used. Flat dies made of tool-steel are sometimes used without hardening. Dies made this way, when worn, may be faced off and used again without the bother of annealing and rehardening.

For special work the dies are made in various shapes, the faces being more or less in the shape of the work to be formed. When the die-faces are shaped to the exact form of the finished piece, the work is known as drop-forging.

Tongs for Steam-hammer Work.—The tongs used for holding work under the steam-hammer should be very carefully fitted and the jaws so shaped that they hold the stock on all sides. Ordinary flat-jawed tongs should not be used, as the work is liable to be jarred or slip out sideways.

Fig. 175 shows the jaws of a pair of tongs fitted to square stock. Tongs for other shaped stock should have the jaws formed in a corresponding way; that is, the inside of the jaws, viewed from the end, should have the same shape as the cross-section of the stock they are intended to hold, and should grip the stock firmly on *at least three sides*.

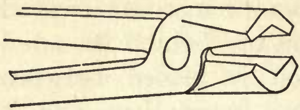


FIG. 175.

Flat-jawed tongs can be easily shaped as above in the manner shown in Fig. 176. The tongs are

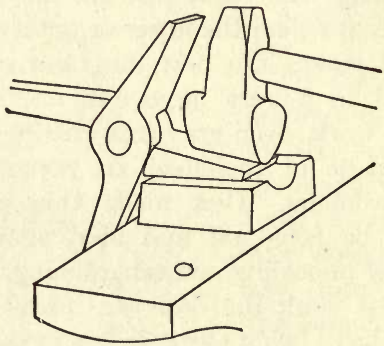


FIG. 176.

heated and held as shown, by placing one jaw, inside up, on a swage. The jaw is grooved or bent by driving down a top-fuller on it. After shaping the other jaw in the same way, the final fitting is done by inserting a short piece of stock of the proper size in the jaws and closing them down tightly over this by hammering.

When fitting tongs to round stock, the finishing may be done between swages, the stock being kept between the jaws while working them into shape.

Tongs for heavy work should have the jaws shaped as shown in Fig. 177. When in use, tongs of this kind are held by slipping a link over the handles to force them together. On very large sizes, this link is driven on with a sledge.

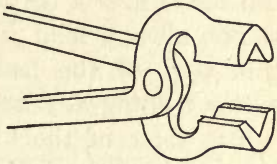


FIG. 177.

To turn the work easily, the link is sometimes made in the shape shown in Fig. 178, with a handle projecting from each end.

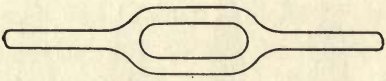


FIG. 178.

Hammer-chisels.—The hot-chisel used for cutting work under the hammer is shaped, ordinarily, like Fig. 179. This is sometimes made of solid tool-

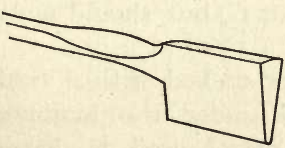


FIG. 179.

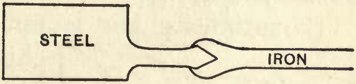


FIG. 180.

steel, and sometimes the blade is made of tool-steel and has a wrought-iron handle welded on. Fig. 180 shows the method of welding on the wrought-iron handle.

The handle of the chisel, close up to the blade, is hammered out comparatively thin. This is to allow the blade to spring slightly without snapping off the handle. The hammer will always knock the blade into a certain position, and as the chisel is not always held in exactly the right way, this thin part of the handle permits a little "give" without doing any harm.

The force of the blow is so great when cutting, that the edge of the chisel must be left rather blunt. The edge should be square across, and not rounding. The proper shape is shown at *A*, Fig.

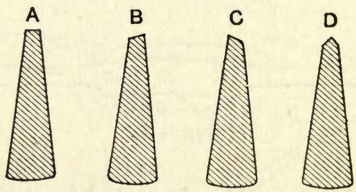


FIG. 181.

181. Sometimes for special work the edge may be slightly beveled, as at *B* or *C*, but should never be shaped like *D*.

Sometimes a bar is cut or nicked with a cold-chisel under the hammer. The chisel used is shaped like Fig. 182, being very flat and stumpy to resist the crushing effect of heavy blows. The three faces of the chisel are of almost equal width.

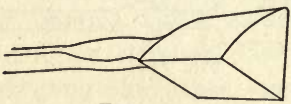


FIG. 182.

Cutting Hot Stock.—Hot cutting is done under the steam-hammer in much the same way as done on the anvil.

If the chisel be held perfectly upright, as shown at *A*, Fig. 183, the cut end of the bar will be left

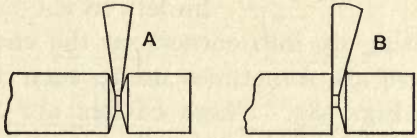


FIG. 183.

bulging out in the middle. When the end is wanted square the cut should be started with the chisel upright, but once started, the chisel should be very slightly tipped, as shown at *B*. When cutting work this way the cut should be made about half way through from all sides. When cutting off large pieces of square stock the chisel should be driven nearly through the bar, leaving only a thin strip of metal, $\frac{1}{8}''$ or $\frac{1}{4}''$ thick, joining the two pieces, *A*, Fig. 184. The bar is then turned over

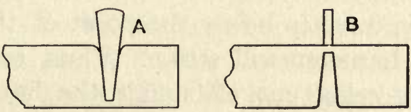


FIG. 184.

on the anvil and a thin bar of steel laid directly on top of this thin strip, as shown at *B*, Fig. 184. One hard blow of the hammer sends the thin bar of steel between the two pieces and completely cuts out the thin connecting strip of metal. This leaves the ends of both pieces smooth, while if the chisel is used for cutting on both sides, the end of one piece will be smooth and the other will have a fin left on it.

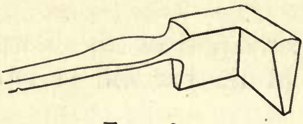


FIG. 185.

For cutting up into corners on the ends of slots bent cutters are sometimes used; such a cutter is shown in Fig. 185. These cutters are also made curved, and special shapes made for special work.

General Notes on Steam-hammer.—When working under the hammer, great care should always be taken to be sure that everything is in the proper position before striking a blow. The work *must* rest *flat* and *solid* on the anvil, and the part to be worked should be held as nearly as possible below the center of the hammer-die; if the work be done under one edge or corner of the hammer-die, the result is a "foul" blow, which has a tendency to tip the ram and strain the frame.

When tools are used, they should always be held in such a way that the part of the tool touching the work is directly below the point of the tool on which the hammer will strike. Thus, supposing a piece were being cut off under the hammer, the chisel should be held exactly upright, and directly under the center of the hammer, as shown at *A*, Fig. 186. In this way a fair cut is made. If the chisel were not held upright, but slantingly, as shown at *B*, the result of the blow would be as shown by the dotted lines, the chisel would be turned over and knocked flat, and, in some cases, might be even thrown very forcibly from under the hammer.

When a piece is to be worked out to any great extent, the blows should be *heavy*, and the end of

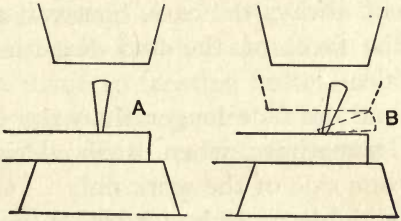


FIG. 186.

the stock being hammered should bulge out slightly, like *A*, Fig. 187, showing that the metal is being

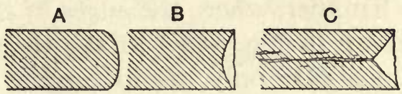


FIG. 187.

worked clear through. If light blows are used the end of the piece will forge out convex, like *B*, showing that the metal on the outside of the bar has been worked more than that on the inside. If this sort of work is continued, the bar will split and work hollow in the center, like *C*.

Round shafts formed between flat dies are very liable to be split in this way when not carefully handled.

The faces of the hammer- and anvil-dies are generally of the same width, but not always the same length. Thus, when the hammer is resting on the anvil, the front and back sides of the two dies are in line with each other, while either one or both ends of the anvil-die project beyond the ends of the hammer-die.

This is not always the case, however, as in many hammers the faces of the two dies are the same shape and size.

Having one die face longer than the other is an advantage sometimes when a shoulder is to be formed on one side of the work only.

When a shoulder is to be formed on both sides of a piece the work should be placed under the hammer in such a way that the top die will work in one shoulder, while the bottom die is forming the other; in other words, the work should be done from the side of the hammer, where the edges of the dies are even, as shown in Fig. 188. If the shoulder is required on one side only, as in forging tongs, the

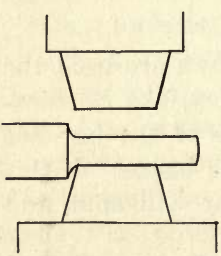


FIG. 188.

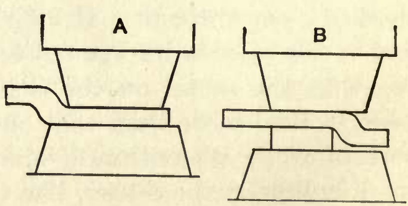


FIG. 189.

work should be so placed as to work in the shoulder with the top die, while the bottom die keeps the under side of the work straight, as in Fig. 189, *A*.

The same object, a shoulder on one side only, may be accomplished by using a block, as shown at *B*, Fig. 189. The block may be used as shown, or the positions of work and block may be reversed and the work laid with flat side on the anvil and block placed on top.

This method of forming shoulders will be taken up more in detail in treating individual forgings.

Tools: Swages.—In general, the tools used in steam-hammer work, except in special cases, are very simple.

Swages for finishing work up to about 3″ or 4″ in diameter are commonly made as shown in Fig. 190. The two parts of the swage are held apart

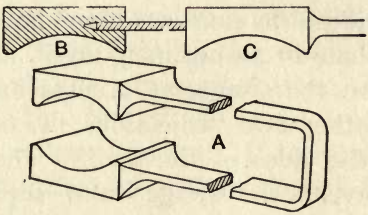


FIG. 190.

by the long spring handle. This spring handle may be made as shown at *B*, by forming it of a separate piece of stock and fastening it to the swage, by making a thin slot in the side of the block with a hot-chisel or punch, forcing the handle into this and closing the metal around it with a few light blows around the hole with the edge of a fuller.

Another method of forming the handle (*C*) is to draw out the same piece from which the blocks are made, hammering down the center of the stock to form the handle, and leaving the ends full size to make the swages.

Swages for large work are made sometimes as shown in Fig. 191. The one shown at *B* is made

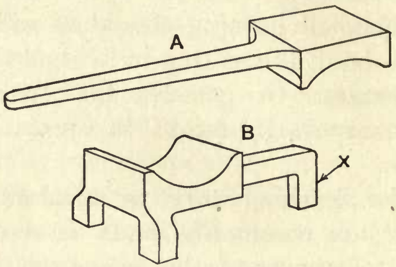


FIG. 191.

for an anvil-die having a square hole, similar to the hardie-hole in an ordinary anvil, near one end. The horn on the swage, at *x*, slips into this hole, while the other two projections fit, one on either side, over the sides of the anvil. These horns, or fingers, prevent the swage from slipping around when in use.

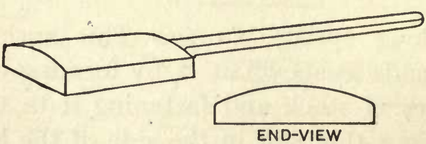


FIG. 192.

Tapering and Fullering Tool.—As the faces of the anvil- and hammer-dies are flat and parallel, it is not possible to finish smoothly between the bare dies, any work having tapering sides.

By using a tool similar to the one shown in Fig. 192 tapering work may be smoothly finished.

Taper Work.—The use of the tool illustrated above is shown in Fig. 193. For roughing out taper work, the tool is used with the curved side

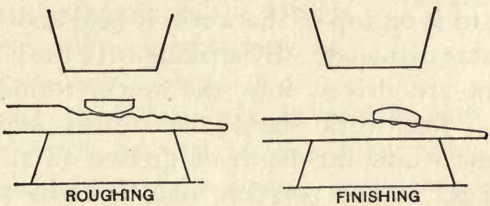


FIG. 193.

down, the straight side being flat with the hammer-die. When finishing the taper, the tool is reversed, the flat side being held at the desired angle and the hammer striking the curved side.. This curved side enables the tool to do good work through quite a wide range of angles. If too great an angle is attempted, the tool will be forced from under the hammer by the wedging action.

Fullers.—Fullers such as used for ordinary hand forgings are very seldom employed in steam-hammer work. To take their place simple round bars are used. When much used, the bars should be of tool-steel.

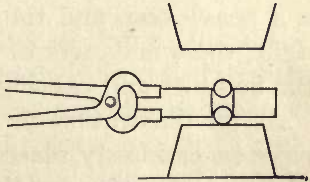


FIG. 194.

One use of round bars, as mentioned above, is illustrated in Fig. 194. Here the work, as shown, has a semicircular groove extending around it, forming a "neck." The groove is formed by placing a short piece of round steel of the proper size on the anvil-die; on this is placed the work, with the spot where the neck is to be formed directly on top of the bar. Exactly above the bar, and parallel to it on top of the work, is held another bar of the same diameter. By striking with the hammer, the bars are driven into the work, forming the groove. The work should be turned frequently to insure a uniform depth of groove on all sides; for, if held in one position, one bar will work in deeper than the other.

Adjusting Work Under the Hammer.—When work is first laid on the anvil the hammer should always be lowered lightly down on it in order to properly "locate" it. This brings the work flat and true with the die-faces; and if held in this position (and care should be taken to see that it is), there will be little chance of the jumping, jarring, and slipping, caused by holding the forging in the wrong position. This is particularly true when using tools, as great care must be taken to see that the hammer strikes them fairly. If the first blow is a heavy one, and the work is not placed exactly right, there is danger of the piece flying from under the hammer and causing a serious accident.

As an illustration of the above, suppose that a piece be carelessly placed on the anvil, as shown in Fig. 195, the piece resting on the edge of the anvil only, not flat on the face, as it should.

When the hammer strikes quickly and hard two things may happen: either the bar will be bent (as it will if very hot and soft) or it will be knocked into the position shown by the dotted lines. If the hammer be lowered lightly at first, the bar will be pushed down flat, and assumes the dotted position easily, where it may be held for the heavy blows.

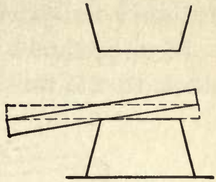


FIG. 195.

Squaring Up Work.—It frequently happens in hammer work, as well as in hand forging, that a piece which should be square in section becomes lopsided and diamond-shaped.

To correct this fault the forging should be held as shown in Fig. 196, with the long diagonal of

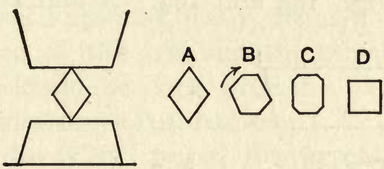


FIG. 196.

the diamond shape perpendicular to the face of the anvil.

A few blows will flatten the work into the shape shown at *B*; the work should then be rolled slightly in the direction of the arrow and the hammering continued, the forging taking the shape of *C*, and, as the rolling and hammering are continued, finally, the square section *D*.

Making Small Tongs.—As an example of manipulation under the hammer, the making of a pair of ordinary flat-jawed tongs is a good illustration.

Fig. 197 shows the different steps from the straight stock to the finished piece.

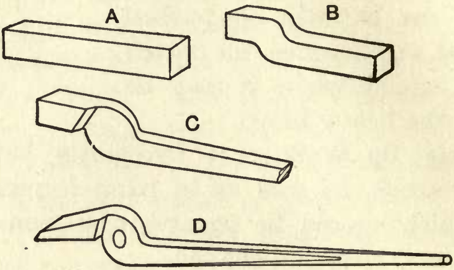


FIG. 197.

The stock is heated to a high heat and bent as shown in Figs. 198 and 199. *A* and *B* (Fig. 198)

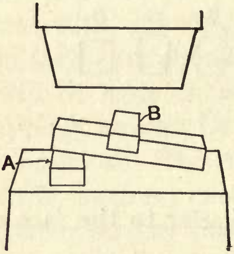


FIG. 198.

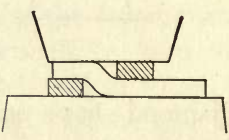


FIG. 199.

are two pieces of flat iron of the *same thickness.* The stock is placed like Fig. 198, the hammer brought down lightly, to make sure that everything is in the proper position, and then one hard blow bends the stock into shape (Fig. 199).

Fig. 200 shows the method of starting the eye and working in the shoulder. The bent piece is laid flat on the anvil and a piece of flat steel laid on top, in such a position that one side of the steel will cut into the work and form the shoulder for

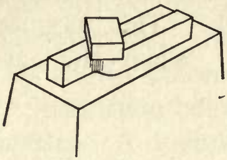


FIG. 200.

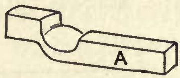


FIG. 201.

the jaw of the tongs. The steel is pounded into the work until the metal is forged thin enough to form the eye. This leaves the work in the shape shown in Fig. 201. The part *A*, Fig. 201, is afterward drawn out to form the handle, the jaw and eye are formed up, and, lastly, the eye is punched. The forming of the jaw and the punching of the rivet-hole should be done with the hand-hammer, and not under the steam-hammer.

The handle is, of course, drawn out under the steam-hammer, but needs no particular description. For careful finishing, the taper tool illustrated in Fig. 192, may be used, or a sledge and swages.

As a general thing, steam-hammer work does not differ very much from forging done on the anvil. The method of operation, in either case, is almost the same; but, when working under the hammer, the work is more quickly done and should be handled more rapidly.

Crank-shafts.—The crank-shaft, shown in Figs.

128 and 129, is a quite common example of steam-hammer work.

The different operations are about the same as described for making it on the anvil.

A specially shaped tool is used to make the cuts each side of the crank cheek. This tool and its use are shown in Fig. 202. When the cuts are

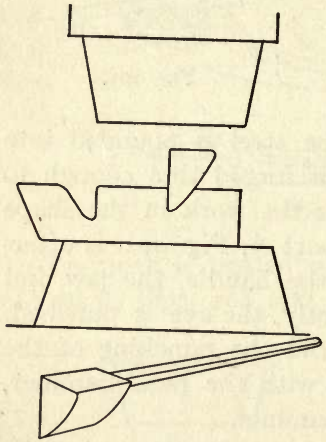


FIG. 202.

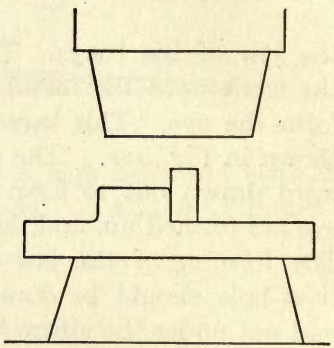


FIG. 203.

very deep, they should first be made with a hot-chisel and then spread with the spreading tool. If the shoulder is not very high, both operations, of cutting and spreading, may be done at once with the spreading tool.

After marking and opening out the cuts, the same precautions, to avoid cold-shuts, must be taken as are used when doing the same sort of work on the anvil. The work should be held and handled much the same as illustrated in Fig. 131, only in this case the sledge and anvil are replaced by the top and bottom dies of the steam-hammer.

A block of steel may be used for squaring up into the shoulder, as shown in Fig. 203. If a shoulder is to be formed on both sides, one block may be placed below and another above the work, somewhat as shown before in Fig. 194; the round bars in the illustration being replaced with square ones.

Knuckles.—A knuckle such as shown in Fig. 139 would be made by identically the same process as described for making it on the anvil. A few suggestions might be made, however.

After the end of the bar has been split and bent apart, ready for shaping, the work should be handled, under the hammer, as shown in Fig. 204. It

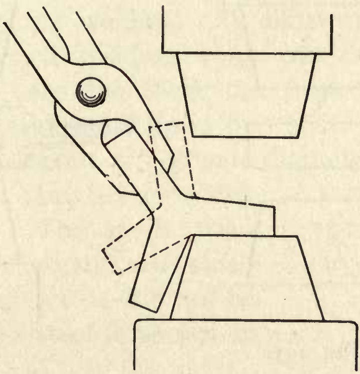


FIG. 204.

should first be placed as shown by the solid lines, and as the hammering proceeds, should be gradually worked over into the position shown by the dotted lines. The other side is worked in the same way.

After drawing out and shaping the ends the knuckle is finished by bending the ends together over a block, in the same way as shown in Fig. 144, the work being done under the hammer.

Connecting-rod. Drawing Out between Shoulders.—The forging illustrated in Fig. 126, while hardly the exact proportions of common connecting-rods, is near enough the proper shape to be a good example of that kind of forging.

The forging, after the proper stock calculation has been made, is started by making the cuts near the two ends, as shown in Fig. 127. The distance, *A*, must be so calculated, as explained before, that

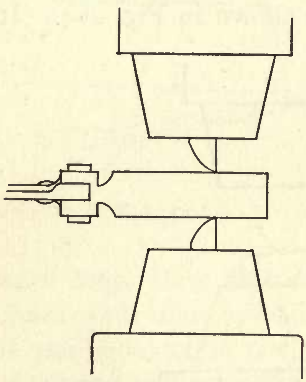


FIG. 205.

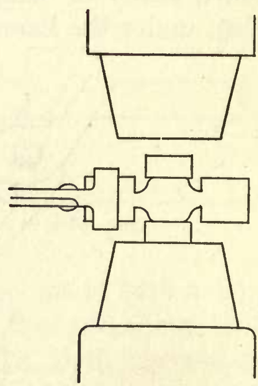


FIG. 206.

the stock represented by that dimension, when drawn out, will form the shape, 2″ in diameter and 24″ long, connecting the two wide ends.

The cuts are made with the spreading tool used in connection with a short block shaped the same as the tool, or a second tool, the tools being placed one above and one below the work, as shown in Fig. 205.

After making the cuts the stock between them is drawn down to the proper size and finished.

It sometimes happens that the distance *A* is so short that the cuts are closer together than the width of the die-faces, thus making it impossible to draw out the work by using the flat dies. This difficulty may be overcome by using two narrow blocks as shown in Fig. 206.

Weldless Rings—Special Shapes.—It is often necessary to make rings and similar shapes without a weld. The simple process is illustrated in Figs. 155-7. Rings may be made in this way under the steam-hammer much more rapidly than is possible by bending and welding. To illustrate the rapidity with which weldless rings can be made, the author has seen the stock cut from the bar, the ring forged and trued up in one heat. The ring in question was about 10″ outside diameter, the section of stock in rim being about 1″ square. The stock used was about 3″ square, soft steel.

A forging for a die to be made of tool-steel is shown in Fig. 207.

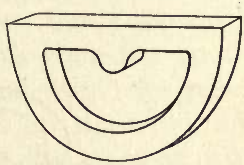


FIG. 207.

This is made in the same general way as weldless rings. The stock is cut, shaped into a disc, punched, and worked over a mandril into the shape shown at *A*, Fig. 208.

The lug, projecting toward the center from the flat edge of the die, is shaped on a special mandril, the work being done as shown at *B*, the thick side

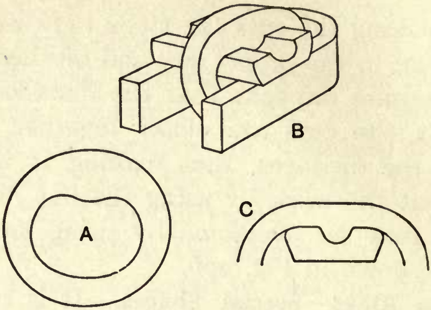


FIG. 208.

of the ring being driven into the groove in the mandril and shaped up as shown at *C*, where the end view of the mandril and ring is shown.

If the flat edge of the die is very long, it may be straightened out by using a flat mandril and work-

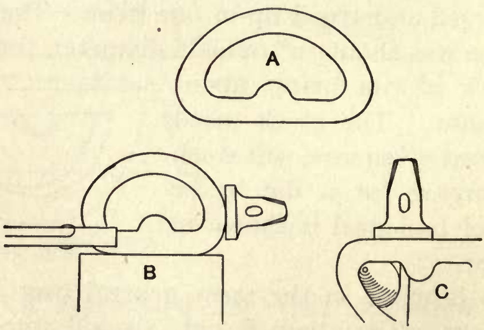


FIG. 209.

ing each side of the projecting lug after the lug has been formed.

The forging leaves the hammer in the shape shown in Fig. 209 at *A*. The finishing of the sharp corner is done on the anvil with hand tools, in much the same way that any corner is squared up, Figs. *B* and *C* giving a general idea of working up the corner by using a flatter.

Punches.—The punches used for this kind of work, and in fact for all punching under the steam-hammer, should be short and thick.

A punch made as shown in Fig. 210 is very satisfactory for general work. This punch is simply a short tapering pin with a shallow groove formed around it about one third of the length from the big end. A bar of small round iron ($\frac{3}{8}''$ is about right for small punches) is heated, wrapped around the punch in the groove and twisted tight, as shown.

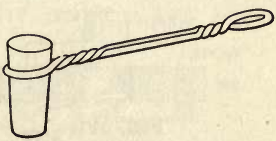


FIG. 210.

The punching is done in exactly the same way as with hand tools; that is, the punch is driven to a depth of about one half or two thirds the thickness of the piece, with the work lying flat on the anvil; the piece is then turned over, the punch started with the work still flat on the anvil, and the hole completed by placing a disc, or some other object with a hole in it, on the anvil; on this the work is placed with the hole in the disc directly under where the punch will come through. The punch is then driven through and the hole completed.

The end of the punch must not be allowed to become red-hot. If the punch is left in contact with the work too long, it will become heated, and, after a few blows, the end will spread out in a mushroom shape and stick in the hole.

To prevent the above, the punch should be lifted out of the hole and cooled between every few blows.

Sometimes, when a hole can be accurately located, an arrangement like that shown in Fig. 211 is used. The punch in this case is only slightly longer than the thickness of the piece to be pierced, and is used with the big end *down* as shown.

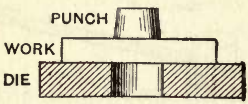


FIG. 211.

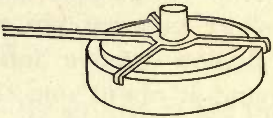


FIG. 212.

The punch is driven, together with the piece of metal which is cut out, through into the hole in the die, which is just enough larger to give clearance to the punch.

A convenient arrangement for locating the punch centrally with the hole in the die is shown in Fig. 212.

The die should be somewhat larger in diameter than the work to be punched. The work is first placed in the proper position on the die and the punch placed on top. The punch is located by using a spider-shaped arrangement made from thin iron. This spider has a central ring with a hole in the center large enough to slip easily over the punch. Radiating from the ring are four arms, three of which have their ends bent down to fit around the outside of the die, the fourth being longer and used for a handle. The ends of the bent arms are so shaped that where they touch the outside of the die the central hole is exactly over the hole in the die.

After locating the punch with the spider, and while the spider is still in place, a light blow of the hammer starts the punch, after which the spider is lifted off and the punch driven through.

Forming Bosses on Flanges, etc.—A boss, on a flange or other flat piece, such as shown in Fig. 213, may be very easily formed by using a few simple

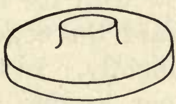


FIG. 213.

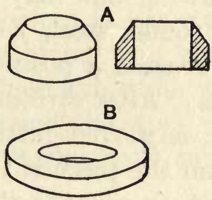


FIG. 214.

tools. The special tools are shown in Fig. 214, and are: a round cutter used for starting the boss, shown at *A*, which also shows a section of the tool, and a flat disc, shown at *B*, used for flattening and finishing the metal around the boss.

The stock is first forged into shape slightly thicker than the boss is to be finished, as it flattens down somewhat in the forging.

The boss is started by making a cut with the circular cutter, as shown at *A*, Fig. 215, where is also shown a section of the forging after the cut has been made.

The metal outside of the cut is then flattened out, as shown by the dotted lines. This flattening

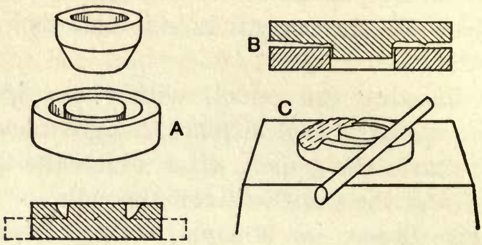


FIG. 215.

and drawing out may be done easily by using a bar of round steel, as shown at *C*. The bar is placed in such a position as to fall just outside of the boss. After striking a blow with the hammer, the bar is moved farther toward the edge of the work and the piece is turned slightly. In this way the stock is roughly thinned out, leaving the boss standing. To finish the work, the forging is turned bottom side up over the disc, with the boss extending down into the hole in the disc, as shown at *B*. With a few blows, the disc is forced up around the boss and finishes the metal off smoothly.

The disc need not necessarily be large enough to extend to the edge of the work; for if a disc as described above is used to finish around the boss, the edge of the work may be drawn down in the usual way under the hammer.

A disc is not absolutely necessary in any case; but the work may be more carefully and quickly finished in this way.

Round Tapering Work.—A round tapering shape, such as shown at *A*, Fig. 216, should be first

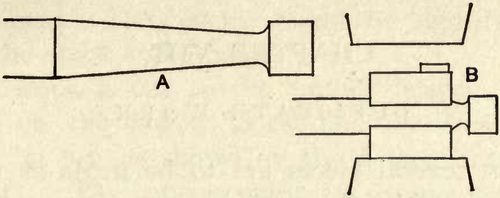


FIG. 216.

roughly forged into shape. It may be started by working in the shoulder next the head with round bars, in the way illustrated before in Fig. 194.

The roughing out may be done with square or flat pieces, using them in much the same way; or one piece only may be used and the work allowed to lie flat on the anvil, with the head projecting over the edge.

After roughing out, the work may be finished with swages. As ordinarily used, the swages would leave the forging straight, with the opposite sides parallel. To form a taper, a thin strip should be held on top of the upper swage close to and parallel with one of the edges, as shown at *B*, Fig. 216. The strip causes the swage to tip and slant, thus forming the work tapering.

CHAPTER VIII.

DUPLICATE WORK.

When several pieces are to be made as nearly alike as possible, the work is generally more easily done by using "dies" or "jigs."

Generally speaking, "dies" are blocks of metal having faces shaped for bending or forming work. The term "jig" may be applied to almost any contrivance used for helping to bend, shape, or form work. As ordinarily used, a jig, generally, is simply a combination of some sort of form or flat plate and one or more clamps and levers for bending.

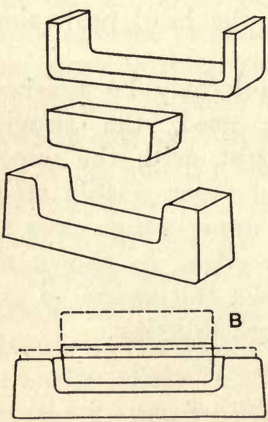


Fig. 217.

Dies, or jigs, for simple bending may be easily and cheaply made of ordinary cast iron; and, for most purposes, left rough, or unfinished.

Simple Bending. — The bend shown in Fig. 217 is a fair example of simple work. The dies for making this bend are two blocks of cast iron made as shown, one simply a rectangular block the size of the inside of the bend to be made, the other a block having on one side a groove the same shape as the outside of the piece to be bent. The blocks should be slightly wider than the stock to be bent.

The stock is cut to the proper length, heated, placed on the hollow block, and the small block placed on top, as shown by the dotted lines at *B*, Fig. 217. The bend is made by driving down the small block with a blow of the hammer.

Work of this kind may be easily done under a steam-hammer; and the dies described here are intended for use in this way, most of them having been designed for, and used under, a 200-lb. hammer.

Dies of this kind may be fitted to the jaws of an ordinary vise, the bending being done by tightening up the screw.

A die such as described above should have a little "clearance"; that is, the opening in the hollow die should be slightly larger at the top than at the bottom. The small, or top, die should be made accordingly, slightly smaller at the bottom.

To make the dies easier to handle, a hole may be drilled and tapped in each block and pieces of round bars threaded and screwed into the holes to form handles. This is more fully described in the following example:

Fig. 218, *A*, is a hook bent from stock $\frac{3}{8}'' \times 1''$, to fit around the flange of an I beam. The hooks were about 6″ long when finished. To bend these, two cast-iron blocks, or dies, were used, shown at

B. The dies were rough castings. Patterns were made by laying out the hook on a piece of 2″ white

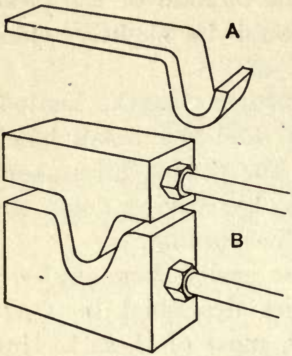


FIG. 218.

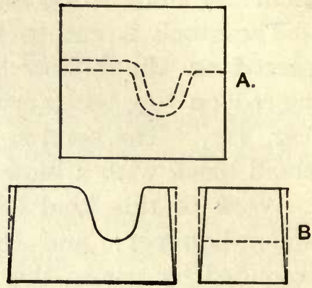


FIG. 219.

pine and then sawing to shape with a band-saw. The block was "laid off" as shown in Fig. 219, *A*, the sawing being done on the dotted lines. This left the blocks of such a shape that the space between them, when they were brought together with the upper and lower edges parallel, was just equal to the thickness of the stock to be bent.

Patterns of this kind should be given plenty of "draft," which may be quickly and easily done by planing the sides, after the blocks are sawed out, to taper slightly as shown in Fig. 219, *B*, where the dotted lines show the square sides before being planed off for draft as indicated by the solid lines.

When the castings were made, a $^{13}/_{32}$″ hole was drilled in the right-hand end of each block and tapped with $\frac{1}{2}$″ tap. A piece of $\frac{1}{2}$″ round iron about 30″ long was threaded with a die for about $1\frac{1}{2}$″ on each end and bent up to form the handle.

A nut was run on each end and the blocks screwed on and locked by screwing the nut up against them, making the finished dies as shown in Fig. 218. The handle formed a spring, holding the dies far enough apart to allow the iron to be placed between them.

As mentioned before, dies of this kind can be easily made to cover a variety of work, and are very inexpensive. The dies in question, for instance, required about half an hour's pattern work, and about as much time more to fit the handles. Calculating shop time at 50 cents per hour and castings at 5 cents per pound, and allowing for the handle, the entire cost of these dies was less than $1.25.

The same handle can be used for any number of dies of about the same size, and if any one of these dies should break, it can be replaced at a very trifling cost.

Cast-iron dies of this character will bend several hundred pieces and show no signs of giving out, although they *may* snap at the first piece if made of hard iron. On an important job it is generally wise to cast an extra set to have in case the first prove defective.

Almost any simple shape may be bent in this way, and the dies may be used on any ordinary steam-hammer with flat forging faces; and not only that, but, not having to be fastened down in any way, they may be placed under the hammer, or removed, without interfering with other work.

Loop with Bent-in Ends.—For larger work, it is often better to have a die to replace the lower die of the hammer, as in the case mentioned below.

A number of forgings were wanted like *A*, Fig. 220. The stock was cut to the proper length and

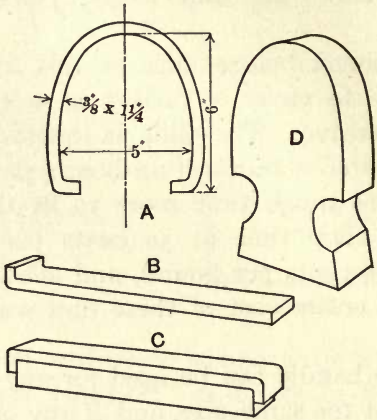


FIG. 220.

the ends bent at right angles. To make all the pieces alike, one end of each piece was first bent, as shown at *B*, in a vise. The other ends of the pieces were then all bent the same way, by hooking the bent end over a bar cut to the proper length and bending down the straight end over the other end of the bar, as shown at *C*. To make the final bend, a cast-iron form was used similar to *D*. This casting was about $2\frac{1}{2}''$ thick, and the dovetail-shaped base fitted the slot in the anvil base of the hammer. When the form was used, the anvil-die was removed and the form put in its place.

The strips to be bent were laid on top of this form and a heavy piece of flat stock, $1'' \times 2''$, bent into a U shape to fit the outside of the forging, placed on top. A light blow of the hammer would force the U-shaped piece down, bending the stock into the proper shape. Fig. 221 shows the operation, the dotted lines indicating the position of the pieces before bringing down the hammer.

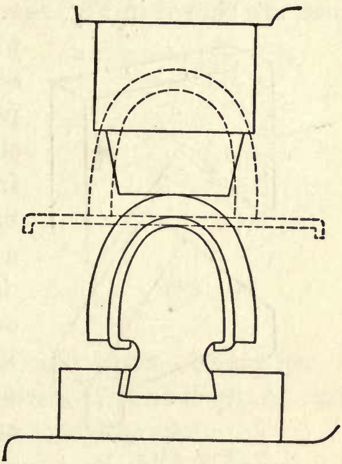


FIG. 221.

The most satisfactory results were obtained by bringing the hammer down lightly on the work, then, by turning on a full head of steam, the ram was forced down comparatively slowly, bending the stock gradually and easily. This was much more satisfactory than a quick, sharp blow.

It is not necessary to have the U-shaped piece of exactly the same shape as the forging. It is sufficient if the lower ends of the U are the proper distance apart. As the strip is bent over the form, it naturally follows the outline; and it is only necessary to force it against the form at the lower points of the sides.

The last bend might have been made by using a second die fastened to the ram of the hammer in place of the U-shaped loop.

Two dies are necessary for much work; but these are more expensive to make. The upper die can be easily made to fit in the dovetail on the ram and be held in place with a key.

Right-angle Bending.—Very convenient tools for bending right angles, in stock ½″ or less in thickness, are shown in Fig. 222. The lower one is made to fit easily over the anvil of the steam-hammer, the projecting lips on either side preventing the die from sliding forward or back. The upper one has a handle screwed in, as described before. Both of these bending tools are made of cast iron, the patterns being simply sawed from a 2″ plank.

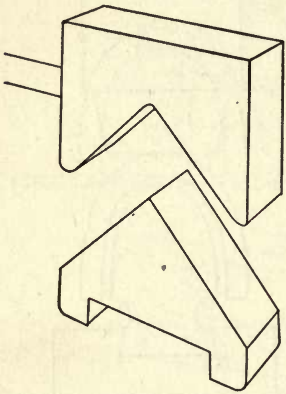


FIG. 222.

Cast-iron dies of this kind should be made of a tough, gray iron, rather than the harder white iron, as they are less liable to break if cast from the former.

Many of the regular hammer dies, that is, the dies with flat faces for general forging, are made of cast iron; but the iron in this case is of another quality—chilled iron—the faces being chilled, or hardened, for a depth of an inch or more.

Circular Bending—Coil Springs.—The dies described before have been for simple bends; the blows, or bending force, coming from one direction only. In the following example, where a complete circle, or more than a circle, is formed, an arrangement of a different nature is required.

The spring shown in Fig. 223 is an example of this kind. In this particular case the bending was done cold; but for hot bending the operation is exactly the same.

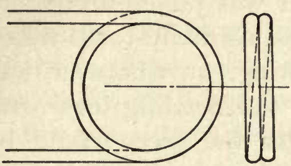


FIG. 223.

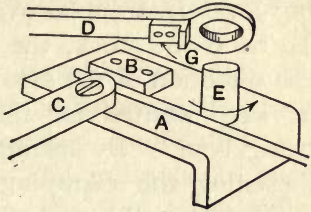


FIG. 224.

This jig (Fig. 224) was built upon a base-plate, *A*, about $\frac{3}{8}''$ thick, having one end bent down at right angles for clamping in an ordinary vise.

The post *E* was simply a $1''$ stud screwed into the plate. *B* was a piece of $\frac{3}{8}'' \times 1''$ stock about $2''$ long, fastened down with two rivets, and served as a stop for clamping the stock against while bending. *C* was a lever made of a piece of $\frac{3}{4}'' \times 1''$ stock about $10''$ long, having one end ground rounding as shown. This lever turned on the screw *F*, threaded into the base-plate. *D* was the bending lever, having a hole punched and forged in the end large enough to turn easily on the stud *E*. On the under side of this lever was riveted a short piece of iron having one end bent down at right angles. This piece was so placed that the distance between stud *E* and the inside face of bent end, when the lever was in position for bending, was about $^1/_{64}''$ greater than the thickness of the stock to be bent.

When in operation, the stock to be bent was placed in the position shown in the sketch, the lever *C* pulled over to lock it in place, and the bending lever *D* dropped over it in the position shown. To bend the stock, the lever was pulled around in the direction of the arrow and as many turns taken as were wanted for the spring, or whatever was being bent. By lifting off the bending lever and loosening the clamping lever the piece could be slipped from the stud.

With jigs of any kind a suitable stop should always be provided to place the end of the stock against, in order to insure placing and bending all pieces as nearly as possible alike.

Drop-forgings. — Strictly speaking, drop-forgings are forgings made between dies in a drop-press or forge. Each die has a cavity in its face, so shaped that when the dies are in contact the hole left has the form of the desired forging. One of the dies is fastened to the bed of the drop-press, directly in line with and under the other die, which is keyed to the under side of the drop, a heavy weight running between upright guides. The forging is done by raising the drop and allowing it to fall between the guides of its own weight.

There are generally two or more sets of cavities in the die-faces, one set being used for roughing out, or "breaking down," the stock roughly to shape; another set for finishing.

The dies mentioned above would be known as the "breaking-down" and "finishing" dies, respectively. Sometimes several intermediate dies are used.

In a general way, the term drop-forging may be used to describe almost any forging formed between shaped dies whether made by a drop-press or other means.

Taking the word in its broadest meaning, the example given below might be called a drop-forging, the work being done between shaped dies.

Eye-bolt — Drop-forging. — The example in question is the eye-bolt given in Fig. 225. The different steps in the making, and the dies used, are shown in Fig. 226.

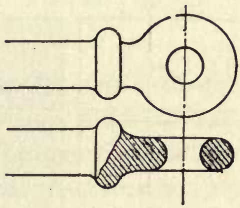


FIG. 225.

Round stock is used, and first shaped like *A*, Fig. 226, the forming being done in the die *B*. This die, as well as the other one, is made in the same way as ordinary steam-hammer swages; that is, simply two blocks of tool-steel fastened together with a spring handle. The inside faces of the blocks are formed to shape the piece as shown.

The stock is revolved through about 90 degrees between each two blows of the steam-hammer, and the hammering continued until the die-faces just touch.

For the second step the ball is flattened to about the thickness of the finished eye between the bare hammer-dies. The hole is then punched, under the hammer, with an ordinary punch.

The forging is finished with a few blows in the finishing die *D*, which is shown by a sectional cut and plan. This die is so shaped that, when the two parts are together, the hole left is exactly the

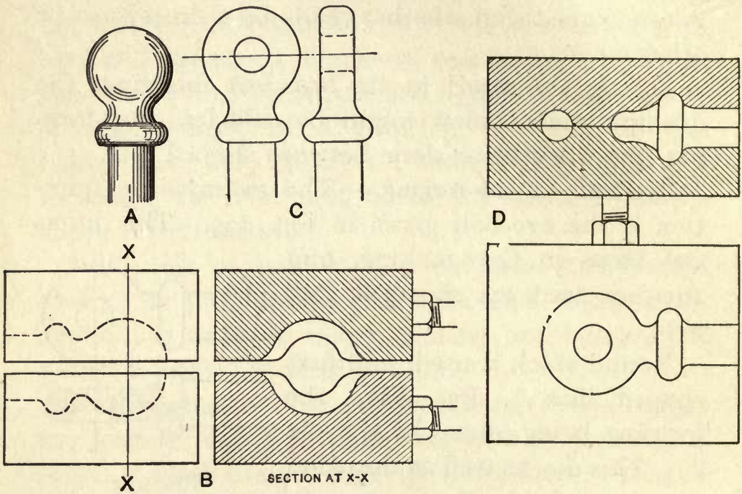


FIG. 226.

shape of the finished forging. In the first die, however, it should be noticed that the holes do not conform exactly to the desired shape of the forging; here the holes, instead of being semicircular, are rounded off considerably at the edges. This is shown more clearly in Fig. 227, *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 a semicircle in section, the stock, being larger than the small parts of the hole, after a blow, is left like *B*, the metal being forced out between the flat faces of the die and forming 'fins.' When the bar is turned and again hit, these fins are doubled in and make a bad place in the forging.

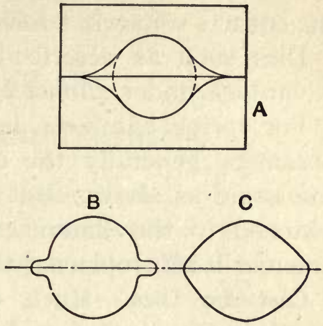


FIG. 227.

When the hole is a modified semicircle, as described above, the stock will be formed like *C*, and may be turned and worked without injury or danger of cold-shuts.

Forming Dies Hot.—Making dies for work of the above kind is generally an expensive process, particularly if the work be done in the machine-shop.

Rough dies for this kind of work may be cheaply made in the forge-shop by forming them hot.

The blocks for the dies are forged and prepared, and a blank, or 'master,' forging the same shape and size as the forgings the dies are expected to form is made from tool-steel and hardened.

The die blanks are then heated, the master placed between them, and the dies hammered together, the master being turned frequently during the hammering.

This, of course, leaves a cavity the shape of the master.

When two or more sets of dies are necessary there, of course, must be separate masters for each set of dies. Dies made in this way will have the corners of the cavities rounded off, as the metal is naturally pulled away during the forming, leaving the corners somewhat relieved.

Dies such as described above may be used to advantage under almost any steam-hammer.

For spring hammers, helve hammers, and power hammers generally the die *faces* may be formed the same as above; but the die-blocks should be fastened to the hammer and anvil of the power hammer itself, replacing the ordinary dies.

Cast-iron Dies.—Much drop-forging is done with cast iron dies, and for rough work that is not too heavy they are very satisfactory, and the first cost is very small as compared with the steel dies used for the same purpose.

Drop-forging can be done in this way with the steam-hammer, by keying the dies in the dovetails made for the top and bottom hammer-dies.

Welding in particular is done in this way, as the metal to be worked is in such a soft condition that there is little chance of smashing the die.

CHAPTER IX.

TOOL FORGING AND TEMPERING.

It is assumed that the general method of tempering as described before is understood, and only special directions will be given in particular cases in the following pages.

Forging Heat.—Any tool-steel forging on which there is any great amount of work to be done should have the heavy forging and shaping done at a yellow heat. At this heat the metal works easily and properly, and the heavy pounding refines the grain and leaves the steel in proper condition to receive a cutting edge. When a tool is merely to be smoothed off or finished, or forged to a very slight extent, the work should be done at a much lower heat, just above the hardening temperature.

Very little hammering should be done at any heat below the hardening temperature.

Cold-chisels.—The ordinary cold-chisel is so simple in shape that no detail directions are necessary for forging. The stock should be heated to a yellow heat and forged into shape and finished as smooth as possible. If properly forged the end, or edge, will bulge out, like Fig. 228. This should be *nicked* across with a sharp hot-chisel (but not cut off), as shown at *C*, and broken off after the tool has been hardened. This broken edge will then

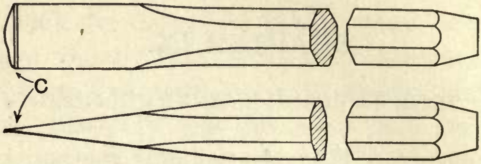


FIG. 228.

show the grain and indicate whether the steel has been hardened at a proper temperature.

When hardening, the chisel should be heated red-hot as far back from the point as the line *A*, Fig. 229. Great care must be taken to heat slowly enough to heat the thicker part of the chisel without overheating the point. If the point does become too hot, 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.

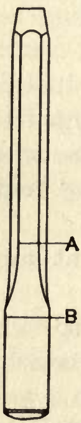


FIG. 229.

When the chisel has been properly heated to the hardening heat, the end should be hardened in cold water back to the line *B*, Fig. 235. As soon as the end is cold the chisel should be withdrawn from the water and one side of the end polished off with a piece of emery or something of that nature, as described before.

The part of the chisel from *A* to *B* will be still red-hot, and the heat from this part will gradually reheat the point of the tool. As the metal is reheated the polished surface will change color, showing at first yellow, brown, and at last purple. As soon as the purple, almost blue color reaches the nick at the end, the chisel should again be cooled, this time completely. The waste end may now be snapped off and the grain examined. To test for proper hardness, try the end of the chisel with a fine file, which should scratch it slightly. If the grain is too coarse, the tool should be rehardened at a *lower* temperature, while if the metal is too soft, it should be rehardened at a *higher* temperature.

Cape-chisel.—The cape-chisel, illustrated in Fig. 230, is used for cutting grooves and working at the

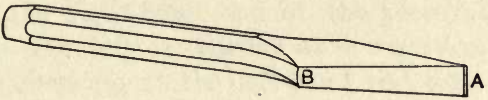


FIG. 230.

bottom of narrow channels. The cutting edge *A* should be wider than any part of the blade back to *B*, which should be somewhat thinner in order that the blade may "clear" when working in a slot the width of *A*.

The chisel is started by thinning down *B* over the horn of the anvil, as shown at *A*, Fig. 231. The finishing is done with a hammer or flatter in the manner illustrated at *B*. The chisel should *not* be worked flat on top of the anvil, as shown at *C*, as this knocks the blade out of shape.

The cape-chisel is tempered the same as a cold-chisel.

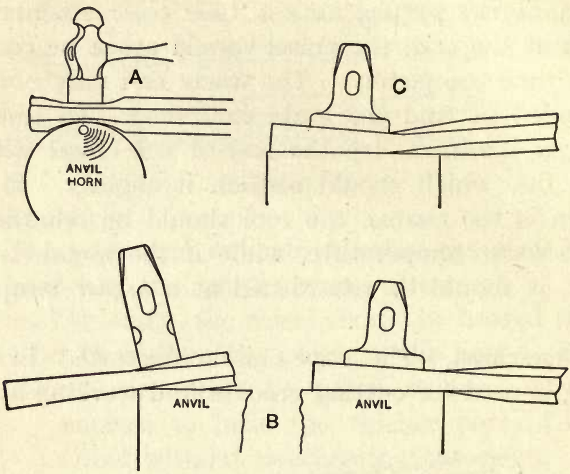


FIG. 231.

Square- and Round-nose Cape-chisels.—The chisels are started in the same way as an ordinary cape-chisel, the ends being left somewhat more stubby.

The end is then finished round or square, as shown in Fig. 232, and tempered the same as a cold-chisel.

Round-nose cape-chisels are sometimes used to center drills, and are then called "centering" chisels.

Lathe-tools in General.—The same general forms of lathe-tools are followed in nearly all shops; but in different places the shapes are altered somewhat to suit individual tastes.

Right- and Left-hand Tools.—Such tools as side tools, diamond points, etc., are generally made in pairs—that is, right- and left-handed. If a tool is made with the cutting edge on the left-hand side (as the tool is looked at from the top with the shank

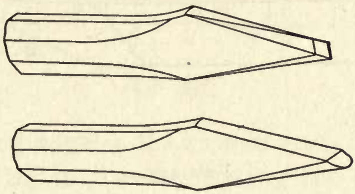


FIG. 232.

of the tool nearest the observer), it would be called a *right-hand* tool. That is, a tool which begins its cut at the right-hand end of the piece and cuts towards the left is known as a *right-hand* tool; one commencing at the left-hand end and cutting towards the right would be known as a *left-hand* tool.

The general shape of right- and left-hand tools for the same use is practically the same excepting that the cutting edges are on opposite sides.

Round-nose and Thread Tools.—Round-nose and thread tools are practically alike, the difference being in the grinding of the end. The thread tool is sometimes made a little thinner at the point.

The round-nose tool, Fig. 233, is so simple in shape that no description of the forging is necessary. Care must be taken to have proper "clearance." The cutting is all done at or near the end, and the sides must be so shaped that they "clear" the upper edge of the end. In other words, the upper edge of the shaped end must be

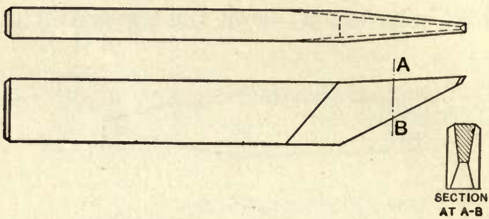


FIG. 233.

wider at every point than the lower edge, as shown by the section.

For hardening, the tool should be heated about as far as the line *A*, Fig. 234, and cooled up to the

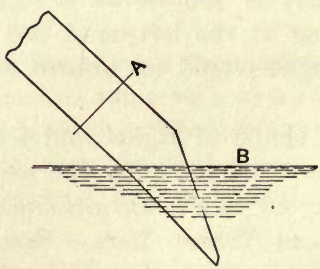


FIG. 234.

line *B*. Temper color of scale should be light yellow.

Cutting-off Tools.—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. A tool forged this way is shown in Fig. 235.

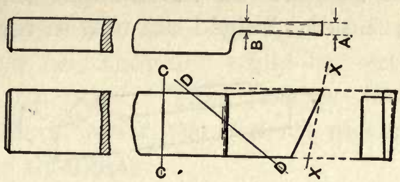


FIG. 235.

The cutting edge is the extreme tip of the blade, and the cutting is done by forcing the tool straight into the work, the edge cutting a narrow groove. The only part of the tool which should touch the work is the extreme end, or cutting edge; therefore the thickest part of the blade must be the cutting edge, the sides gradually tapering back in all directions and becoming thinner, as shown in the drawing, *A* being wider than *B*.

The cutting edge should be slightly above the level of the top of the tool, or, in other words, the blade should slant slightly upwards.

The clearance angle at the end of the tool is about right for lathe-tools; but for plainer tools the end should be made more nearly square, about as shown by the line *X—X*.

For hardening, the heat should extend to about the line *C—C*, and the end should be cooled to about the line *D—D*. Temper color should be light yellow.

The tool may be forged by starting with a fuller cut, as shown at *A*, Fig. 236. The blade is roughly forged into shape with a sledge, or, on light stock, a hand-hammer, working over the edge of the anvil to form the shoulder in the manner shown at *B*. This leaves the end bulged out and in rough shape,

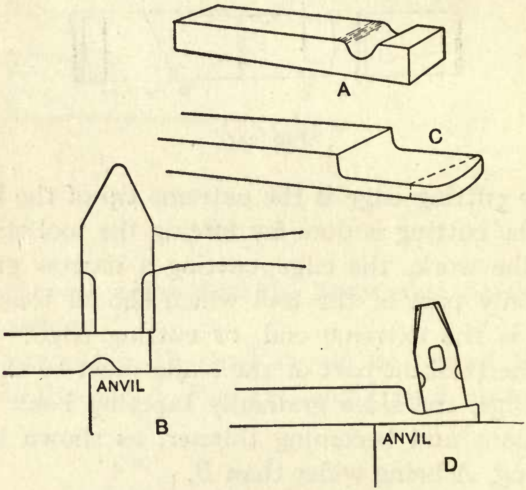


FIG. 236.

similar to *C*. The end should be trimmed off with a sharp hot-chisel along the dotted line.

The finishing may be done over the corner of the anvil, using a hand-hammer or flatter, in the same way as when starting the tool; or a set-hammer may be used, as shown at *D*.

Care must be taken to have proper clearance on all sides of the blade. It is a good plan to upset the end of the blade slightly by striking a few light blows the last thing on the end at the cutting edge, then adding a little clearance.

When a tool is wanted with the blade forged in the center of the shank, the two shoulders are formed by using a set-hammer and working at the edge of the anvil face, letting the corner of the anvil shape one shoulder while the set-hammer is forming the other. This process has been described before under the general method of forming double shoulders.

Bent Cutting-off Tool.—The bent cutting-off tool,

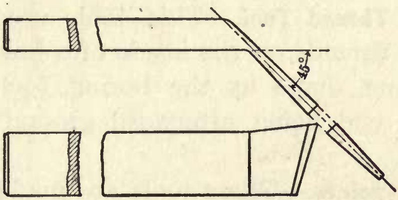


FIG. 237.

Fig. 237, is made and tempered exactly the same as the straight tool, excepting that the blade is bent backward toward the shank through an angle of about 45 degrees.

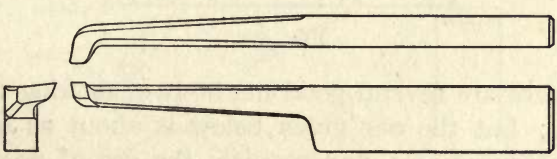


FIG. 238.

Boring Tool.—The boring tool, illustrated in Fig. 238, needs no particular description. The length of the thin shank depends upon the depth of the hole the tool is to be used in, but, as a general rule, should not be made any longer than necessary.

This thin shank is started with a fuller cut and drawn out in much the same way as the cutting-off tool was started.

The cutting edge is at the end of the small, bent nose. The only part of the tool required tempered is the bent nose, or end, which should be given the same temper color as the other lathe-tools—light yellow.

Internal Thread Tool.—This tool, used for cutting screw threads on the inside of a hole, is forged to the same shape as the boring tool described above, the end being afterward ground somewhat differently.

Diamond-points.—These tools are made right and left.

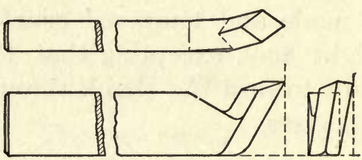


FIG. 239.

There are several good methods of making these tools; but the one given below is about as quick and easy as any, and requires the use of no tools excepting the hand-hammer and sledge.

The diamond-point is started as shown at *A*, Fig. 240, by holding the stock at an angle of about 45 degrees over the outside edge of the anvil. It is first slightly nicked by being driven down with a sledge against the corner, and the bent end down to the dotted position with a few blows, as indicated by the arrow.

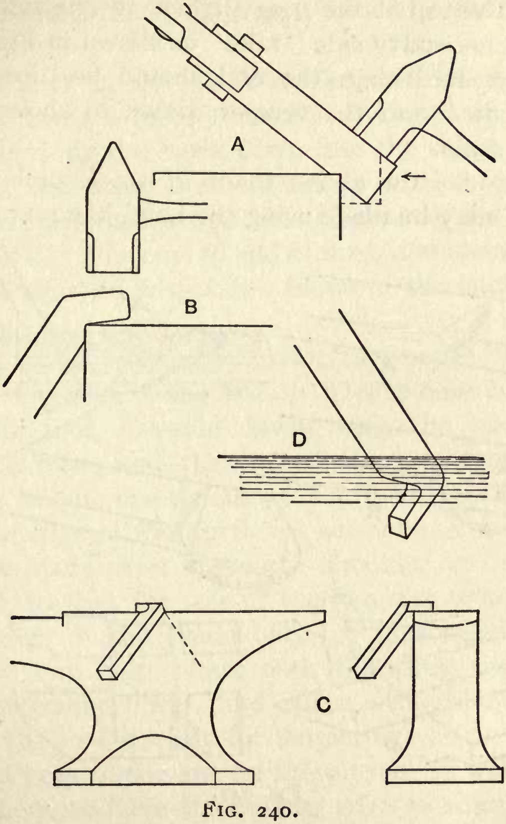


FIG. 240.

This end is further bent by holding and striking as illustrated at *B*. The diamond shape is given to the end by swinging the tool back and forth and striking as shown at *C*, which gives a side and end view of tool in position on the anvil.

The tool is finished by trimming the end with a sharp hot-chisel and so bending the end as to throw the top of the nose slightly to one side, giving the necessary side "rake" as shown in Fig. 239.

When hardening, the end should be dipped as shown at *D* and the temper drawn to show light-yellow scale.

Tools like the above made of stock as large as $\frac{1}{2}'' \times 1''$ may be made using the hand-hammer alone.

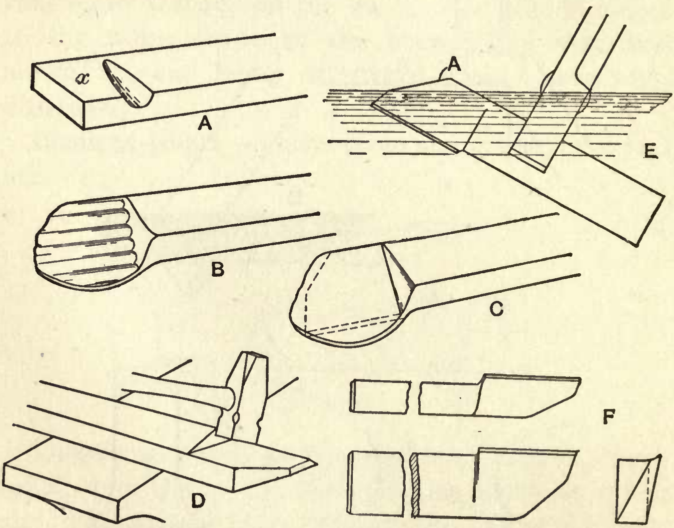


Fig. 241.

Side Tools.—Side tools, or side-finishing tools, as they are also called, are generally made about the shape shown in Fig. 241. These tools are made right and left and are also made bent. The bent side tools have the ends forged the same; but the blade is afterward bent toward the shank, cutting edge out, at an angle of about 45 degrees.

The side tool may be started by making a fuller cut as shown at *A*, Fig. 241, near the end of the stock.

The part of the stock marked *x* is then drawn out by using a fuller turned in the opposite direction, working the stock down into the shape shown at *B*. The blade is smoothed up with a set-hammer and trimmed with a hot-chisel along the dotted lines on *C*. The curved end of the blade is smoothed up and finished with a few blows of the hand-hammer.

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 one-eighth of an inch 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 straightening the blade the tool is ready for tempering.

It is very important on these tools, as well as on all others, to have the cutting edge as smooth and true as possible; it is, therefore, best, the very last thing, to smooth up this part of a tool, using the hand- or set-hammer. Above all things, the cutting edge must not be rounded off, as this necessitates grinding down the edge until the rounded part has been completely ground off.

While the side tool is being heated for tempering, it should be placed in the fire with the cutting edge up. It is more easy to avoid overheating of the edge in this way.

The blade is hardened by dipping in water as shown at *E*, only a small part of back, *A*, of the blade extending above the water and remaining red-hot. The tool is taken from the water, quickly polished on the flat side, and the temper drawn to show a very 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 tipping the tool in such a way as to bring that end of the blade which was before too soft deeper in the water.

Centering Tool.—The centering tool, Fig. 242, used for starting holes on face-plate and chuck work, is started in much the same way as the boring tool. The end is flattened out thin and trimmed into shape with a hot-chisel. The right-hand side of the end should be cut from the top side and the left-hand from the other, leaving the end the same shape as a flat drill.

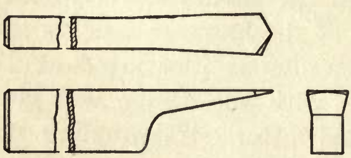


FIG. 242.

Tempered the same as other lathe-tools.

Finishing Tool.—This tool, Fig. 243, is started by bending the end of the stock down over the edge of the anvil in the same way as when starting the diamond-point.

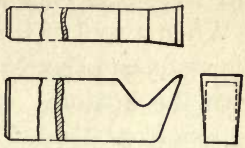


FIG. 243.

The end is flattened and widened by working with a hand- or set-hammer, as shown at *A*, Fig. 244. This leaves the end bent out too nearly straight; but, after being shaped, it is bent into the proper angle, in the manner illus-

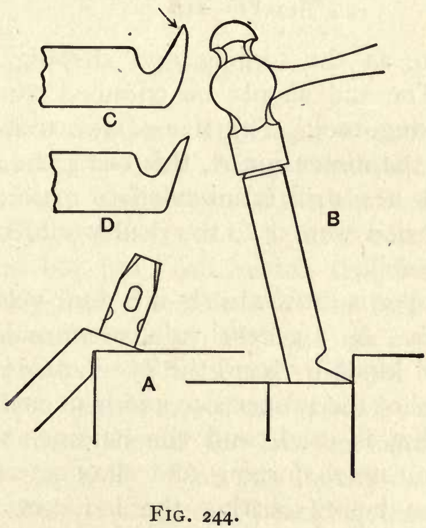


FIG. 244.

trated at *B*. The blade will then probably be bent somewhat like *C*, but a few blows with a hammer, at the point and in the direction indicated by the arrow, will straighten this out, leaving it like *D*. After trimming and smoothing, the tool is ready for tempering. The blade should be tempered to just show the very lightest yellow at cutting edge.

When a tool of this kind is to be used on a planer, the front end should make more nearly a right angle with the bottom; or, in other words, there should be less front "rake" or "clearance."

Flat Drills.—The flat drill, Fig. 245, needs no

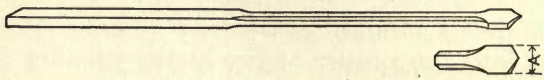


FIG. 245.

description, as the forging and shaping are very simple. The end should be trimmed the same as the centering tool. The size of the tool is determined by the dimension *A*, this being the same size as the hole the drill is intended to make; thus, if this dimension were 1″, the drill would be known as an inch drill.

The temper is drawn to show a dark-yellow scale.

Hammers.—As a general rule, when making hammers of all kinds by hand the eye is made first. A bar of steel of the proper size and convenient length for handling is used, and the hammer forged on the end, as much forging and shaping as possible being done before cutting the hammer from the bar.

The hole for the eye is punched in the usual way at the proper distance from the end of the bar, using a punch having a handle (Fig. 70).

The nose of the punch is slightly smaller but has the same shape as the eye is to finish. Great care must be taken to have the hole true and straight. It is very difficult and sometimes impossible to straighten up a crooked hole.

After punching the eye, the sides of the stock are generally bulged out, and to prevent knocking the eye out of shape while forging down this bulge a drift-pin, Fig. 246, is used. This is made

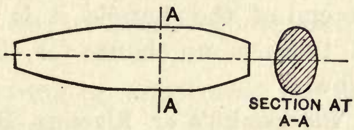


FIG. 246.

of tool-steel and tapers from near the center toward each end, one end being somewhat smaller than the other. The center of the pin is the same shape and size as the eye is to be in the hammer.

When the bar has been heated the drift-pin is driven tightly into the hole and the bulge forged down in the same way (*B*, Fig. 248) as a solid bar would be treated. When the drift-pin becomes heated it must be driven out and cooled, and under no circumstances should the bar be heated with the pin in the hole. The pin should always be used when there is danger of knocking the eye out of shape.

The steel used for hammers, and "battering tools" in general, should be of a lower temper (contain less carbon) than that used for lathe-tools.

The eye of a hammer should not be of uniform size throughout, but should be larger at the ends and taper slightly toward the center, as illustrated in Fig. 247, which shows a section of a hammer cut through the center of the eye.

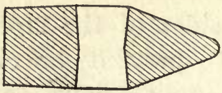


FIG. 247.

When the eye is made in this way (slightly contracted at the middle), the hammer-handle may be driven in tightly from one end; then by driving one or more wedges in the end of the handle it is held firmly in place and there is no chance for the head to work up or down.

Cross-pene, Blacksmith's or Riveting Hammer.—A hammer of this kind is shown at *C*, Fig. 6.

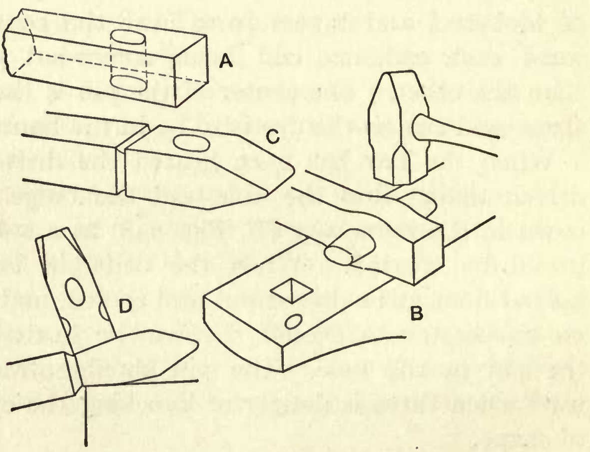


FIG. 248.

The different steps in the process of forging are illustrated in Fig. 248. First the eye is punched as shown at *A*. The pene is then drawn out and shaped and a cut started at the point where the end of the hammer will come (*C*), the drift-pin being used, as shown at *B*, while forging the metal around the eye.

The other end of the hammer is then worked up into shape, using a set-hammer as indicated at *D*.

When the hammer is as nearly finished as may be while still on the bar, it is cut off with a hot-chisel, leaving the end as nearly square and true as possible.

After squaring up and truing the face the hammer is tempered.

For tempering, the whole hammer is heated in a slow fire to an even hardening heat; while hardening, the tongs should grasp the side of the hammer, one jaw being inserted in the eye.

Both ends should be tempered, this being done by hardening first one end, then the other.

The small end is hardened first by cooling, as shown in Fig. 249. As soon as this end has cooled, the position is instantly reversed and the large end of the hammer dipped in the water and hardened. While the large end is cooling, the smaller one is polished and the temper color watched for. When a dark-brown scale appears at the end the hammer is again reversed, bringing the large end uppermost and the pene in the water. The face

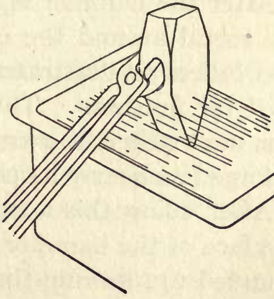


FIG. 249.

end is polished and tempered in the same way as the small end. 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 and the large end also polished, the colors being 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.

Under no circumstances should the eye be cooled while still red-hot.

For some special work hammer-faces must be very hard; but for ordinary usage the temper as given above is very satisfactory.

Ball Pene-hammer.—The ball pene-hammer, Fig. 5, is started by punching the eye.

The hammer is roughed out with two fullers in the manner illustrated at *A*, Fig. 250.

The size of stock used should be such that it will easily round up to form the large end of the hammer.

After the hammer is roughed out as shown at *A*, the metal around the eye is spread sidewise, using two fullers as illustrated at *B*, a set-hammer being used for finishing. This leaves the forging like *C*. The next step is to round and shape the ball, which is forged as nearly as possible to the finished shape.

After doing this a cut is made in the bar where the face of the hammer will come, and the large end rounded up, leaving the work like *D*.

The necked parts of the hammer each side of the eye are smoothed and finished with fullers of the proper size. Some hammers are made with these necks round in section, but the commoner shape is octagonal.

After smoothing off, the hammer is cut from the bar and the face forged true. Both ends are ground true and tempered. This hammer should be tem-

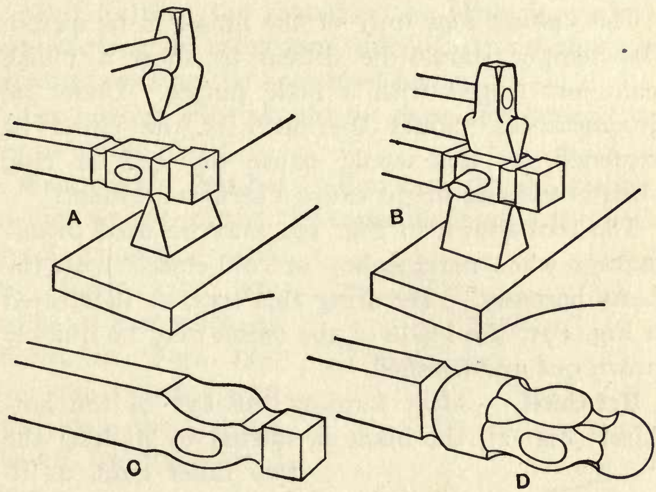


FIG. 250.

pered in the same way as described above for tempering the riveting-hammer.

Ball pene-hammers may be made with the steam-hammer in practically the same way as described, only substituting round bars of steel for use in place of fullers.

Sledges.—Sledges are made and tempered in the same general way as riveting-hammers. Sledges may be forged and finished almost entirely under the steam-hammer.

Blacksmith's Cold-chisel.—This tool (Fig. 2) is forged in practically the same way as the cross-pene hammer described before. The end, of course, is drawn out longer and thinner, the thin edge coming parallel with the eye instead of at right angles to it.

The *cutting edge* only of the chisel is tempered. The temper should be drawn to show a bluish scale just tinged with a little purple. Under no circumstances should the head of the chisel be hardened, as this would cause the end to chip when in use and might cause a serious accident.

The tool shown in Fig. 192 may be used to advantage when making hot- or cold-chisels with the steam-hammer. By using this tool, as illustrated in Fig. 193, the blade of the chisel may be quickly drawn out and finished.

Hot-chisel.—After forming the eye of the hot-chisel (Fig. 2), the blade is started by making the two fuller cuts, as illustrated in Fig. 251. The end is drawn down as indicated by the dotted lines. The head is shaped and

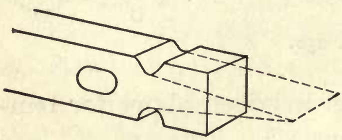


FIG. 251.

the chisel cut from the bar in the same way that the riveting-hammer was treated.

This chisel should have its cutting edge tempered the same as that of the cold-chisel.

Hardies.—Hardies such as shown in Fig. 2 should be started by drawing out the stem. This stem is drawn down to the right size to fit the hardy-hole in the anvil and the piece cut from the bar. This is heated, the stem placed in the hole in the anvil, and the piece driven down into the hole and against the face of the anvil, thus forming a good shoulder between the stem and the head of the hardy.

After forming the shoulder, the blade is worked out, starting by using two fullers in the same way as when starting the hot-chisel blade.

The cutting edge should be given the same temper as a cold-chisel.

Blacksmith's Punches. — Punches shaped similar to Fig. 70 are started the same manner as the hot-chisel, excepting that the fuller cuts are made on four sides, as shown in Fig. 252. The end is then drawn out to the shape shown by the dotted lines.

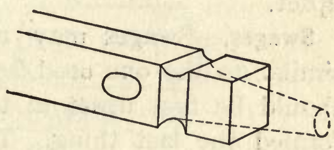


FIG. 252.

Temper same as cold-chisel.

Set-hammers — Flatters. — The set-hammer, Fig. 15, is so simple that no directions are necessary for shaping. The face only should be tempered and that should show a dark-brown or purple color.

Flatters such as shown in Fig. 14 may be made by upsetting the end of a small bar, the upset part forming the wide face; or a bar large enough to form the face may be used and the head, or shank, drawn down.

The eye should be punched after the face has been made. The face should be tempered to about a blue.

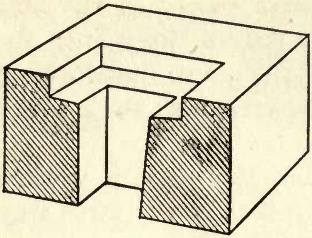


FIG. 253.

When many are to be made a swage-block similar to Fig. 253 should be used. Half only of the block is shown in the figure, the other half being cut away to show the shape of the hole which is the size of the finished flatter.

When using this block the stock is first cut to the proper length, heated, placed in the hole, and upset.

Swages.—Swages may also be made in a block similar to the one used for the flatter. The swage should be first upset in the block and the crease formed the last thing. The crease may be made with a fuller or a bar of round stock the proper size.

Fullers.—Fullers are made in the same way as swages.

All of these tools may be upset and forged under the steam-hammer, using the die, or swage, blocks as described above. The swage-blocks may be made of cast iron.

CHAPTER X.

MISCELLANEOUS WORK.

Shrinking.—When iron is heated it expands, and upon being cooled it contracts to practically its original size.

This property is utilized in doing what is known as "shrinking."

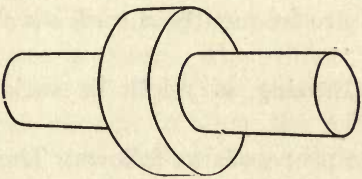


FIG. 254.

A common example of this sort of work is illustrated in Fig. 254, showing a collar "shrunk" on a shaft. The collar and shaft are made separately. The inside diameter of the hole through the collar is made slightly less than the outside diameter of the shaft. When the collar and shaft are ready to go together the collar is heated red-hot. The high temperature causes the metal to expand and thus increases the diameter of the hole, making it larger (if the sizes have been properly proportioned) than the outside diameter of the shaft. The collar is then taken from the fire, brushed clean of all ashes and dirt, and slipped on the shaft and into the proper position, where it is cooled as quickly as possible. This cooling causes the collar to contract and locks it firmly in place.

If the collar be allowed to cool slowly it will heat the shaft, which will expand and stretch the collar somewhat; then, as both cool together and contract, the collar will be loose on the shaft.

This is the method used for shrinking tires on wheels. The tire is made just large enough to slip on the wheel when hot, but not large enough to go on cold. It is then heated, put in place, and quickly cooled.

Couplings are frequently shrunk on shafts in this way.

Brazing.—Brazing, it might be said, is soldering with brass.

Briefly the process is as follows: The surfaces to be joined are cleaned thoroughly where they are to come in contact with each other. The pieces are then fastened together in the proper shape by binding with wire, or holding with some sort of clamp. The joint is heated, a flux (generally borax) being added to prevent oxidation of the surfaces, and the "spelter" (prepared brass) sprinkled over the joint, the heat being raised until the brass melts and flows into the joint, making a union between the pieces. Ordinarily it requires a bright-red or dull-yellow heat to melt the brass properly.

Almost any metal that will stand the heat can be brazed. Great care must be used when 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.

Brass wire, brass filings, or small strips of rolled brass may be used in place of the spelter. Brass wire in particular is very convenient to use in some places, as it can be bent into shape and held in place easily.

A simple brazed joint is illustrated in Fig. 255, which shows a flange (in this case a large washer) brazed around the end of a pipe. It is not necessary to use any clamps or wires to hold the work together, as the joint may be made tight enough to hold the pieces in place. The joint should be tight enough in spots to hold the pieces together, but must be open enough to allow the melted brass to run between the two pieces. Where the pipe comes in contact with the flange the outside should be free from scale and filed bright, the inside of the flange being treated in the same way.

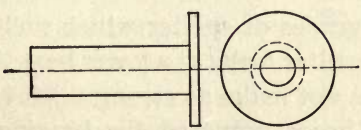


FIG. 255.

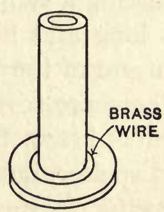


FIG. 256.

When the pieces have been properly cleaned and forced together, a piece of brass wire should be bent around the pipe at the joint, as shown in Fig. 256, and the work laid on the fire with the flange down. The fire should be a clean bright bed of coals. As soon as the work is in the fire the joint should be sprinkled with the flux; in fact, it is a good plan to put on some of the flux *before* putting the work in the fire. Ordinary borax can be used as a flux, although a mixture of about three parts borax and one part sal ammoniac seems to give much better results.

The heat should be gradually raised until the brass melts and runs all around and into the joint, when the piece should be lifted from the fire.

The brazing could be done with spelter in place of the brass wire. If spelter were to be used the piece would be laid on the fire and the joint covered with the flux as before. As soon as the flux starts to melt, the spelter mixed with a large amount of flux is spread on the joint and melted down as the brass wire was before. For placing the spelter when brazing it is convenient to have a sort of a long-handled spoon. This is easily made by taking a strip of iron about $\frac{3}{4}'' \times \frac{1}{8}''$ three or four feet long and hollowing one end slightly with the pene end of the hammer.

There are several grades of spelter which melt at different heats. Soft spelter melts at a lower heat than hard spelter, but does not make as strong a joint.

Spelter is simply brass prepared for brazing in small flakes and can be bought ready for use. The following way has been recommended for the preparation of spelter: Soft brass is melted in a ladle and poured into a bucket filled with water having in it finely chopped straw, the water being given a swirling motion before pouring in the brass. The brass settles to the bottom in small particles. Care must be taken when melting the brass not to burn out the zinc. To avoid this, cover the metal in ladle with powdered charcoal or coal. When the zinc begins to burn it gives a brilliant flame and dense white smoke, leaving a deposit of white oxide of zinc.

Another example of brazing is the T shown in

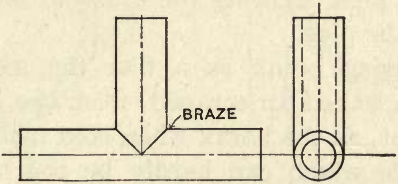


FIG. 257.

Fig. 257. Here two pipes are to be brazed to each other in the form of an inverted T.

A clamp must be used to hold the pieces in proper position while brazing, as one pipe is simply stuck on the outside of the other. A simple clamp is shown in Fig. 258 consisting of a piece of flat iron having one hole near each end to receive the two small bolts, as illustrated. This strip lies across the end of the pipe forming the short

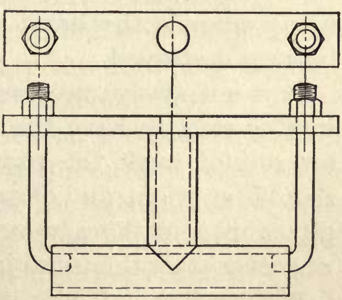


FIG. 258.

stem of the T, and the bent ends of the bolts hook into the ends of the bottom pipe. The whole is held together by tightening down on the nuts.

The brazing needs no particular description, as the spelter or wire is laid on the joint and melted into place as before.

A piece of this kind serves as a good illustration of the strength of a brazed joint. If a well-made joint of this kind be hammered apart, the short limb will sometimes tear out or pull off a section of the longer pipe, showing the braze to be almost as strong as the pipe.

When using borax as a flux the melted scale should be cleared (or scraped) from the work while still red-hot, as the borax when cold makes a hard, glassy scale which can hardly be touched with a file. The cleaning may be easily done by plunging the brazed piece, while still red-hot, into water. On small work the cleaning is very thoroughly done if the piece, while still red-hot, is dipped into melted cyanide of potassium and then instantly plunged into water. If allowed to remain in the cyanide many seconds the brass will be eaten off and the brazing destroyed.

It is not always necessary when brazing wrought iron or steel to have the joint thoroughly cleaned; for careful work the parts to be brazed together should be bright and clean, but for rough work the pieces are sometimes brazed without any preparation whatever other than scraping off any loose dirt or scale.

Pipe-bending. — There is one simple fact about pipe-bending which, if always carried in mind, makes it comparatively easy.

Let the full lines in Fig. 259 represent a cross-section of a piece of pipe before bending. Now suppose the pipe be heated and an attempt made to bend it without taking any precautions what-

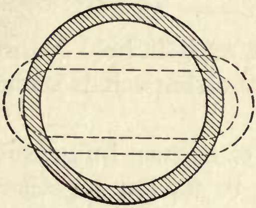


FIG. 259.

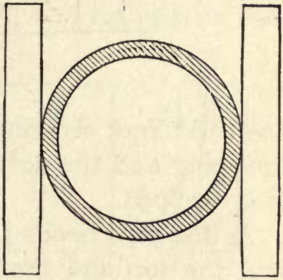


FIG. 260.

ever. The concave side of the pipe will flatten down against the outside of the curve, leaving the cross-section something as shown by the dotted lines; that is, the top and bottom of the pipe will be forced together, while the sides will be pushed apart. In other words, the pipe collapses.

If the sides can be prevented from bulging out while being bent it will stop the flattening together of the top and bottom. A simple way of doing this is to bend the pipe between two flat plates held the same distance apart as the outside diameter of the pipe (Fig. 260). Pipe can sometimes be bent in a vise in this way, the jaws of the vise taking the place of the flat plates mentioned above.

Large pipe may be bent something in the following way: If the pipe is long and heavy the part to be bent should be heated, and then while one end is supported, the other end is dropped repeatedly on the floor. The weight of the pipe will cause it to bend in the heated part. Fig. 261 illustrates this,

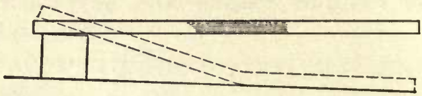


FIG. 261.

the solid lines showing the pipe as it is held before dropping and the dotted lines the shape it takes as it is dropped.

As the pipe bends the sides, of course, bulge out, and the top and bottom tend to flatten together; but this is remedied by laying the pipe flat and driving the bulging sides together with a flatter.

Another way of bending is to put the end of the pipe in one of the holes of a heavy swage-block (as illustrated in Fig. 262), the bend then being made

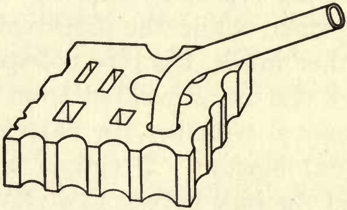


FIG. 262.

by pulling over the free end. The same precaution must, of course, be taken as when bending in other ways.

The fact that by preventing the sides of the pipe from bulging it may be made to retain its proper shape is particularly valuable when several pieces are to be bent just alike. In this case a jig is made which consists of two side plates, to prevent the sides of the pipe from bulging, and a block between these plates to give the proper shape to the curve.

A piece of bent pipe which was formed in this

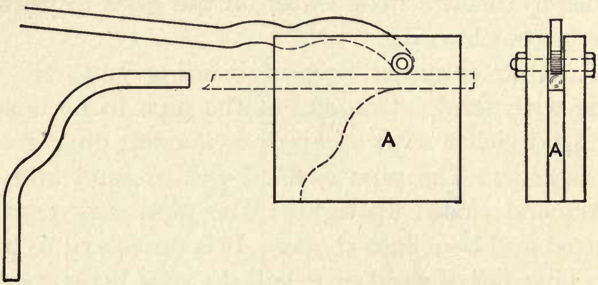


FIG. 263.

way is shown in Fig. 263, together with the jig used for bending it.

The pipe was regular one-quarter-inch gas-pipe. The jig was made as follows: The sides were made of two pieces of board about $1\frac{1}{2}''$ thick. Between these sides was a board, *A*, sawed to the shape of the inside curve of the bent pipe. This piece was slightly thicker than the outside diameter of the pipe (about $1/32''$ being added for clearance). The inside face of the sides and the edge of the block *A* were protected from the red-hot pipe by a thin sheet of iron tacked to them.

A bending lever was made by bending a piece of $\frac{3}{8}'' \times 1''$ stock into the shape of the outside of the pipe. This lever was held in place by a $\frac{1}{2}''$ bolt passing through the sides of the jig, as shown.

To bend the pipe it was heated to a yellow heat, put in the jig as indicated by the dotted lines and the lever pulled over, forcing the hot pipe to take the form of the block.

A jig of this sort is easily and cheaply made and gives good service, although it is necessary sometimes to throw a little water on the sides to prevent them from burning.

Another common way of bending is to fill the pipe with sand. One end of the pipe to be bent is plugged either with a cap or a wooden plug driven in tightly. The pipe is filled *full* of sand and the other end closed up tight. The pipe may then be heated and bent into shape. It is necessary to have the pipe *full* of sand or it will do very little good.

For very thin pipe the best thing is to fill with melted rosin. This, of course, can only be used when the tubing or pipe is very thin and is bent cold, as heating the pipe would cause the rosin to run out.

Thin copper tubing may be bent in this way.

A quite common form of pipe-bending jig is illustrated in Fig. 264.

The outside edge of the semicircular casting has a groove in it that just fits half-way round the pipe. The small wheel attached to the lever has a corresponding groove on its edge. When the two are in the position shown the hole left between them is the same shape and size as the cross-section of the pipe.

To bend the pipe, the lever is swung to the extreme left. the end of the heated pipe inserted in the catch at *A* (which has a hole in it the same size as the pipe), and the lever pulled back to the right, bending the pipe as it goes.

The stem on the lower edge of the casting was

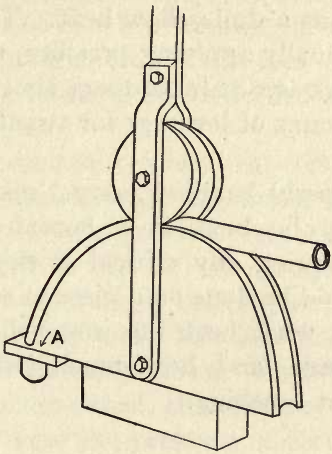


FIG. 264.

made to fit in a vise, where the jig was held while in operation.

Annealing Copper and Brass. — Brass or copper may be softened or annealed by heating the metal to a red heat and cooling suddenly in cold water, copper being annealed in the same way that steel is hardened. Copper annealed this way is left very soft, somewhat like lead. Hammering copper or brass causes it to harden and become springy. When working brass or copper, if much bending or hammering is done, the metal should be annealed frequently.

Bending Cast Iron.—It is sometimes necessary to straighten castings which have become warped or twisted. This may be done to some extent by heating the iron and bending into the desired shape. The part to be bent should be heated to what might be described as a dull-yellow heat. The bending is done by gradually applying pressure, not by blows. For light work two pairs of tongs should give about the right amount of leverage for twisting and bending.

When properly handled (very "gingerly"), thin castings may be bent to a considerable extent. Before attempting any critical work some experimenting should be done on a piece of scrap to determine at just what heat the iron will work to the best advantage, and how much bending it will stand without breaking.

HEAT TREATMENT OF STEEL.

This important subject is receiving a great deal of attention in all up-to-date manufacturing plants whose output receives, when in use, any unusual strains demanding conditions that are not manifest in steel treated by ordinary methods. The subject covers the processes of heating for forging, annealing, hardening and tempering and various modifications of the processes mentioned.

The *most* important factor is the *man* that does the work, or who supervises it. Many claims are made by men selling furnaces, heat-recording instruments and the various paraphernalia used in a heat-treating plant as to the possibilities to be obtained when using the articles they sell. Many of these are desirable, some are indispensable. But *best* results cannot be obtained unless they are used by a "good" man. There is no furnace, pyrometer or other part of the equipment of a heat-treating plant made that will take the place of *brains*. In fact, the better the equipment, the better the man needed in order to get maximum results.

To obtain best results when heat-treating steel the workman must understand the metal he is working on. There is no valid excuse at the present time for a man engaged in any of the processes of heat-treating steel not having a working knowledge of the subject. He should know how it is made, what elements go into its composition, what effect each of these has upon the steel, the effect of varying percentages, and how the presence of certain elements may modify the effect of others. The effect of various temperatures on steel of different analyses and the effect of cooling heated steel at different time rates should be understood. While a long experience in this particular line of business is a valuable asset to any man, it does not enable him to successfully handle tools and steels that he is not familiar with.

Twenty-five years ago there was comparatively little literature devoted to this subject. To-day there are many excellent books to be had. Some are of particular value to the graduate metallurgist but of little use to the practical man of ordinary education, others are so written that they are of value to both, while still others are intended for the man who is devoting his time to the actual processes involved in the practical operations in the heat-treating room.

The workman should not be content with the study of the latter *alone* as he will never understand the subject as he should until he *knows* the metal he is treating. Space prevents our taking up the study of the making of steel, or to any great extent the influence of the elements, but the writer wishes to urge on every reader, and on every man engaged in heat-treating steel the necessity of a thorough study of *steel* in order that he may know how to best apply the information given in this, and other books written especially for the practical man.

Steel is affected by heat to a greater degree than is generally understood Reference to any one of a number of handbooks will convince one of the truthfulness of this statement. In the table of "Coefficients of the Expansion of Solids" is found the amount steel expands per degree of heat absorbed. Reason dictates that if the metal is expanded by heat the various portions should be heated as uniformly as possible in order that uneven expansion does not take place, because if one portion is heated more than another strains are set up. These strains tend to weaken or rupture the steel. If these strains do not manifest themselves at the time the piece is unevenly heated they will during subsequent treatment.

While it is necessary to uniformly heat steel to avoid the trouble just mentioned, long exposure of the metal to high heats, especially if it contains considerable carbon tends to weaken it. Knowledge gained by experience enables the operator to so apply heat that the desired uniform temperature may be obtained with the minimum of weakness due to either strains or long heats.

Steel that has been heated for forging, annealing, hardening or any of the other processes involved in heat treating must be cooled. The method and rapidity of cooling has a pronounced effect on the metal. The writer's attention was called to a batch of forgings that could not be machined on account of hardness. Investigation showed that previous batches which had machined easily had been placed in an iron box, in the bottom of which was a quantity of hot ashes. These forgings were placed in the box while red hot. The repeated addition of forgings as they left the drop hammer prevented rapid cooling, thus insuring a condition that made machining an easy matter. This box was so located that no moisture or drafts of air could reach it. The forgings under consideration were made from steel of the same analysis as former batches, but the work was done by a "new man" and thrown while red hot onto a floor of damp earth, with the result that portions of many of the pieces were partially hardened, thus rendering machining impossible until they were annealed. The cost of annealing, plus that of milling cutters spoiled in the attempt to machine the pieces, made the cost of that particular lot greatly in excess of what it should have been.

In some lines of work, especially that branch devoted to the making of guns of certain types, and munitions, certain portions of the product are given a degree of hardness before the finish machining operations. While it is common practice in many shops to harden pieces before finishing and then bring them to size by grinding the operations referred to above are accomplished by means of cutting tools. This practice makes necessary a very exact knowledge of the desirable methods of treating both the product and the cutting tools used. Exact temperatures and time exposures to heat are essential, and as these vary somewhat according to the composition of the steel used intelligently conducted experiments aided by accurate heat determining instruments are necessary.

Annealing, while primarily a softening process, has been extended so as to produce certain desirable qualities not possessed by the steel as furnished by the mills.

Forgings and other articles are many times strengthened and toughened to a degree not dreamed of by anyone twenty-five or thirty years ago. These results are directly traceable to the efforts of men who are thoroughly familiar with the nature and composition of steel and the effects of heat on its structure and strength. The credit for much of this knowledge belongs to some of our leading metallurgists coupled with the efforts of practical men.

While a technical education specialized along the lines under consideration is highly desirable, any man of ordinary education and intelligence can by diligent study and practice acquire a knowledge of the subject of Steel and Its Heat Treatment that will be of inestimable value to himself and others. The day has passed when some one man who was supposed to "know it all," or who by the application of some secret powder, or other concoction could do the supposedly impossible, and who, as a result, could dictate the running of this branch of the business. There is a *reason* for everything, and when one *knows* the reason he is able to meet almost any emergency.

Steel.—The word "steel" conveys very little meaning to the man who is familiar with the composition of the various alloys of iron usually grouped under this heading. We often hear the terms open-hearth steel, Bessemer steel, crucible steel, high steel, low steel, hard steel, soft steel, alloy steel, etc. A term often used and which means very little is machine steel, or machinery steel as it is sometimes called. The so-called machine steel may contain very little carbon, or it may have a fairly high percentage. In the first case it would be soft and comparatively weak, while, in the latter, it would be much harder and stronger under a steadily applied load. Under ordinary circumstances both would be tagged "machine steel" whether made by either the Bessemer or the open-hearth process, provided it was to be used in making parts of machines, implements, etc.

An intelligent study of the subject will show that steels of various compositions are made to meet varying demands. In ordinary steels the element present to give strength, or to make hardening of the metal possible, is carbon, and as this element is used to give the desired condition men familiar with the metal usually distinguish it by the carbon content. The term "percentage of carbon" is used by many while others state the amount in "points." A point is one one-hundredth part of one per cent of any element that goes into the composition of iron or steel. A 40-point carbon steel contains 0.40 per cent carbon. In speaking of this steel one would say 40-point carbon steel, or $\frac{4}{10}$ per cent carbon steel. If it was made by the open-hearth process it would be spoken of as 40-point, or $\frac{4}{10}$ per cent, open-hearth steel; if made by the Bessemer process it would be called 40-point, or $\frac{4}{10}$ per cent, Bessemer steel.

The product of the Bessemer converter and of the open-hearth furnace having the same carbon content may be similar in most respects, or they may be widely different. As the time consumed in running a charge in the converter is much less than the necessary time in the open-hearth furnace the product is more liable to be variable.

There are two types of Bessemer converters and the same number of open-hearth furnaces, namely the acid and basic. and the product of each is known as acid steel or basic steel. Very little, if any basic Bessemer steel is made in the United States, while both acid and basic open-hearth steels are produced here. Knowing these facts one is able to designate a steel very accurately by stating the kind and carbon content; as, 60-point carbon basic open-hearth steel. Under ordinary conditions the percentages of other elements entering into the composition conform very nearly to fixed formulas, but where any of these vary to any degree in order to produce some desired result, the content of these elements is stated also.

The custom prevailing in some shops of ordering so many feet of machine steel is to be discouraged, for, while this term may have some specific meaning with the steel manufacturer, it has little or none with the average mechanic, purchasing agent, manufacturer or man employed in a steel warehouse. The receiving of stock ordered in this way and then of storing it in a common rack has been, and is a source of unsatisfactory product and serious loss to many concerns.

As *few* kinds and grades of steel as is consistent with good results should be used in any one plant unless those in charge have a working knowledge of steel, and closely follow the various kinds and grades, and see that they are marked or tagged so they can be readily distinguished, as otherwise endless confusion will result.

The purchase of Bessemer steel for any purpose where a uniform analysis is necessary, or where it is to be hardened or case hardened is not to be recommended unless all stock received is to be subjected to chemical analysis and physical tests. Even when these precautions are observed the various bars in a shipment are liable to vary in analysis to an extent that will cause serious trouble. For this reason the use of the product of the acid Bessemer converter is to be discouraged where the product is to be hardened or where it is to be subjected to shock or intermittent strains of any sort.

If acid open-hearth steel is to be case hardened, and especially if the carburizer to be used is *raw* bone, the phosphorus content in the steel should be *low* as the effect of phosphorus, if present in more than allowable percentages, is to produce brittleness under any but a *steady* load. For the reasons mentioned it is generally safer to use *basic* open-hearth steel where the product is to be hardened in any way. These statements are intended to apply to plants whose size do not warrant the employing of a chemist, and where the purchaser must rely on the steel warehouse for its product.

Most steel mills will, on request, give an analysis best suited to a given purpose, if a description of the work to be made together with the physical strains it is to receive in use are stated.

Alloy Steels.—In order to obtain the maximum of strength without increasing the size of the piece, various elements are used in connection with the carbon. Certain of these elements reduce the tendency to break from repeated stresses and vibration thus increasing the life of the article. Such steels require heat treatment because in the natural or annealed state they are little, if any, better than plain carbon steels. When properly heat treated they show a decided improvement in physical characteristics.

Nickel Steel.—Nickel steel containing 0.15 per cent carbon is used for parts that are to be case hardened and which require a very hard suıface with a tough strong interior, or core. It is especially suited for gears that are to be case hardened. That containing

0.20 to 0.25 per cent is also used for pieces that require case hardening, but the process must be adapted to the increase of carbon. If properly treated the core will be stronger than if a lower carbon steel was used.

Nickel steel with 0.30 to 0.35 per cent carbon is used, at times, for parts that are case hardened but is not to be recommended. It is especially valuable for such parts as automobile driving shafts, crank shafts, axles, etc. The particular heat treatment necessary to produce desired results depends on the requirements of the individual piece. Wide variations as to the ultimate strength and elastic limit are obtained by using various quenching mediums, and by variations in temper drawings.

Nickel-chromium Steels.—Steel containing nickel and chromium in combination with carbon is used. The percentage of these elements varies according to the requirements of the piece. For use in making gears that are to be oil hardened the carbon content is about 0.5 per cent, while, for those requiring case hardening it is about 0.25 per cent. The amount of nickel varies from 1 to 3.5 per cent and the chromium from .3 to 1.5 per cent.

Chrome-vanadium Steels.—Chrome-vanadium steel with a low carbon content is used for parts that require case hardening, and the carbon should not exceed 0.20 per cent. The 0.40 to 0.45 per cent carbon steel is used where great strength together with toughness is required. It is extensively used for gears, springs and other articles that are to be quenched in oil.

Tool Steel.—By the term "tool steel" we mean the product of the crucible process made especially for cutting-tool purposes. However, a large amount of crucible tool steel is used in making parts of machines, etc., and many times it is used where a good grade of open-hearth steel would answer the purpose as well and at a lower cost. On the other hand, considerable high carbon open-hearth steel is used for cutting and other tools. Notwithstanding its lower initial cost its use is not to be advocated unless those in charge have a knowledge of the subject that makes it possible for them to rightly decide as to what tools it is suitable for. When one considers that many dollars' worth of labor may be expended on a tool the steel in which costs but comparatively little, it is apparent that saving on steel may be costly "economy." However, if a "cheap" steel will answer the purpose as well it is folly to buy a high-priced article, especially where it is used in large quantities. High price does not always mean adaptability. A steel may cost many times as much as another that is far better suited for a given purpose. The essential thing to consider is the fitness of the steel for the purpose for which it is to be used. When the *right* steel is to be had it should be procured regardless of cost.

Tool steel is made with a great range of carbon content. Where it is to be subjected to battering action, or other severe usage, and is to do no cutting, the carbon runs from 0.60 to 0.70 per cent, while, for cutting tools requiring *extreme* hardness it may be 1.60 per cent or even higher. The various percentages between these extremes are adapted for most tools used in cutting, pressing, bending and the various other processes involved in working metals into marketable condition.

The high-carbon steels require extreme care in the various heat-treating processes, and their use is discouraged by some on this account. The arguments advanced against its use appear to a skilled man without foundation, because men skilled in this branch of work can be had if they are given the necessary inducements.

The higher the carbon the lower the critical point of the steel. If the operator bears this fact in mind he will have no trouble in determining the proper heats to employ in forging, annealing and hardening high-carbon steel. The idea entertained by some manufacturers that they must use a steel that fits the ability of their employees seems to be without proper foundation. It is better to use steel suited to requirements, and then employ workmen capable of properly treating it.

The percentage of carbon is many times denoted by the term "temper." When used in this connection it has no association with the "letting down" process known as drawing the temper after hardening. The following table gives the uses of steel of various carbon contents as adopted by at least one manufacturing concern, and conforms very closely to general usage. It cannot be regarded as absolutely correct under all conditions, but answers as an approximate guide.

Percentage of Carbon.	Tools.
1.60	Tools requiring extreme hardness where toughness is not essential, for cutting partially hardened forgings, etc.
1.50	Turning hard metals, turning chilled rolls, etc.
1.40	Turning hard metals, corrugating tools, brass working tools and where a fine edge is required in connection with light cuts.
1.30	General tools for lathe work, cold trimming dies, cutting dies.
1.20	This is the steel used more than any other for general cutting tool purposes, jewelers' rolls, small taps, twist drills, milling cutters for ordinary cuts, punch press dies, dinking dies, screw threading dies.
1.10	Taps in general, axes, saws, wood-working tools, milling cutters for rough usage, small punches, reamers, broaches.
1.00	Large milling cutters, drifts, swages, springs.
.90	Cold dropping dies, cold chisels, hand-driven punches, punch-press dies and punches to be subjected to rough usage, large milling cutters to be pack hardened.
.80	Shear knives, blacksmiths' cold chisels, hammers, sledges, tack chisels, boiler-makers' tools, hammer dies, masons' tools.
.70	Blacksmiths' tools in general, hot drifts, hot sets, track tools.
.60	Tools to be used for hot work to stand battering, drop forging dies for hot work, hot trimming dies, flatters, fullers, hot swages.
.50	Striking up dies for hot work that are water cooled.

While the table gives a general idea of the adaptability of steels of various carbons it is necessary many times to use different grades to accomplish some desired result. For instance, 1.20 per cent carbon steel is recommended for the ordinary run of taps, yet taps used for sizing a hole already threaded and where but a very small amount of stock is to be removed are many times made from 1.40 per cent carbon steel as it will retain its size much longer. Small milling cutters that take light cuts on pieces of irregular form are sometimes made from 1.40 per cent carbon steel. The use of higher carbons than those specified require the exercise of extreme care in heating and quenching, but the results obtained warrant the extra care and expense.

Light in the Hardening Room.—The degree of light allowable in a heat-treating room is of vital importance, and the ideas of men engaged in the various branches of the business do not always coincide. The writer has visited shops where the rooms devoted to this work were absolutely dark except for an individual incandescent light here and there, but these so located that they did not cast any rays toward any heating furnace. He has been in plants where the furnaces were located in rooms whose walls and ceilings were a mass of glass, allowing strong, direct light free access to every portion of the room. The former condition is far preferable to the latter so far as ability to discern heats is concerned, but objectionable from the standpoint of the workman's health.

A heat-treating room should be dry and well ventilated, and should be, so far as possible, a comfortable place to work in, but the lighting system should be so arranged that no direct or strong light can enter it, and the light throughout the room should be as uniform as possible. A workman engaged at a furnace observing heats finds himself handicapped if when he looks away from his furnace he finds that his eyes encounter a strong light in some other part of the room. When he looks back at his work it is several seconds before his eyes adjust themselves to the change. It might appear to one not intimately conversant with the heat-treating problem that the increasing use of heat-measuring instruments and systematic methods of treating steel now employed that the eye was being less relied on than formerly, such is not the case. The pyrometer and the systematic time systems so successfully employed are really only aids to the workman. The human element is more important than ever under the conditions that prevail, and their importance will increase as conditions become better systematized. It is always a mistake to think that any system or instrument can take the place of brains. They are wonderful helps, but never substitutes.

The lighting of the room under consideration should be scientifically planned. A diffused light that is as constant as possible should be obtained. The exact degree of light that will give the best results cannot be arbitrarily stated, but should be so adjusted as to give best results. The aim in a number of places is to get a constant light approaching as nearly as possible what is known as twilight.

The advantage claimed for the totally dark room is that the light is absolutely constant. This is true, but the many disadvantages resulting from this condition seems to outweigh the resulting good.

Where but one small furnace is used in a plant, it is customary to locate it in a spot that is not wanted for anything else, regardless of the fitness of the location. It is necessary many times to place a furnace in a room with the regular metal cutting machines that require a good, strong direct light. Under such circumstances it should be placed where it will get the least possible amount of this light, or if this is not possible devise some way of shutting the light off so it cannot strike the furnace or into it, or into the workman's eyes. Thousands of tools are ruined each year because this precaution is not taken.

Heating Furnaces.—Under this heading we will consider the various forms of heating devices used in the ordinary hardening room. The blacksmith's forge while not exactly a furnace is used very extensively in heating steel for forging and hardening. Where many pieces of a kind are to be heated its use is not to be advocated, as some form of furnace having an enclosed heating chamber is generally preferable, but where but few pieces of a given size and form are to be treated, and these to be followed by others of various design a large, clean fire provides a very satisfactory means of heating.

Muffle Furnaces.—Muffle furnaces were at one time very extensively used in heating steel for hardening. The work was placed in a muffle, or chamber, so constructed that the products of combustion could not come in contact with the pieces being heated. As a result oxidation of the surfaces was practically eliminated. As the heating is done entirely by radiation the cost of fuel is greatly in excess of a furnace where the flame comes in direct contact with the work. For certain kinds of work especially small pieces and those of intricate shape the muffle furnace provides an ideal means of heating.

Semi-muffle Furnaces.—In this type a chamber is provided for the work, and the flame circulates around the walls for a distance and then enters the chamber. The mixture of fuel flame, and air is so regulated that perfect combustion takes place before it comes in contact with the work. This type of furnace is very satisfactory for most classes of work when heating for annealing, hardening, etc.

Direct Flame Furnaces.—In heating for forging, and where the steel is enclosed in boxes when heating for case hardening and the various heat-treating operations, furnaces are many times constructed so that the flame enters directly into the heating chamber, thus insuring a very intense heat at a comparatively low fuel cost.

The question often asked is, "What is the *best* type of furnace?" There is no "best" type of furnace. The kind, size and design should conform to the character of the work to be treated. Many excellent furnaces are to be obtained from manufacturers who have made a specialty of heat-treating apparatus for years. When a furnace that exactly meets requirements can be purchased this course is to be advocated. Many times furnace manufacturers will design and build a special type or size of furnace at a figure that is less than such an article can be built for in a shop not especially equipped to do such work. At times it is possible to design and build a satisfactory furnace in the shop where it is to be used, provided those in charge have a thorough knowledge of furnace design.

Furnaces are built so that the fuel gases and blast enter at variously located openings and the advisability of any particular design must necessarily depend on the character of the work and the results desired. Fig. 265 shows an under-fired furnace, the gases entering at the bottom as shown. The gas and air uniting in the combustion chamber and rising to the roof, and are then forced down onto the floor of the furnace. In this particular furnace there are no walls extending up from the floor. If work is placed very near the edge, excessive heating of the portions nearest the rising gases is almost sure to result.

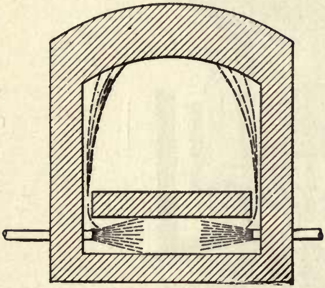


FIG. 265.

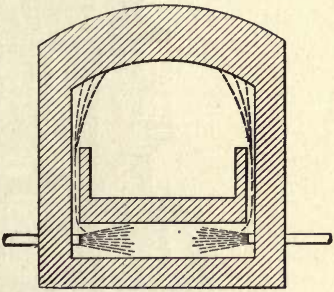


FIG. 266.

Fig. 266 shows a design identical with Fig. 265 except that upright walls are added, to prevent the undesirable results mentioned. The height of these walls is not material so long as they are high enough to prevent uneven heating, and yet not sufficiently high to prevent the gases flowing naturally into the chamber. If carried too high the gases are forced through the small openings at high velocity and impinge against the upper portions of pieces in the furnace heating them hotter than the balance, this is especially true of large pieces that extend up well toward the roof.

Top-fired Furnaces.—Where the work is encased in boxes or tubes top-fired furnaces are many times used. The floor should be thoroughly perforated or made up of grates or bars, or the bottom portions of boxes, or articles being heated will be much cooler

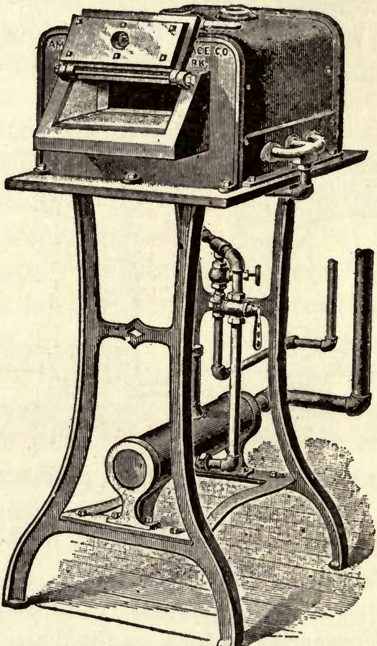


FIG. 267.

than the tops. Such furnaces properly designed and intelligently operated give good results at a comparatively low fuel cost. Although if unprotected pieces, such as dies, etc., are to be heated it is doubtful if as good results will be obtained as with an underfired furnace.

Fig. 267 shows a small furnace used in heating comparatively small pieces. The fuel used is illuminating gas. For all around work up to the capacity of the furnace this is a very satisfactory type. Fig. 268 shows a furnace designed for heating reamers and other long and comparatively slender articles. As

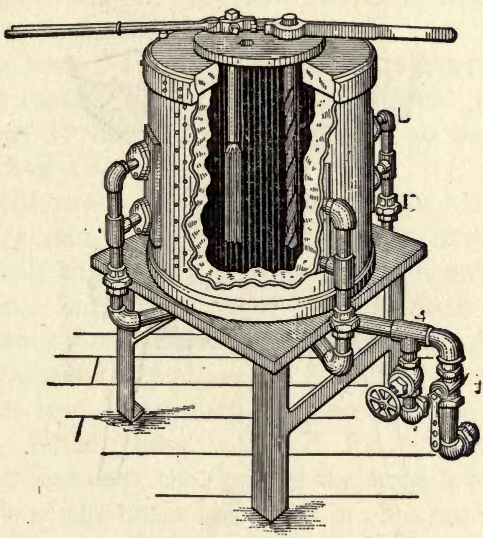


FIG. 268.

these pieces are suspended from the top there is little danger of their springing when heating. A coke burning furnace is shown in Fig. 269. For certain purposes this furnace is very satisfactory. It is an especially desirable type for use in heating high-speed steel for forging.

Fuel.—Various forms of fuel are used in heating furnaces. Among the commonly used forms are anthracite (hard) coal, bituminous (soft) coal, coke, charcoal, illuminating gas, producer gas, fuel oil, kerosene and gasoline. The advisability of using any certain kind depends on the character of the furnace, the nature of the work to be heated, and the locality of the factory.

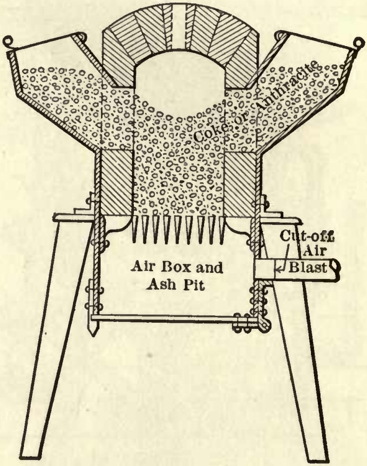


FIG. 269.

In certain parts of the country a particular form of fuel may be difficult to get, or too expensive to use. Where illuminating gas can be obtained cheaply we have a very satisfactory means of heating small furnaces. Where fuel oil can be easily obtained at a reasonable cost we have one of the very best means of heating large furnaces, and it also works well for small furnaces provided they are equipped with suitable burners.

Kerosene and gasoline are sometimes used as fuel. The cost of this fuel, however, is apt to be greatly in excess of fuel oil. Charcoal is used in the blacksmith's forge for heating tool steel, while coke is quite extensively used in small furnaces of different types. Both anthracite and bituminous coal are used in large and small furnaces where the steel does not come in direct contact with the fuel.

Some large plants are provided with gas producers used in making gas for heating purposes. Furnaces equipped to burn illuminating gas can be run on this fuel at a small cost.

Small furnaces are usually made of a height that allows a man of ordinary stature to observe the interior of the heating chamber without any special exertion. Large furnaces, if used for pieces or boxes of ordinary size are made so that the floor of the furnace is about 2 feet above the floor level of the room, in order that boxes may be placed in the furnace easily. While those intended for heating extra heavy pieces have the floor on the same level as the room floor, the boxes being run in on a truck of the design shown in Fig. 270.

To describe the ideal furnace for all around purposes would be impossible, as the character of the work to be heated, the desired results and the fuel to be used must all be taken into consideration. The writer has in mind a hardening plant having twelve large furnaces used in heating steel. Several of these are designed for carburizing work for case hardening. These are run at temperatures varying from 1650° to 1850° F. while others are intended for pieces that are to be pack hardened and where uniform temperatures not exceeding 1450° F. are desired. One furnace is used for pack hardening high-speed steel and requires temperatures ranging from 1750° to 2250° F. while others are used for all around work. Most of these use fuel oil for heating, while those used for work requiring the lower temperatures use hard coal as fuel. Contrary to the claims of many furnace men it is found that very

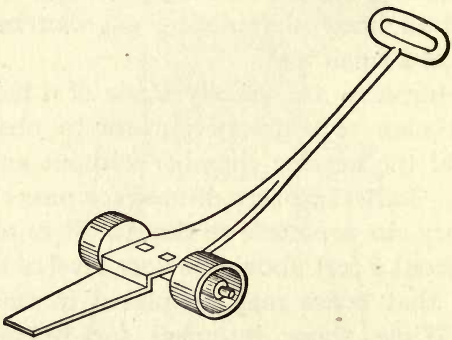


FIG. 270.

uniform results, at low temperatures, can be maintained with this fuel, under ordinary conditions.

Lead Bath.—Lead provides a fairly satisfactory method of heating steel. In many shops it has given way to various salts which are lighter and do not oxidize as readily. However, red hot lead affords a very good means of heating if certain precautions are observed. Oxidation of the surface may be overcome to a degree by keeping it covered with powdered charcoal. The practice of using any old scrap lead cannot be too severely condemned, as good results can only be obtained by using a brand of pig lead known as "commercially pure lead."

The crucible used to hold the lead should be of graphite. The life of graphite crucibles may be very materially lengthened by annealing before they are used, which is done by placing in a furnace, heating to a full red, and then removing and placing on top of the furnace, or in some warm place where no current of air can strike them, and left until cool.

Crucibles may be heated in a coke or coal fire, but better results follow the use of specially designed furnaces burning gas or oil as shown in Fig. 271. The burners should be so arranged that the flame will circulate around the crucible instead of impinging against it. A piece of fire brick should be placed under it for the crucible to rest on.

After using and before cooling the lead should be poured out of the crucible as the expansion of the metal when it is remelted would crack the crucible. It is advisable to cast the lead into small blocks, as it can be conveniently handled when recharging the crucible.

Melted lead has a tendency to stick to steel unless the surface of the piece is coated with some substance. There are several dips that are used with more or less satisfactory results. A dip commonly used is made by dissolving 1 lb. of ferro-cyanide of potassium in 1 gal. of boiling water; when this cools it is ready for use. Salt is dissolved in water until a saturated solution is obtained. A thin paste of rye flour is sometimes used. The following paste has been used by the writer for many years with excellent results: pulverized charred leather 2 parts, table salt 4 parts, wheat flour 3 parts. The ingredients are well mixed and water is added to the mixture until it reaches the consistency of varnish.

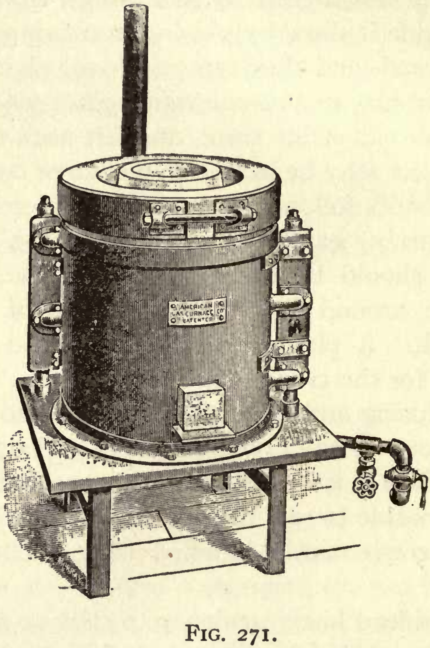


FIG. 271.

After the pieces are immersed in any of the dips they should be placed where they will dry quickly. This is done many times by placing them on the plate on top of the furnace and also serves to preheat the pieces before they are placed in the lead. Moisture of any kind must never be allowed to get into the lead or particles will fly, which may produce blindness if they enter the eyes. If the paste mentioned is used its fusing point indicates the proper temperature at which ordinary carbon tool steels are hardened. As steel is lighter than lead articles to be heated will float on the surface of the bath unless held under the surface. If many pieces are being treated much time can be saved by using a holder of some form for this purpose.

Preheating before putting in the lead is necessary for pieces having large and small portions adjacent to each other.

A gas-fired furnace equipped with an automatic heat controller is shown in Fig. 272. It is claimed by the manufacturers that Gas Blast Furnaces operated with it will not vary more than 5° F. from a fixed temperature to which the instrument is set.

The instrument consists of two distinct parts: A pyrometer, so constructed that the movement of the dial pointer both indicates and controls the temperature, and a pneumatic valve attached to the furnace operated by the same air pressure supplied to the furnace for combustion, admitting both gas and air in the correct proportion to maintain the desired temperature.

While such a controller is of but little practical value on a furnace doing a variety work in small lots, or which are made from varying grades of steel, its usefulness where large batches of delicate tools are heated can hardly be overestimated.

Heat-recording Instruments.—Manufacturers are realizing more and more the importance of *proper* temperatures in the heat treatment of steel. Modern appliances used in testing the hardness of materials show that a variation of a few degrees has a pronounced effect on the condition of the steel. The

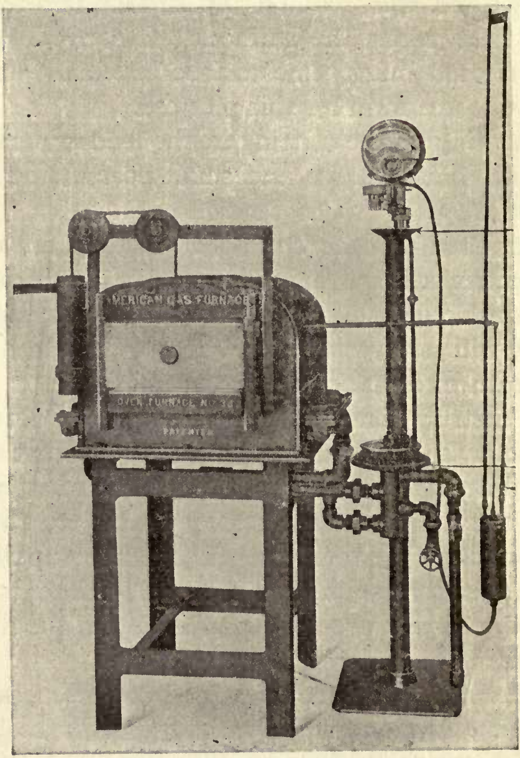


FIG. 272.

higher the carbon content the more pronounced the effect of heat. Tools made from high carbon steels and that are to be subjected to excessive strains are found to be very much injured, at times, when heated above the proper temperature. The writer has seen cases where a 1.60 per cent carbon steel heated 15° F. above the temperature it should have received, was decidedly inferior to that cut from the same bars and heated to the right temperature. Some writers claim to have observed like results at even slighter variations than noted above. Steel that is underheated shows as great, or even greater, variations so far as practical results are concerned.

Knowing that a slight variation in temperature leads to undesirable results, and that the human eye is not to be absolutely relied upon, it is apparent that in order to meet modern requirements articles made from high carbon steel must be heated under conditions that render it possible to obtain very nearly exact temperatures.

At the present time there are a number of reliable pyrometers on the market. Any one of these will give desirable results if properly installed and carefully watched. Like all delicate instruments and complicated machinery they need frequent inspection and careful testing. Pyrometers should be calibrated every little while to make sure they are recording correctly. The writer knows of one concern whose chemist tests all pyrometers once a week; in another factory they are tested every other day. The frequency with which these tests *should* be made cannot be stated arbitrarily, but they should be made whenever, in the judgment of the furnace man, everything is not exactly right.

A man whose eyes are trained to discern heats can tell within a few degrees the temperature in a furnace, provided it does not exceed 1800° F. if light conditions are favorable. If the pyrometer reading does not closely correspond to the temperature as indicated by practical tests, and results do not tally with results obtained by previous treatment under the same conditions, no time should be lost in calibrating the instrument.

The writer's attention was called at one time to a large lot of projectiles that were giving considerable trouble when machined. These pieces were supposed to be heated to 1550° F. and quenched in a bath of oil, after which they were reheated to 1000° F. This treatment was given prior to the essential machining operations. Chemical analysis showed that the various pieces were of practically the same composition as former batches that machined satisfactorily. Investigation in the heat-treating plant showed, according to observation, that the temperature of 1550° F. was much exceeded. When tested out with "sentinel cones" the pyrometer was found to register nearly 200° F. out of the way. It was also calibrated in connection with a test pyrometer and the amount of variation noted substantiated. There is little excuse for any such variation as just noted, as the color variation should have been apparent to the furnace man no matter what the pyrometer readings may have been.

It is customary in most large plants to have an extra pyrometer known as a "test pyrometer" whose accuracy is known. This instrument is coupled up and used in connection with the regular pyrometer and the readings compared. In the absence of a test pyrometer sentinel cones may be used. These cones are made from earthy and metallic substances and the fusing temperature is marked on each cone. It is a good plan to have on hand a number of cones of different fusing points.

In making a test a cone of the desired grade is placed in the furnace while the temperature is low and the heat gradually increased until the cone breaks down. At the moment it breaks down note the reading of the pyrometer. If the pyrometer is used to denote various temperatures a number of cones having different fusing points may be placed in the furnace at a time, those having the lowest and highest fusing points corresponding with the range of temperature usually indicated by the pyrometer. When making these tests it is advisable to have two men, one to watch the cones and the other the reading of the pyrometer. When a cone crumbles the man observing it gives a signal and the other notes the reading.

Sentinel cones are also useful where there are no pyrometers. By occasionally placing one, whose predetermined fusing point is the same as the temperature to which the work should be heated, in the furnace together with a piece of steel of about the size and shape of the cone and gradually raising the temperature of thefurnace until the cone breaks down. The appearance of the steel should be carefully noted at the instant the cone crumbles. This practice tends to keep fixed in the operator's mind the exact temperature to which he should heat the steel he is treating to get desired results.

The writer would not be understood as advocating the use of cones when a good pyrometer is available, neither would he advise their use in calibrating pyrometers when it is possible to obtain another instrument of known reliability, but in the absence of these the cones may be made to answer.

Pure salt may be used in testing pyrometer readings. Insert the thermo-couple in a small crucible containing pure salt and heat the salt to 1600° F. Remove the crucible from the furnace and allow it to cool. At the freezing point of salt, which is 1472° F. or 800° C., note the pyrometer reading. When the salt is cooled to the freezing point the temperature remains fairly constant for a short time, after which the cooling down to normal is fairly uniform.

The melting point of several different metals may be satisfactorily employed for checking pyrometers. The melting points of those most generally used for this purpose are as follows:

Tin	450° F.
Zinc	787° F.
Silver	1761° F.

In many cases each furnace is provided with a pyrometer, while under different conditions a number of furnaces are connected to one pyrometer, each furnace reading being obtained by means of a switch. When working under the latter condition each furnace must be numbered and the switch thrown to a pole corresponding to the number of the furnace whose temperature is to be read. Such a switchboard is shown in Fig. 273.

In some large heat-treating plants a central pyrometer is maintained; this is connected with the various furnaces, and is in charge of an operator who, by means of various colored lights located on each furnace, signals the furnace man regarding his heats. Three electric lights are on each furnace. The red light burns when the temperature is too low, the white light when the temperature is within the accepted limits, and the green light when the temperature is too high.

FIG. 273.

Fig. 274 shows an Automatic Signaling Equipment which is attached to the furnace and is directly controlled by the furnace temperature. This does away with the central pyrometer.

In Fig. 275 is shown a thermo-couple immersed in a pot of molten lead. The application is the same if other metals, or salts are used in the bath.

In many large plants where the amount of work warrants the outlay recording pyrometers are installed in the office of the superintendent, or other official. These instruments indicate and record the furnace temperatures, whereby it is possible for those in charge to keep records of the temperatures.

Baths.—There are many forms of baths used in hardening, and an almost endless number of liquids

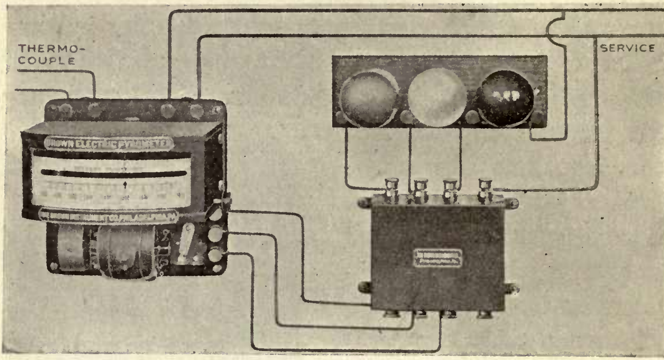


FIG. 274.

and mixtures for cooling. The particular form desirable depends on the nature of the work to be cooled.

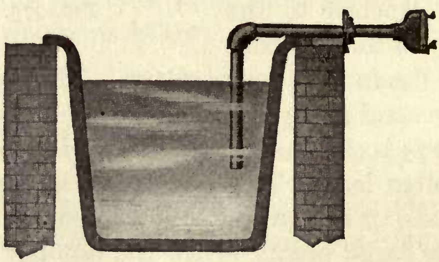


FIG. 275.

A pail, barrel, or tank answers very well for many kinds of work, and is entirely unsuited for others. Where but a few small pieces are to be hardened a small vessel may be used, but larger pieces require a generous quantity of liquid to do away with change of temperature. Where many pieces are to be done in succession some means must be provided to keep the bath at an even temperature. At other times it is necessary to project the liquid against some certain portion of the piece.

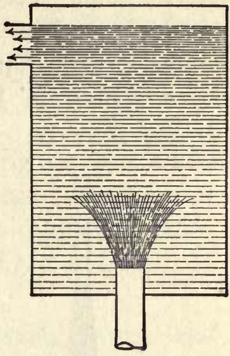


FIG. 276.

A common form of bath having a jet coming up from the bottom is shown in Fig. 276. If a certain temperature is not essential the inlet pipe may be connected with the street main, or some other source of supply. An overflow pipe larger than the inlet must be provided, as shown.

If brine, oil or some favorite mixture is used the liquid may be taken as it comes from the overflow and pumped to a tank located a few feet above the bath. A pipe from this tank allows the liquid to return to the bath by gravity. Where there is danger of the liquid becoming heated a bath of the design shown in Fig. 277 is used. The liquid is drawn from the bath by means of a pump and forced through coils of pipe in an outer tank and returned to the bath as shown. This form may have many modifications. The writer knows of one hardening plant

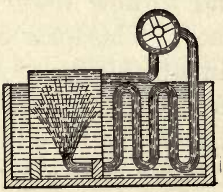


FIG. 277.

located on the bank of a river where the cooling coils are run into the river at some distance below the surface. This is necessary as many large pieces are hardened in the bath every day.

For an all around bath for many kinds of work the form shown in Fig. 278 is excellent. The general design may be planned to meet the needs of the individual shop. There are six or more pipes up the sides of the tank which are perforated in such a manner that the water or other fluid is projected toward the center. If it is desired it may be so arranged as to have the pipes swing toward the center when hardening small pieces. The center pipe is much shorter and open at the top to allow the liquid to flow toward the surface. This form of bath is invaluable for such work as drills, taps and other pieces having grooves or flutes, as the liquid is able to reach every part of the surface. The liquid projected through the holes in the upright pipes against the irregular surface prevents the steam, resulting from the contact of red hot metal and the fluid, from pocketing at any point.

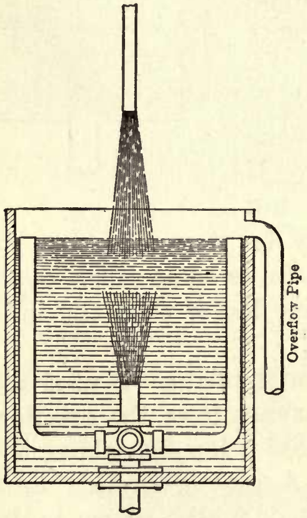


FIG. 278.

When hardening cylindrical-shaped pieces whose ends as well as circumference must be hard, this bath will be found most effective as a pipe may be added above the tank and a jet thrown downwards. This, together with the jet coming up from the bottom, insures the hardening of the walls of countersunk center holes in such pieces as lathe mandrels, etc.

In many instances the hardening of the *entire* surface of the cylindrical pieces without having here and there soft spots is found to be a difficult matter. The use of this bath properly arranged will obviate this difficulty.

When work is heated in hardening boxes and dumped into a bath ununiform results are many times obtained as the pieces go into the bath in a body and slow cooling of some pieces follow. A form of bath that obviates this difficulty is shown in Fig. 279 where wires are arranged so as to separate the pieces and cause them to rotate as they descend. The depth of the bath should be such that the pieces will be cooled below a red before reaching the bottom, or an agitator may be provided to keep them in motion until cool.

Fig. 280 represents a bath that is many times used with good results when hardening pieces of various forms. The work travels down the inclined shelves, rolling over and over until the bottom is reached.

Ball-shaped pieces are difficult to harden in a bath of ordinary construction, but show uniform results when quenched in one of the designs shown in Fig. 281. The depth of the tank must conform to the size of the pieces, although a deep tank insures good results on both large and small work. The false bottom (*a*) may be of wire netting of a size that will not allow the piece to pass through. The liquid must enter at the bottom with sufficient force to prevent the pieces resting on the netting which, being inclined, causes them to move toward the

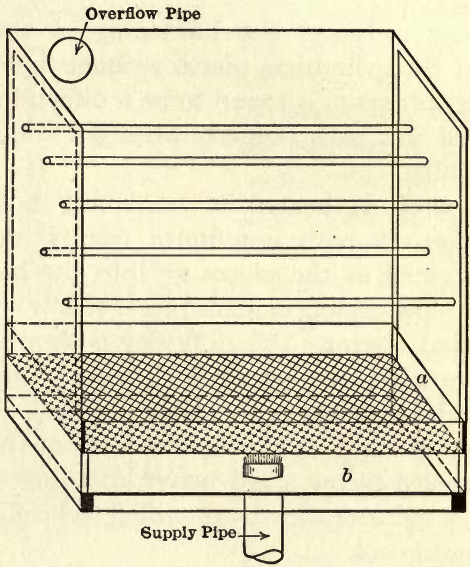


FIG. 279.

lower portions from which they drop into the perforated tray. The tray being removable may be raised occasionally and the pieces taken away.

At times it is necessary to harden pieces of a size that do not show good results when immersed in a body of water, and which may be hardened satisfactorily if one or more large streams of water are projected against the portions desired hard. Take, for instance, the block shown in Fig. 282 which is about 10″ in diameter and 6″ long. The projecting ends must be hard while it is immaterial whether the balance of the block is hard or soft. Repeated efforts to harden in a body of water where large,

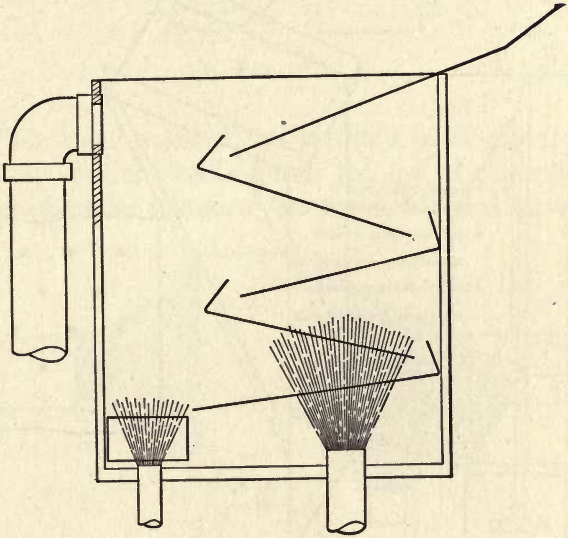


FIG. 280.

strong jets were projected against the ends resulted in failure as steam was generated in such quantities that the water could not act on the portions desired hard. Excellent results, however, were obtained when the pieces were suspended and heavy streams of water projected against the ends as shown in Fig. 283. By the use of this device the steam readily escaped into the air and did not retard the cooling action of the water. This method of cooling may be modified to meet various conditions. In connection with the streams against the ends, pipes may be provided so as to force water against all portions of the piece if desirable.

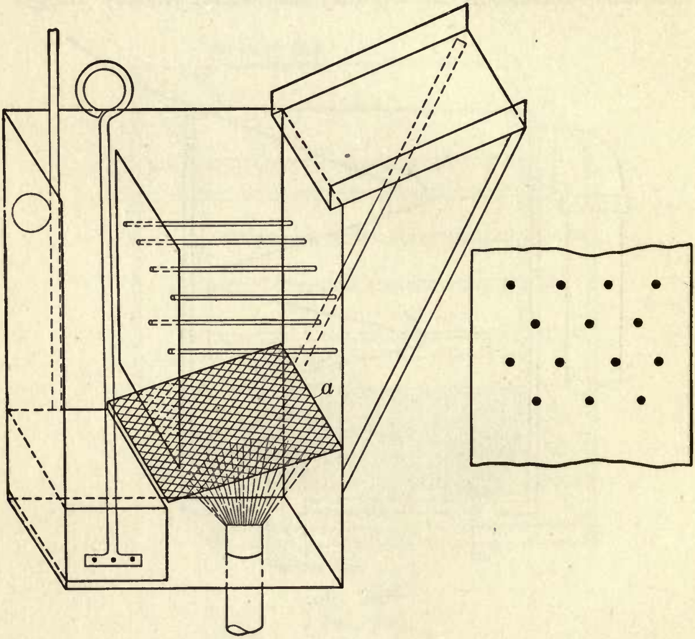


FIG. 281.

While we have given several designs of baths, some of which are intended for general use, and others for special kinds of work, it is many times necessary to make baths of a design that will accomplish a specific result. It would not be possible to anticipate every requirement, and those in charge of heat-treating departments must *invent* something that will insure the desired result.

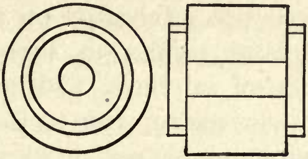


FIG. 282.

While clear water is the medium most often used in baths, better results follow the use of other fluids at times, as for instance, brine which is a solution of

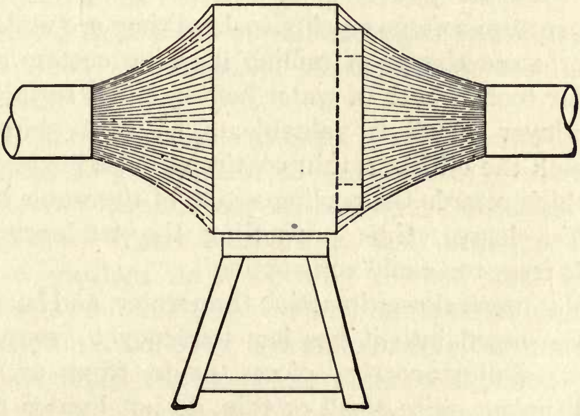


FIG. 283.

salt and water. The amount of salt varies according to the result to be attained, ranging from a small amount to enough to produce a saturated solution. Borax, alum, ammonia, cyanide of potassium, corrosive sublimate, citric acid, sulphuric acid and numerous other things are sometimes used. The use of cyanide and corrosive sublimate or any other violent poison is not advocated on account of the possibility of fatal results to those using them. While a solution of sulphuric acid and water many times insures a surface superior to that obtained by other mediums, its use is not advocated for articles that are not to be used and discarded within a short time, as it "rots" the steel. Dies and similar tools hardened in this bath, and laid away for a time, will be found worthless. It is claimed that steel hardened in this solution and then reheated to 650° F. will show no bad results, but, reheating to this temperature softens cutting tools so they are useless.

For some classes of milling machine cutters and similar tools a bath of water having on its surface a thin layer of oil is valuable. The steel plunged through the oil has a thin coating of oil adhering to it, which retards the cooling action of the water to a certain degree, thus preventing the tendency to crack from too rapid contraction.

Oil is much slower in action than water, and heated steel plunged into it has less tendency to warp or crack. Unfortunately, pieces made from carbon steel, unless quite small or thin, do not harden sufficiently for most purposes when quenched in it. However, articles of certain size and shape will harden nicely in it and when it will give the desired hardness its use is to be advocated.

All oils are not alike in their ability to extract heat from steel, consequently different kinds are used to give a variety of results. Lard oil is used many times where toughness is desirable rather than hardness. Raw linseed oil, sperm oil, cotton-seed oil, fish oil and the various hardening and tempering oils are used either alone or mixed with one another, or with light mineral oils.

At times borax, alum, soda, turpentine, beeswax and various other ingredients are placed in oil used in hardening. The use of turpentine, kerosene, or other ingredients having a low "flashing" point as an admixture is hardly to be advocated unless the party using it is thoroughly versed in its action, and is provided with equipment that makes their use safe. Serious burns, loss of life and property have resulted from some unwise attempts to follow some published statement of extraordinary results obtained.

It is found possible at times to mix a heavy animal oil and a light mineral oil and produce good results in cases where neither one alone gave satisfaction.

Water.—Water is used more than any other liquid as a medium for quenching red-hot steel in the process of hardening. Where but a small quantity is used in a still bath, it is undoubtedly true that best results follow the use of rain water, or of boiled water. Where it is necessary to provide a constant supply of fresh water it is customary to connect directly with a water main, or to pump from a stream or well. In such cases it is necessary to use the water without regard to its purity or its fitness for the work. One objection to such conditions is the varying temperature of water from mains or rivers, and the extreme coldness of that from wells, especially artesian wells. Water from the two former sources varies in temperature according to the seasons.

As *extremely cold* water should seldom be used for pieces of intricate shape, and as, in most cases, it does not work as well as when at a temperature of 70° F., it is advisable to provide some means of raising it to the desired temperature before it enters the bath. This may be accomplished by connecting a steam supply pipe with the inlet pipe, and by adjusting the flow of the steam by means of a valve so that the incoming water will be of the proper temperature. In a factory manufacturing tableware, such as spoons, forks, etc., it was found that the dies used in striking up this work showed a tendency to crack when quenched. It was found that the bath, which was quite ingenious in design, was supplied with water from an artesian well and was extremely cold. A steam pipe was connected with the supply pipe as shown in Fig. 284 and the water heated to from 60° to 70° F. before striking the heated dies, as a result the cracking was eliminated and the

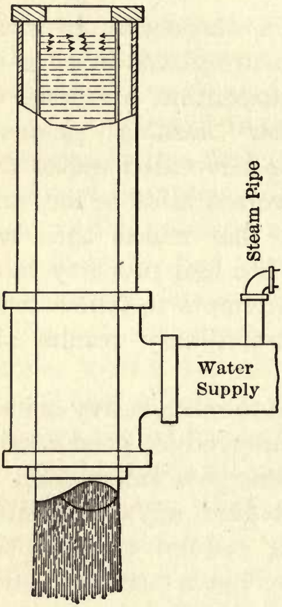


Fig. 284.

dies were found to stand up as well or better than before.

It will be seen that the quenching device in Fig. 284 was made up of two pipes, the outer one somewhat larger than the inner. The inner pipe had holes drilled through its walls so that the water, under the pressure of the pump, would pass through and strike the die held in the inner pipe, which was made to act as a drainage pipe. The water was conducted away fast enough so that there was no body of water in the inner pipe. As the water was projected in numerous jets all vapor was carried away and could not pocket at any part of the die. A modification of this form of bath could be successfully applied to many classes of work where steam causes soft spots by collecting at some essential portion when work is immersed in a *body* of water.

It is undoubtedly true that a deep penetration can be obtained by the use of the design just considered. Experienced hardeners know that jets of water properly applied are more effective, especially in the case of large pieces, than a *body* of water even when the latter is of generous proportions.

Use of Salt.—There are pieces that do not show up favorably when quenched in brine because of its drastic action on the steel and yet when quenched in water do not seem to show a uniform surface hardness, occasioned probably, by a slight oxidation of the surface. This oxide not scaling off uniformly does not allow the water to attack the surface at *all* points as it should. In such cases a handful of fine table salt sprinkled on the surface of the bath at the moment the piece is immersed will work wonders, as it causes the oxide to scale off, thus leaving a clean surface for the water to act on.

Many times where a brine bath does not work well a weaker solution of salt and water will be found to work satisfactorily. The amount of salt will depend on the character of the work. If the article to be hardened is made of high-carbon steel a weaker solution should be used than for one containing less carbon.

Quenching with Steam, Vapor and Water Sprays.—There are conditions under which pieces will harden more uniformly and satisfactorily if quenched in the open by means of jets of steam, or vapor, or by sprays of water so arranged that all portions desired hard will be acted on by the quenching medium.

The hardener in a plant doing job work encounters, occasionally, pieces that do not harden well when dipped in a bath. Sometimes the shape is such that in spite of any arrangement of supply pipes steam will pocket at some point and retard the action of the cooling medium. The same piece if cooled in the open air by means of properly arranged streams of steam, vapor, or water jets, will harden well as the steam can readily escape into the atmosphere. At times very light pieces are hardened by means of jets of air, or by a volume of air; the air, however, should not be under very great pressure as volume rather than velocity counts in cases of this kind. However, on account of the oxidizing action of air on hot steel its use is not to be advocated unless the work is done by one entirely familiar with the process.

Hardening.—Steel is hardened by heating to a red and plunging in some cooling bath. The particular cooling medium must depend on the size and shape of the piece, on the use to which it is to be put and also upon the composition of the steel from which it is made.

The commonly used baths are water, brine, and water containing some substance such as borax, alum, etc., oil, tallow, or some of the so-called fats. This subject is more fully taken up under the subject of baths.

The *exact* temperature to which steel must be heated to harden cannot be stated arbitrarily, as a tool having slender portions easily acted on by the bath need not be given as high a temperature as a large bulky piece, but in no case should it be heated hotter than is necessary to produce the desired result, as temperatures that are higher than necessary perceptibly weaken steel.

When one considers the enormous strain to which the cutting edge of a tool is subjected when in use it will be seen that the maximum of strength is essential.

The necessity of uniformly heating steel is more pronounced when hardening than with any of the other heat-treating processes. It is absolutely essential that no *portion* of the piece be overheated as this will produce an ununiform grain and the overheated portion will be weakened even though it is allowed to cool to the temperature of the balance of the piece before quenching in the bath.

When a die (Fig. 285) is heated too rapidly in the fire the corners and edges are overheated. When the piece is quenched in the bath it cracks, or the overheated portions break off as shown. If for any reason any portion of a tool becomes overheated, it should be removed from the fire and allowed to cool. It may then be reheated for hardening.

While steel should never be overheated, there is less danger of permanently harming it from so doing, than if most of it was brought to the proper temperature and the balance overheated. It is safe to say that a large percentage of the troubles experi-

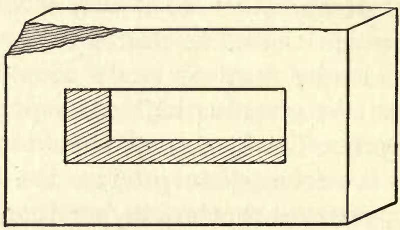


FIG. 285.

enced when hardening are due to the fact that the steel is not heated uniformly.

It is essential that the *cooling* of a piece of steel in hardening should be as uniform as possible. During the cooling process contraction takes place; if the contraction is too ununiform the steel will be torn apart. If one portion cools rapidly and becomes hard and unyielding while the portion next to it continues contracting it is almost sure to crack.

For this reason it is necessary many times to retard the cooling of some section, which may be done by covering the portion to be cooled slowly, with a previously prepared piece of iron, or smearing it with oil or soap while red hot and just before it is quenched. Examples of this practice will be shown under "Hardening Dies."

At times the inequality of contraction may be overcome by dipping a heavier section *first*, then gradually immersing the lighter portion as shown in Fig. 286 where an axe is being dipped in the bath.

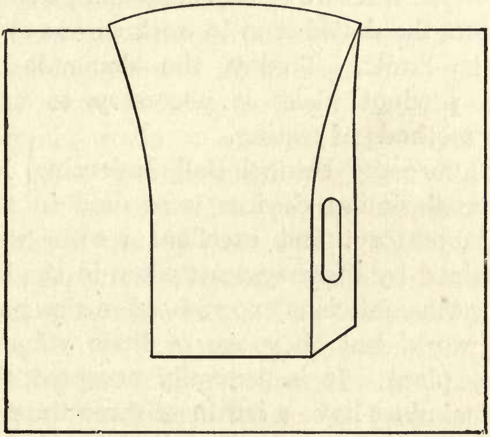


FIG. 286.

It is a mistake to assume that extremely *cold* baths are always necessary, for while the degree of hardness depends on how quickly the heat is extracted, extremely cold baths do not always absorb heat from steel as rapidly as those that are not as cold, and the shock to the steel is not nearly as great if the chill is removed from the quenching fluid.

For many classes of work, baths that are at a temperature of from 80° to 100° F. are found to give excellent results, while for thin pieces where extreme hardness is not essential and toughness is desirable, the contents of the bath may be considerably warmer than the temperature mentioned.

Testing for Hardness.—The methods formerly employed in hardness tests consisted in trying the surface with a file, and the depth of penetration with a center punch, these in connection with the observation of the fracture of an occasional piece made it possible for the skilled man to work within the former allowable limits. To-day the demands on the finished product make it necessary to use more reliable methods of testing.

To be sure the Brinnel Ball Indenting Machine and several similar devices were used in an occasional laboratory, and excellent results were and are obtained by these systems when in the hands of expert mathematicians experienced in this particular line of work, but they are of little value in the ordinary plant. It is generally accepted that the *perfect tool* must have a hardness three times that of the metal it is to cut. To obtain this necessary hardness one must know that the proper temperature cannot be exceeded when hardening, or excessive brittleness will result. To overcome this brittleness the temper must be drawn to a degree that makes the tool too soft to accomplish desired results. By means of the "scleroscope" it is possible to measure the degree of hardness, and also to ascertain whether the steel has been properly heated.

Steel of a certain carbon content hardened at the proper temperature should show a certain scleroscope reading. It is customary in some shops to take a test piece from a bar of steel from which a number of costly tools are to be made. The test piece is hardened under the very best of conditions by a skillful hardener and the degree of hardness found by means of the "scleroscope." A record is made of the reading, and when the tools are hardened it is used in determining whether they are in the best possible condition.

The Shore Scleroscope consists of a small hammer whose striking point is a diamond of rare cleavage formation whose striking surface is slightly rounded. This hammer works in a vertical tube as shown in Fig. 287. Graduations which read from 0 to 140 are provided. The operation of the machine is so simple that it can be successfully used by anyone who has sufficient intelligence to enable him to work in a heat-treating room. The hammer is raised to the top of the instrument by pressing a bulb as shown in Fig. 288 where the instrument is being used in testing a projectile. When the hammer reaches the top of the tube it engages with a hook which holds it suspended. The leveling rod at the right of the scale Fig. 287 enables the operator to determine when the instrument is plumb, adjustment is effected by means of the knurled leveling screws. The hammer is released by again pressing the bulb and drops to the work. The rebound of the hammer indicates the degree of hardness of the piece.

The surface that is to receive the blow must be perfectly smooth in order to insure correct readings.

Instructions accompany the instrument and should be followed as closely as possible.

The hardness of 1 per cent carbon tool steel prop-

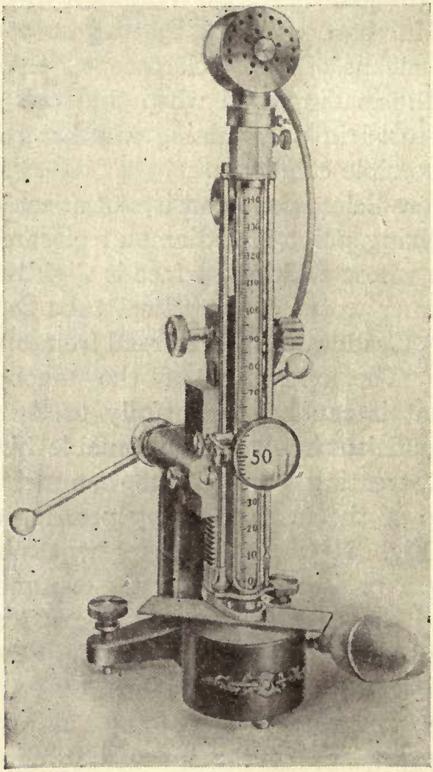


FIG. 287.

erly treated is about 100; 90 is a low value and 110 is considered high.

As previously stated it is generally accepted that the perfect tool must have a hardness three times that of the metal it is to cut. Unannealed tool steel of 1 per cent carbon content is found, by test, to have a hardness of from 40 to 45 points. According to the rule just quoted a tool could not be hardened so as to cut this satisfactorily; however, the same steel properly annealed shows a hardness of only 30 to 31 points, and as a tool made from 1 per cent carbon steel properly hardened should show 95 points, or better, it becomes an easy matter to produce satisfactory results. From the example just cited it is apparent that the instrument can be used to determine whether steel is properly annealed. In this way thousands of dollars can be saved in cutting tools if the annealed product is tested before machining.

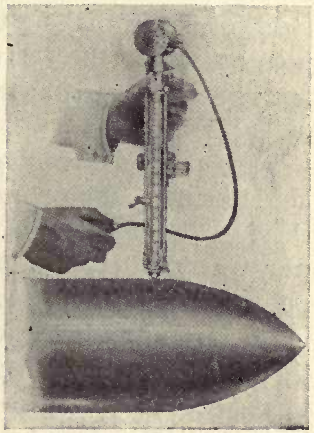


FIG. 288.

High-speed steel when hardened does not show as high hardness test as good grades of carbon tool steel. The effectiveness of high-speed steel does not depend altogether on its hardness, but rather on the fact that it does not lose its ability to cut when heated to temperatures that would entirely soften carbon steels.

The writer earnestly advises men engaged in the heat treatment of steel to make a study of the testing of materials. Not only is it possible to accurately determine the quality of the annealed or hardened product, but it is also possible to determine whether steel has been overheated, or underheated, or ununiformly heated, by the use of the instrument we have been considering.

By finding the hardness of a metal to be machined, it is possible to determine the carbon content of a steel for use in making tools for machining it. The uses to which the instrument can be put are so numerous and varied that a volume could be written on this subject.

Tempering.—Hardening steel sets up brittleness and strains. Tempering is resorted to to remove these. The temper of a piece should never be drawn any lower than is absolutely necessary as the operation softens the steel. The process of tempering is carried on by heating the hardened steel until the brittleness is reduced the right amount, and this is determined by the amount of heat it absorbs. This heating is done by various means.

Color Method.—When tools and other articles are tempered by the color method, the amount of heat absorbed by the steel is determined by the colors on the surface due to a thin film of oxide which forms when the temperature reaches 420° F. and changes in color as the heat increases. In order to see these colors the surface of the hardened steel must be brightened by some means. Most hardeners provide themselves with a buff-stick, which is a piece of wood with emery cloth attached. The steel is heated over a fire, or on an iron plate over a gas jet, or on a piece of very hot metal, or by any convenient way.

Temper Colors.—While the color method is not the most accurate, it provides a convenient way that answers very well where but a few pieces are to be done. When the heated piece reaches a temperature of 430° F., a very pale yellow is visible on the polished surface. Every few degrees of heat causes changes in the colors as set forth in the accompanying table:

TEMPER COLORS

Color.	Degrees F.	Degrees C.
Very pale yellow	430	221
Bright yellow	440	227
Pale straw yellow	450	232
Straw yellow	460	238
Deep straw	470	243
Dark straw	480	249
Yellow with brown	490	254
Brown	500	260
Brown with red spots	510	266
Brown with purple spots	520	271
Light purple	530	277
Full purple	540	282
Dark purple	550	288
Light blue	560	293
Blue	570	299
Dark blue	600	316
Blue tinged with green	630	332

Baths for Tempering.—A bath of oil provides a very satisfactory method of tempering where many pieces are to be heated or where the nature of the articles renders the use of the color method inadvisable. The pieces are placed in a perforated pail which is suspended in a kettle of oil placed over a fire, or in the regular oil tempering furnace as in

Fig. 289. The temperature of the oil is gauged by means of a thermometer. If the pieces are large, or have some sections heavier than others, the temperature of the oil should be raised *gradually* to insure uniform results. The oil should be agitated frequently, being careful that none is thrown outside of the kettle. The kettle should be provided with a cover which has a long handle so that in case the oil catches fire the cover may be placed in position, thus smothering the blaze which might endanger the operator and property.

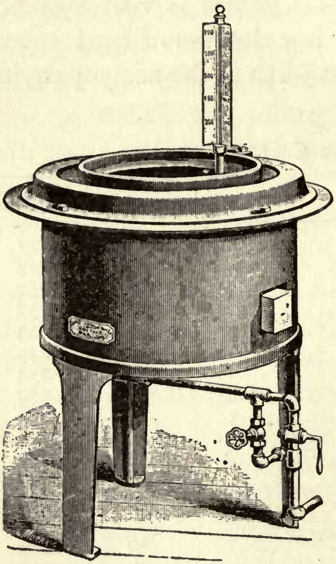


FIG. 289.

Oils with a high flash test may be used. Heavy black cylinder oil is supposed to have a flash test of 725° F. The manufacturers of some special tempering oils claim a flash test of 750° F. for their products but experience does not bear out these claims. In ordinary tempering it is seldom necessary to exceed 630° F. and these tempering oils are perfectly satisfactory up to and above this point.

When an oil tempering furnace is not at hand and temperatures ranging from 430° to 560° F. are desired the following alloys may be used. This table was compiled by Mr. O. M. Becker and shows the melting points of the various alloys of lead and tin.

Lead.	Tin.	Melting Temperature. Degrees F.	Lead.	Tin.	Melting Temperature. Degrees F.
14	8	420	24	8	480
15	8	430	28	8	490
16	8	440	38	8	510
17	8	450	60	8	530
18½	8	460	96	8	550
20	8	470	200	8	560

These alloys should be carefully made and then run into small strips in a mold. When used, bars having the desired melting point should be placed in a melting pot heated by gas, if possible, as gas flames are more easily controlled to the melting point. The insertion of the tool causes the metal to cool and set around the steel. If the heating is carried on gradually the tool should be uniformly heated to the desired temperature when the alloy melts clear of the tool. While this gives excellent results when properly carried on, it is necessarily costly and leaves room for unsatisfactory results in any but a skilled workman's hands.

For temperature above 700° F. a bath of molten lead is used with good results if the lead is agitated frequently. This is necessary as lead forms a "dead" bath, that is, it does not circulate freely, and unless artificial circulation is resorted to, the pieces will not be heated uniformly throughout. The temperature of the bath must be gauged with a pyrometer as shown in Fig. 275 and the pieces, especially if large, allowed to remain until they are heated to the temperature of the lead.

The workman should always bear in mind the fact that steel *hardened* at the proper temperature is the strongest possible. If this temperature is exceeded, unnecessary brittleness results which necessitates drawing the temper lower than it should be; thus leaving the tool softer than is consistent with best results. A tool hardened at the proper temperature by one man, and drawn to 400° F. gave splendid results. A similar tool made from the same bar, hardened by another man had to be drawn to 460° F. to prevent the cutting edge from flaking. The first tool did more than ten times the amount of work, and could be run considerably faster.

There are several forms of tempering machines on the market. Some of these, especially those having revolving trays that hold the pieces of work, give very good results. Such a furnace is shown in Fig. 290. It must be borne in mind, however, that the thermometer provided does not necessarily register the temperature of the *steel*, and, therefore, due allowance must be made for this difference. For this reason this machine may be run so as to give good results where a given size and kind of piece is being tempered right along, and it is for this condition the machine is made.

While red-hot plates are commonly used in tempering, and answer very well for small pieces whose shape is such that sudden expansion at some portion does no harm, there are many classes of work where their use is not to be advocated. If it is desirable

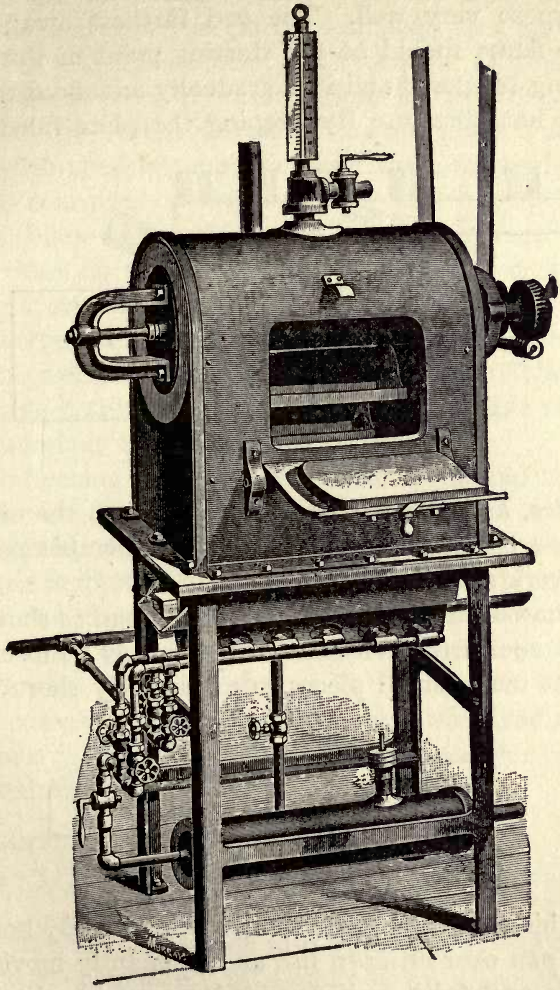


FIG. 290.

to use a plate the one shown in Fig. 291 answers the purpose very well. The end farthest away from the flame should be the starting point of the piece being tempered and it is gradually advanced toward the hot portion. By keeping the plate filled with

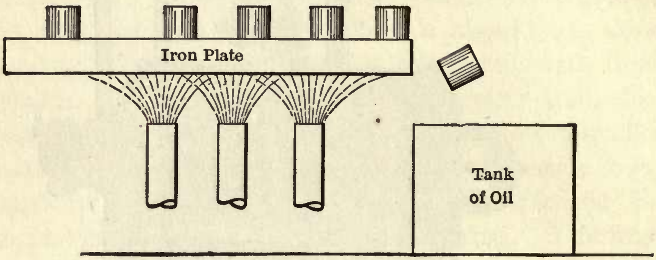


FIG. 291.

pieces, and as some are pushed off into the oil and others placed on the cool end, a considerable amount of work may be done.

Drawing in Sand.—A long-handled pan as shown in Fig. 292 provides a means of uniformly tempering a great many small pieces in a relatively short time.

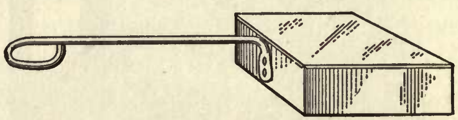


FIG. 292.

Nothing but clean sand should be used. By holding the pan over an open fire and constantly moving it back and forth uniform results may be obtained. Articles having sharp edges and corners *should not* be drawn in a sand-shaking pan.

Thermometer Scales.—While there are three thermometer scales in general use—namely the Fahrenheit (F.), Centigrade (C)., and Reaumur (R.)—but two of these enter into calculations in heat-treating plants in the United States. The Fahrenheit is used in English-speaking countries, and the Centigrade in several countries on the continent, and to a considerable degree in scientific work. As a great many of the writers on the subject under consideration state temperature readings according to the Centigrade scale and most men employed in heat-treating plants bave heen educated to think according to the Fahrenheit scale it seems wise to give the comparative table of Fahrenheit and Centigrade readings.

The freezing point of fresh water is marked at 32 degrees on the Fahrenheit scale, and at 0 on the Centigrade, while the boiling point, at atmospheric pressure is marked at 212 degrees on the Fahrenheit and at 100 degrees on the Centigrade.

The table on p. 254 is obtained by use of the following rule.

To convert Fahrenheit into Centigrade Readings: Subtract 32 from Fahrenheit, divide remainder by 9, and multiply by 5.

EXAMPLE: Change 430° F. to C.

$432-32=398 \quad 398 \div 9=44.22 \quad 44.22 \times 5=221.1.$

Ans. 430° F = 221.1° C.

To convert Centigrade into Fahrenheit Readings: Divide by 5, multiply by 9 and add 32.

EXAMPLE: Change 788° C. to F.

$788 \div 5=157.6 \quad 157.6 \times 9=1418 \quad 1418 \div 32=1450$ F.

Ans. 788° C. = 1450° F.

Fahrenheit and Centigrade Thermometer Scales.

F.	C.	F.	C.	F.	C.
−40	−40	190	87.8	1300	704.0
−35	−37.2	195	90.6	1350	732.0
−30	−34.4	200	93.3	1400	760.0
−25	−31.7	205	96.1	1425	773.9
−20	−28.9	210	98.9	1450	788.0
−15	−26.1	212	100.0	1475	801.6
−10	−23.3	215	101.7	1500	816.0
− 5	−20.6	225	107.2	1550	844.0
0	−17.8	250	121.2	1600	872.0
5	−15	300	148.9	1650	899.0
10	−12.2	350	176.7	1700	926.0
15	− 9.4	400	204.4	1750	954.0
20	− 6.7	425	218.3	1800	982.0
25	− 3.9	430	221.1	1850	1010.0
30	− 1 1	440	226.7	1900	1038.0
32	0.0	450	232.2	1950	1065.5
35	1.7	460	237.8	2000	1093.0
40	4.4	470	243.3	2050	1121.0
45	7.2	480	248.9	2100	1149.0
50	10.0	490	254.9	2150	1176.5
55	12.8	500	260.0	2200	1204.0
60	15.6	510	265.6	2250	1232.0
65	18.3	520	271.1	2300	1260 0
70	21.1	530	276.7	2350	1287.5
75	23.9	540	282.2	2400	1315.5
80	26.7	550	287.8	2450	1343.0
85	29.4	560	293.3	2500	1371.0
90	32.2	570	298.9	2550	1399.0
95	35.0	580	304.4	2600	1426.5
100	37.8	590	310.0	2650	1455.0
105	40.6	600	315.6	2700	1483.0
110	43.3	610	321.1	2750	1510.0
115	46.1	620	326.7	2800	1537.5
120	48.9	630	332.2	2850	1565.0
125	51.7	650	343.3	2900	1593.0
130	54.4	700	371.1	2950	1621.0
135	57.2	750	398.9	3000	1648.5
140	60.0	800	426.7	3050	1676.0
145	62.8	850	454.4	3100	1705.0
150	65.6	900	482.2	3150	1732.0
155	68.3	950	510.0	3200	1760.0
160	71.1	1000	537.8	3300	1815.6
165	73.9	1050	565.5	3400	1871.1
170	76.7	1100	593.0	3500	1926.7
175	79.4	1150	621.0		
180	82.2	1200	648.5		
185	85.0	1250	676.5		

Toughening.—While full annealing relieves strains in steel and gives the maximum toughness, it does not always give the necessary degree of stiffness. In order to produce the toughness and stiffness necessary many different treatments are resorted to. The exact treatment necessary to produce desired results depends on the composition of the steel and the strains it is to receive when in use.

Large, heavy pieces are many times heated to the refining heat and partially quenched in water, after which they are allowed to cool in the air. The internal heat returns to the surface and toughens the external portion. Smaller pieces are partially or wholly cooled in oil and then reheated to give the desired result. The amount of heat given when reheating varies from 500° to 1000° F.

In other cases the pieces are brought to the refining temperature and thrown onto a floor of dry sand in a room where a definite temperature can be maintained. Where this does not produce the necessary degree of stiffness a gentle stream of *warm* air may be blown across the pieces. Better results follow this method when the articles are placed on wire racks so that the air may have free access to all parts.

Large forgings are heated red hot and allowed to cool by piling in heaps and cooled where no draft of air can strike them. It is obvious that such treatment will result in an unevenly cooled surface especially if the steel contains more than 0.40 per cent carbon, as the more exposed portions will cool more quickly than the others. However, if the results are *commercially* satisfactory, the method commends itself on account of the comparatively low cost.

Where large pieces are toughened by quenching in oil, it is necessary, in order to get uniformly good results, to heat to a given pre-determined temperature, quench in oil for a given number of seconds, and then allow the pieces to cool in the air. To insure satisfactory results by this method temperatures, and exposure to the bath, must be determined by experiment, and followed absolutely.

In all shop processes it must be borne in mind that methods commercially possible must be followed, provided they produce results that are commercially satisfactory.

Hardening and Toughening.—In the case of the pipe wrench jaw shown in Fig. 293, it is necessary to harden the portion (*a*), Fig. 294, containing the teeth, and to toughen the rib (*b*). This is accomplished by carefully heating to the proper temperature, which in the case of steel of 0.70 per cent carbon is about 1475° F., then quenching the teeth by holding under a stream of water as shown in Fig. 294. When the red has disappeared from the teeth the piece may be immersed in oil and allowed to remain until cold.

A method of toughening practiced in some places consists in heating to a low red and burying in damp sand, after which they may be reheated to a temperature that insures the desired strength and toughness. While this method gives satisfactory results on certain kinds of work, it is doubtful if it produces as great a degree of strength and toughness as though they were quenched in oil and then tempered.

Articles that have heavy and light sections adjoining each other and where both must be hardened require special care when quenched or the unequal contraction, incident to the difference in size, may

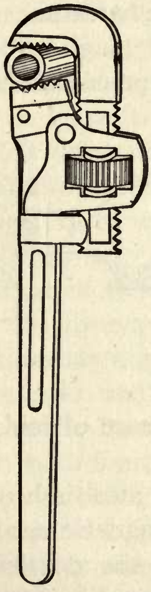


FIG. 293.

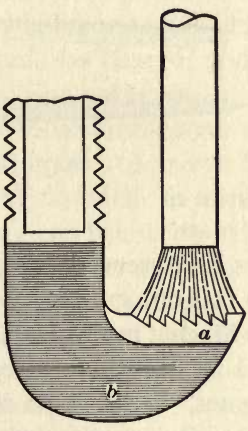


FIG. 294.

result in cracks or breakage. The T slot cutter shown in Fig. 295 is an example that answers well as an illustration. It is necessary to harden, not only the cutting portion, but also the neck (*b*) in order to give it the necessary stiffness and to prevent its roughing up when in use.

To prevent the tool cracking when quenched it is advisable to wind soft iron around the neck at *a* and close up to the body. If small wire is used it is necessary to pass the wire several times around the piece. As the wire is red hot at the time of quenching sudden contraction at this point is avoided.

At times tools of this kind have extremely large center holes in the end that is to be hardened. Such holes should be filled with fire clay dough before the pieces are placed in the fire. This precaution should

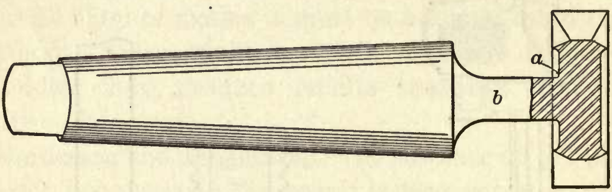


FIG. 295.

always be observed except in the case of tools that are to run on centers.

The Magnet in Hardening.—When steel is heated it retains its ability to attract the magnetic needle, or a magnet, to what is known as the decalescence point. When a piece of steel is heated in a fire that is hotter than the temperature to which the steel should be brought the metal absorbs heat fairly constantly until a certain temperature is reached, when there appears to be a lag in the process; this is known as the *decalescence* point. At this temperature the steel will neither be affected by the magnet, nor will it attract the compass needle. Care should be exercised that the tongs, or other holder ordinarily used is not present when the test is made, or the operator may be deceived. This same piece of steel if heated to a high temperature and allowed to cool, will, when at a certain temperature, show a lag and will, apparently, grow hotter even when cooling in the air. This is known as the *recalescence* point. This phenomenon takes place at a temperature ranging from 85° to 215° F. lower than the decalescence point. Steel must be heated to the decalescence point in order to harden, and it must be quenched before it drops to the recalescence point or it will not harden. Steel should be hardened at the highest temperature to which it *should* be heated, and on a *rising* heat, *never* on a *descending* heat.

The use of the magnet is to be advocated, as the eye is not always to be relied upon. A man's bodily condition has a great deal to do with his ability to discern *heats*, and the lighting conditions many times cause one to be deceived even when the eye, under proper conditions, would give accurate results. As a man grows older, his eyes change and unless he has some standard to check up by he fails to discern *heats*, and is rated as a "back number" at a time when his long experience should make him invaluable. The trouble arises from the fact that the man will not acknowledge to himself that his eyes are changing and instead of realizing this and frequently checking up by means of a magnet, in the absence of a pyrometer, he goes on until it is apparent to everyone that his days of usefulness are past. And many times this is due to the fact that he did not "check" himself frequently rather than to admit a change of eyesight, or ability.

A very successful hardener who is working in a factory where every appliance for producing good results is employed "checks up" ten to fifteen times a day with a magnet. He says he is not sure of his heats when he returns to his fire after leaving and going where the light conditions are different. Most workmen are not aware of the harmful effects of a slight variation in temperature on certain classes of tools. The fact that a tool hardened without cracking or undue distortion is no proof that it is in the best possible condition for the use it is intended for.

While the decalescence point is not in all cases the most suitable temperature to be employed in hardening, it is a safe guide as to the lowest point at which the steel *will* harden properly. The exact amount of additional heat necessary to produce some desired result necessitates a knowledge gained by experience, but the inexperienced man can gain this knowledge by diligent study and intelligently conducted experiments.

Springing.—Springing many times results when pieces are hardened. This may or may not be the hardener's fault. The careful man will use every precaution possible to prevent distortion, but the cause of the trouble may not be anything that he has done, or anything he could counteract had he known of it before hardening. As previously stated the piece of steel may have been straightened cold, or the piece may have been machined with a dull cutting tool which set up strains in the steel. The opening of a blanking die may have been worked out a trifle too large and then pened in cold in which case distortion might result when the die was hardened. Long, slender pieces should never be placed in a furnace, in such a manner that they could bend from the weight of the metal when red hot. If possible, heat in a furnace of the design shown in Fig. 268; if this is not possible place in a tube and turn frequently. When it has reached the proper hardening temperature remove the tube from the furnace and stand in an upright position before taking the piece from the tube. As the piece is lifted vertically the tendency to spring is much less than if it was heated in a horizontal position on the floor of the furnace, drawn out and then brought to a vertical position preparatory to dipping in the bath.

Pieces of this kind should be lowered into the bath in as nearly a perfectly vertical position as possible to prevent one side cooling faster than the other. Pieces of the description under consideration give best results when pack hardened and quenched in oil. However, if the ordinary fire and water method must be used, have the contents of the bath at a temperature of from 80° to 90° F.

Straightening.—If extreme care in heating and quenching is exercised, springing or other distortion will be reduced to the minimum. However, pieces will some times go out of true and must be straightened, by first heating the articles and then applying pressure. This pressure should be gradual and should be kept up until the piece is cooled. If the article is not too large in cross-section and has centers in its ends it may be placed between the centers of a lathe, then heated by means of a Bunsen burner, gas jet, or spirit lamp, until lard oil applied to the surface commences to smoke, after which pressure may be applied to the convex side by means of a tool shank held in the tool post. The pressure should be sufficient to spring the article slightly in the opposite direction, when it may be cooled by applying wet cloths or waste *uniformly* to *all* parts of the surface; or it may be left between the centers until cooled by the air. If it is found to be sprung when tested it should be reheated and the above operation repeated. Do not attempt to spring hardened steel without heating, no matter how many times it has previously been heated. Hardened steel cannot be bent when cold by a man of ordinary experience with any degree of safety. Slender pieces are sometimes straightened after the temper is drawn, and when cold, by pening, by men experienced in this work, but this practice is not to be advocated.

Pieces that have no centers can be straightened in a screw press. It is necessary to support them on blocks located a convenient distance apart, and applying pressure between them after heating.

Changes in Length.—Steel of ordinary composition has a tendency to change in length when hardened. This can be overcome, to a degree, by annealing at a temperature somewhat higher than hardening heats after the pieces are rough machined. Steel containing certain elements has less tendency to change than others and for this reason is advocated for use in making taps. Taps that are annealed as described above and then pack hardened have little tendency to a change of pitch. Consequently this method is advocated whenever possible for this class of tool, particularly where change of pitch is fatal to the tool.

Value of Experiments.—It is advisable, at times, to vary the treatment given a tool and then closely watch results when it is set to work. This does not apply where satisfactory results are being obtained by some method that has been found to work all right; but, in the case of a new kind of tool; or, where a tool is being used on stock entirely different from that used before.

The character of the work a tool is to perform, and the composition of the steel from which it is made must be known in order that the right treatment may be given it. No experienced hardener, or technical expert, for that matter, can always tell offhand the *best* treatment to give a tool unless the conditions mentioned are known. He can in all probability give a *safe* course to pursue in treating it, but this should not be the prime essential to be considered, regardless of the capability of the tool to do the maximum amount of work in a given time. It is, of course, necessary to keep an accurate account of the cost of the various operations performed in a heat-treating department, the same as in any other part of the factory, but because a certain operation cost a given sum to perform at some previous time is no reason that a treatment costing several times as much is not advisable if results in the use of the tool warrant the added expense.

If the material from which the tool is made plus the cost in the tool room of getting it ready for the hardener aggregates $50 it is poor policy to pursue a method in hardening that costs but 50 cents, when a method that involves an expense of $5 would put the tool in condition to produce many times more work before it was scrapped. Yet this "penny wise, pound foolish" system is still adhered to in some shops. The expense account should rather be kept with the tool; its cost of production and maintenance, as against the amount of work produced by it, etc.

The entrance of technically educated men into factories has done a great deal toward eliminating many of the foolish practices in some plants. The technically educated man, however, should "serve his term" in the heat-treating room and the production departments getting familiar with operations and requirements before he is permanently located in the chemical laboratory and allowed to dictate the course and methods to be pursued in the heat-treating department, as otherwise a condition less desirable than that occasioned by "hit or miss" methods may, and probably will, result.

So far as possible each class of tool that is heat treated should receive personal consideration. Its chemical analysis, design, material it is to cut, amount of work it is to produce in a given time, and conditions under which it is to work should be taken into account in determining the treatment it should receive. At times a slight variation in temperature or time exposure will work wonders. A certain class of tool that had been hardened from a temperature of 1400° F. was heated to 1430° F. and an increase of 50 per cent in the amount of work produced by the tool was obtained. A tool made from a well-known alloy steel was hardened at 1375° F. according to instructions on the bar, with fair results. On the advice of a representative of the concern from whom the steel was purchased, one of the tools was hardened at 1500° F. and results way beyond anything thought of were obtained. The writer does not wish to be understood as advocating high temperatures when heating steel for any of the heat-treating processes, but in the case just cited the heat mentioned was needed to bring out certain qualities in the steel.

At times a trifling drop in temperature will work wonders especially in the case of cutting tools having projecting cutting teeth. In some cases a microscopical examination of the surfaces of the fracture in the *body* of the tool might show that the steel was underheated, while a similar examination of a broken tooth would indicate correct heating and yet both body and teeth might have been at the same temperature so far as is humanly possible to heat such pieces. In the case just considered the cutting teeth are the portions to be considered, consequently the temperature employed must be one that gives best results here. This case emphasizes the repeated statements of writers dealing with the subject under consideration that variations of temperature are necessary for pieces of different sizes and shapes made from steel of the same composition.

Annealing.—The term annealing, as generally understood, means the softening of materials so that they will be workable. At the present time, and by those engaged in the heat treating of steel, the word has a much broader meaning. Crucible tool steel as it leaves the finish hammer, or rolls in the steel mill is quite hard and filled with strains. The condition of hardness renders machining difficult, or impossible. To overcome this difficulty, and to remove the strains, the steel is heated to a uniform red and allowed to cool *slowly*.

The exact temperature to which a piece of steel should be heated for annealing depends on the critical temperature of the steel. This temperature varies somewhat and depends on the composition of the steel, on the size, and on the subsequent treatment it is to receive. However, it is generally advisable to bring the steel to a somewhat higher heat than it is to receive when hardened. In this way it is reasonably certain that strains that would otherwise be relieved by the hardening heat, will be eliminated in the annealing. The exact increase in temperature above the critical point cannot be stated arbitrarily, but in ordinary practice is about 50° F. Where special objects are to be attained, this temperature is sometimes exceeded. However, very high annealing heats are liable to produce a product that is difficult to machine, for while it may appear to be soft under a file test, tools will dull rapidly when cutting it.

Where it is necessary to heat pieces much more than 50° F. above the refining heat, in order to release strains that may manifest themselves when hardening, and where the pieces are to be machined, it is, at times, advisable to resort to "double annealing." That is, first, heat to the higher temperature and allow them to cool, then heat to a few degrees above the refining heat and allow them to cool the second time, thus doing away with the crystalline grain incident to the high heat.

In any of the operations involved in the heat treatment of steel it is always advisable to heat as rapidly as possible and yet heat uniformly. On the other hand steel should not be heated *too* rapidly as ununiform heats may set up strains that are more serious than those we are attempting to remove by the annealing process. If a large die block, rectangular in shape, is placed in the furnace and heated there is a tendency, unless care is exercised, to overheat the corners and edges before the center of the block has reached the proper temperature.

A piece of steel always shows the effect of the *last* heat it receives, and each portion of every piece shows the effect of the heat *it* receives, as a result, an overheated piece, if it is ununiformly overheated, shows an ununiform granular condition that varies throughout accordingly as the piece was heated. This granular condition indicates that the steel has been weakened, and if the weakening is not uniform throughout the piece it is in poor condition to be hardened, or to receive excessive strains of any kind. It is a mistake to keep a piece of carbon tool-steel red hot any longer than is necessary after it is uniformly heated throughout, as prolonged heats, when annealing, even when the steel is not overheated, tends to weaken it, and to produce a condition that renders machining with cutting tools difficult.

A mistake often made in annealing is to heat the piece too hot and to hold it at this heat for too long a time; then when an attempt is made to machine it, difficulty is experienced. The piece is returned to the heat-treating department and it is heated hotter and kept hot longer than before, with the result that each time it is treated conditions are found worse.

The writer recalls a die block, on the face of which an impression was to be made by engraving. After repeated attempts to anneal the steel, the block was sent to our plant. An examination of the grain of a piece cut from the block showed it to be extremely granular. While the steel showed soft under file test, it appeared to be extremely weak when broken, indicating excessive and long-continued heats. The block was placed in the furnace and carefully heated to the proper temperature, making sure that the temperature was uniform throughout. It was then removed from the furnace and buried in ashes. The ashes that came in contact with the steel were heated to a temperature of about 1000° F. while the balance of the ashes were not heated, but were perfectly dry. When the piece was cool it was found to be in excellent condition for machining.

A method of annealing, where but a few comparatively small pieces are to be treated, consists in heating to a red and burying in ashes, lime or asbestos and allowing them to remain until cool. If the pieces are properly heated, and the material they are buried in is warm and dry good results generally follow. Burying red-hot steel in cold or damp materials has a tendency to partially harden it. A method practiced by some consists in heating a piece of scrap iron or steel to a red and burying in ashes, lime or whatever is used and allowing it to remain there until the piece to be annealed is properly heated, when it is removed and the steel buried in the heated material.

Box Annealing.—Undoubtedly hundreds of thousands of dollars worth of steel is rendered unfit for use each year by this method of annealing; but, it is not wise to condemn a method because it is not properly done.

As previously stated, the one who is responsible for the heat treatment of steel should understand *steel.* If a batch of small forgings made from a comparatively low carbon steel is to be annealed, it might be perfectly proper to use a method that might prove very unsatisfactory if the same pieces were made from medium or high carbon stock.

It is poor practice to anneal a *large* box of *small* pieces made from high carbon steel, as the pieces located in various parts of the box would remain red hot for different lengths of time. As a result the action of the process would tend to produce a product that was not uniform and difficulty would be experienced when they were machined.

Small pieces should be packed in *small* boxes, and the boxes removed from the furnace as soon as the contents are uniformly heated to the proper temperature. It is not to be understood that small pieces made from low carbon steel would be so easily injured if packed in large boxes, as the lower the carbon the less sensitive the steel is to the injurious effects of long heats. Trouble is experienced here at times when the workman is told. "These pieces are made from machine steel," as the so-called machine steel may contain a high percentage of carbon, and the effect of long-continued heats is just as apparent as though the stock was crucible tool steel of the same carbon content.

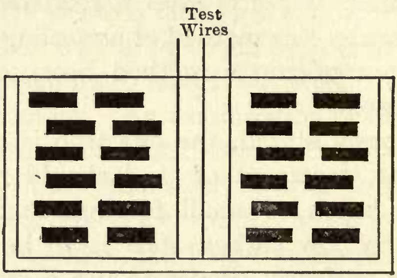


FIG. 296.

It is a good plan to use test wires as shown in Fig. 296 in order to determine when the pieces at the center of the box are heated to the desired temperature. Several $\frac{1}{4}''$ holes are drilled through the box covers as shown, and $\frac{3}{16}''$ wires are thrust down through the packing material to the bottom of the box. When the work has been exposed to the action of the heat for a time one of the wires may be drawn by means of long tongs and its condition noted. In a short time a second wire may be removed and this continued until one is drawn that shows the proper color.

The pieces should be arranged in the box so that they will not be within an inch of the walls at any point. The packing material used may be pulverized charcoal, coal dust, lime, asbestos, sand or any material that will answer the purpose and yet have no undesirable effect on the steel.

Some writers claim that a furnace heated to a given temperature will heat a piece of a given size and shape to a definite temperature in a given time. The writer's experience does not coincide with this claim. There are a number of conditions that have a decided effect on the exact length of time it takes steel to absorb heat. This is especially true of work packed in boxes. It is wise to have records showing the approximate time required to heat given sized pieces and boxes to certain temperatures, but such records should not be considered as absolute.

It sometimes happens that an entirely unlooked-for and undesired result is obtained by packing the steel for annealing in material not suited for the purpose. Where *low* carbon steel pieces are to be annealed, and it is not desirable to increase the carbon content, a packing material that will not impart carbon should be used. A batch of forgings were made for a manufacturer of guns which were to be machined and then bent to an irregular form. As it was necessary to anneal them to put them in condition for machining they were packed in boxes and no thought given to the action of the packing material. The material used was wood charcoal. When machined they cut nicely, but when an attempt was made to bend them to a finished form, they broke. Investigation showed that carbon was charged into them in the annealing process. In order to save the pieces and make bending possible they were re-annealed in forge scale (oxide of iron), which contains no carbon, and which absorbed the excess carbon from the forgings making cold bending possible.

At times high-carbon steel pieces are packed in some material that draws the carbon out and leaves the steel unfit for use. This may be rectified by re-annealing in charred leather or charcoal, making sure that the time exposure for recharging is about the same as when the carbon was extracted.

If it is desirable to use a *high* carbon steel and none is at hand the finished tool may be packed in charred leather and run at a temperature of 1400° to 1450° F. from two to four hours, after which it may be allowed to cool and then hardened.

The operator should understand that while certain materials are very desirable as packing materials when annealing certain pieces their use is to be discouraged for other purposes. Tool steel to be used for most cutting tools can be satisfactorily annealed if packed in charcoal; yet tools to be subjected to certain strains where an increase of carbon is undesirable should not be exposed to charcoal, or any other carburizer. They should not be heated in contact with decarburizers or the carbon content at the surface will be lowered. When in doubt as to the desirable material to be used it is best to select a neutral. The writer has in such cases used, with good results, finely sifted coal ashes, or dry fire clay.

When one understands the action of different packing materials it is possible many times to treat a stock not exactly suited to a certain purpose in such a manner as to add to it, or take from it carbon, and accomplish the desired result.

Articles made from sheet steel, or which are light in cross-section, if made from medium or high-carbon steel seldom show good results if box annealed. Take, for instance, jack-knife blades, springs, etc. Such pieces, especially if they are to be machined, are best annealed by heating in a furnace where no direct flame can strike them, removing as soon as uniformly heated to the proper temperature and placing in a box, in the bottom of which is a quantity of hot ashes. As these pieces are constantly added they cool very slowly. When the box is nearly full the balance of space may be filled with hot ashes. The blades do not remain *red* hot very long, but cool very slowly from about 1000° F. The same pieces if box annealed would have a coarse structure and would give considerable trouble when drilled, or machined by any method.

Water Annealing.—The opinions of writers and hardeners differ widely as to the value of water annealing. The opinion, as generally given, is that it is a good practice to let alone. There are times when it is necessary to anneal a piece of steel as *quickly* as possible, and if the shape of the piece is such that uniform cooling down to the point where the red disappears from the steel when the piece is held in a dark place is possible, fairly good results follow if it is immediately plunged in water, oil, or soapy water.

There are times when it does not seem possible to anneal steel by the regular methods so that it will be in the desired condition, and where water annealing (so-called) will give satisfaction. The writer recalls some tap blanks that could not be threaded in the lathe without "tearing," that is, the stock would tear out on the sides of the thread. The steel appeared to be weakened by the annealing as there was not sufficient strength to hold it together under the action of cutting with the threading tool. As a last resort water annealing was tried. The blanks were heated to a low red and allowed to cool until they reached a point where fine dry sawdust would not sparkle when dropped on them, and then plunged in warm soapy water. After being treated in this manner there was no tearing of the stock and results were perfectly satisfactory. The writer does not wish to be understood as advocating this method of annealing. On the contrary he discourages its use only in exceptional cases, but there are cases where, if carefully carried on, very good results may be obtained. The cooling, however, must be uniform and this is difficult to accomplish unless extreme care is exercised as the lighter sections and edges have a tendency to cool more rapidly than the balance of the piece.

In one shop where it is practiced on rather a large scale pieces of cast iron having a hole somewhat larger than the piece to be annealed drilled in from one end one inch deeper than the length of the piece. These are heated red hot, the red-hot piece of steel inserted in the hole, the end covered and the whole allowed to cool until the steel is to the desired temperature, when it is removed from the case and quenched in warm oil.

Examples of Hardening.—As different kinds and forms of tools require different treatment, it seems advisable to consider them separately rather than to attempt to give general instructions. The one doing the hardening should consider each tool, or each batch of tools, to be treated as a problem, the solution of which depends on several conditions, namely, the use to which it is to be put; the steel from which it is made; the size and shape, and the treatment the steel has received before it comes to the heat-treating room to be hardened,.

Let us first consider a piercing punch to be used in connection with a punch-press die as shown in Fig. 297. In order to determine the temperature to which it should be heated, a knowledge of the kind of steel used is necessary. If the carbon is comparatively low, say 0.9 to 1 per cent, it will require a higher heat than if made from steel containing 1.25 to 1.4 per cent. For the former, a temperature of 1450° F. will be required, while for the latter only 1425° F. should be given. The size of the punch is a determining factor also, as one $\frac{1}{4}''$ diameter will not require as high a heat as one $2''$ diameter. An absolutely uniform heat is essential. Fig. 298 shows one of these punches that was not uniformly heated, and when hardened, it was in the condition shown.

Some of these punches broke in the bath while others broke in use, all showing the same general appearance. When it was suggested that they had not been uniformly heated, the claim was made that this could not be so, as the most modern appliances were used, a certain temperature was maintained in the furnace, and the pieces left in the furnace a certain

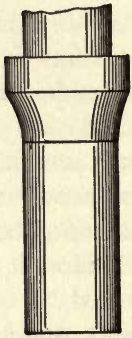


FIG. 297.

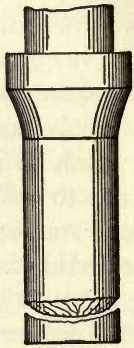


FIG. 298.

length of time, the length of time having been determined by experiment.

A punch from the same lot was carefully heated in a charcoal fire in a blacksmith's forge and quenched in the same bath used for the others, and did not show any weakness when tested or when put to use. Further investigation showed that the pieces had not been uniformly heated. As a result, the hardener was given orders to carefully observe the heat given each piece before quenching.

Cold Chisels.—The efficiency of a cold chisel depends, in a large measure, on the treatment it receives when being forged. A piece of steel if improperly treated in the process of forging cannot be hardened and tempered so it will do the amount of work it should.

As a rule, a chisel to be used for ordinary work is made from steel containing 0.9 to 1.1 per cent carbon. For many small chisels to be used for such work as die sinking, when light cuts are to be taken, and where the ability to hold a keen edge is essential, steel containing a higher percentage is used. The higher the carbon content the greater care necessary when forging.

Small chisels should never be quenched in an extremely cold bath, as this causes brittleness, and extreme toughness is the quality needed. For chisels of ordinary size (1″) a bath whose temperature is about 70° F. gives good results. As 70° F. is about the temperature of the ordinary room there is little need of gauging the heat. In extremely warm weather it may be necessary to add cool water occasionally. Very small chisels many times give excellent results, especially if the carbon content of the steel is high, if the bath is slightly warmer than that mentioned.

The chisel should be *uniformly* heated to the desired temperature for an inch or more above the point to which the hardness is to extend. It should be worked up and down in the bath to prevent a "water line," and around, to avoid steam. When it is properly hardened, remove from the bath and brighten one side with the buff stick and draw the temper.

Many hardeners draw the temper of medium size and large chisels by means of the heat left in the body of the steel after the cutting end is hardened, helping this out when necessary by holding it in the flame of the fire. Others contend that better results follow when the piece is entirely cooled and then reheated for drawing. Either practice is good if carefully carried on. As the cutting end of a chisel is thinner than the portion immediately back of it, extreme care must be observed when heating for hardening or an uneven heat will result, and a break as shown in Fig. 299 will appear when quenching, or when the tool is used.

FIG. 299.

As repeatedly stated, steel shows the effects of the *last* heat it receives, and as high heats perceptibly weaken it extreme care should be taken when hardening chisels. Do not heat any hotter than is necessary to refine the steel. Many times cold chisels receive less attention than tools that cost more in making, but if one will consider that a chisel properly forged, hardened and tempered will do many times more work in a day than one improperly treated, it will be seen that the same care should be exercised as when hardening a more costly tool.

In many shops an account is kept of the amount of work done with a tool; original cost and upkeep placed in one column and the amount of work accomplished with it, in the other column, thus making it possible to find the tool cost per piece of work.

This practice in the case of a cold chisel may not be feasible, but the same care should be exercised in its treatment as would be in the case of a costly die or milling machine cutter with which an account was kept.

Tempering.—Any tool hardened at the proper temperature will stand up in use with less "drawing back" than if given more heat. It is necessary at times to draw the temper of a chisel much more than it should be to give it the necessary toughness, because it was overheated in hardening. If the tool is heated 150° above the refining heat, it will be necessary to draw the temper considerably more than it should be, thus we get extreme brittleness from the overheating, and softness from the tempering.

It is not possible to give the exact temperature to which a chisel should be drawn, as the use to which it is to be put must in a great measure determine this. Small chisels used in die sinking and similar work are many times drawn to a full straw color (460° F.), while those used for rough, heavy work are drawn to a purple. The writer's experience has convinced him that for ordinary work, chisels of the average size give good results if drawn to a very deep brown with the red and purple spots just showing, then check in *warm oil*. Many hardeners check a chisel, after drawing, in cold water, which tends to set up a certain amount of brittleness that is not apparent if oil is used.

Punch-press Dies.—There are many kinds and patterns of dies used in punch-press work. We will consider first a few patterns of blanking dies. Probably no one class of tools gives the hardener in a *job shop* more concern than blanking dies. If the size and design are such that hardening is a simple task, the work is done in the shop where it is made; on the other hand, if the die is liable to go to pieces as a result of heat treatment, it is sent to a place where a specialty is made of such work. There are many things to consider when hardening a die. First, the steel from which it is made; second, the treatment it has received in forging or annealing; third, the treatment it has received by the die maker, and fourth, the use to which it is to be put.

Of course it is necessary that the hardener know whether the steel is low or high carbon, or some alloy steel (as oil hardening steel) that requires special treatment. The treatment it may have received in forging, annealing or by the die maker is difficult to find out and many times has to be ignored. If the die is to be used in punching hard or heavy stock, it may require different temper drawing than if it is to work on soft or thin material.

If we are uncertain as to the forging or annealing it is a good plan to heat the die to a red, slightly above the hardening heat, remove it from the fire and allow it to cool. This is done to remove any strains. It may then be reheated to the desired temperature and immersed in the bath. When placing in the bath grasp it by means of tongs in such a manner as not to cover any essential part, and lower it endwise as shown in Fig. 300, swinging it back and forth so as to force the liquid through the openings. A still bath of brine of generous proportions works nicely. While a bath of the description shown in Fig. 301 with a jet coming in from the side is often used for this purpose, better results follow the use of a still bath, as uneven cooling may result in warping the die.

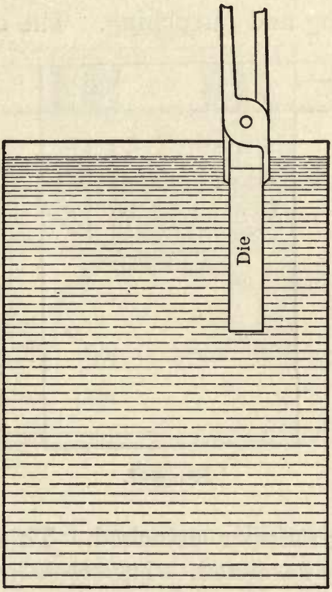


FIG. 300.

When the die has cooled to the temperature of the bath, remove and hold over a fire and heat until moisture applied with the finger will steam from the heat in the steel. When doing this, turn the die repeatedly so that it will absorb the heat uniformly, which is done to remove hardening strains. The surface may now be brightened and the temper drawn.

Dies to be used in blanking pieces from soft steel may be drawn to a full straw color.

In Fig. 302 is shown a die made from thin stock. As this is used in punching cold rolled strip stock of 0.80 per cent carbon it is necessary to use extreme care in heating and quenching. The cut shows the

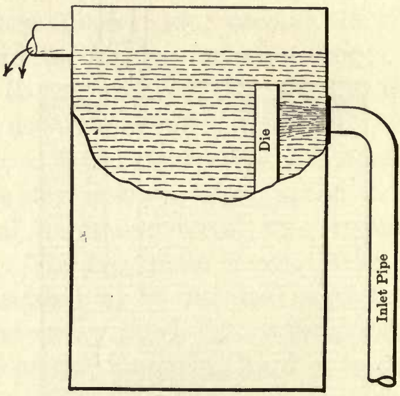


FIG. 301.

die with the stripper attached. This is removed when the die is hardened. The screw holes should be filled with fire clay dough as it is not necessary to harden the walls of these, and the danger of cracking is reduced by so doing. As stated this die is made from thin stock ($\frac{3}{8}''$), as a result the top and bottom must be uniformly cooled or the die will spring. A bath made by dissolving 10 tablespoonfuls of salt to a gallon of water is used. The bath is kept as nearly as possible at a temperature of 80° F. The die is immersed endwise and worked back and forth to force the liquid through the opening and to cool both flat surfaces as uniformly as possible. The temper is drawn by heating in oil to 450° F.

Fig. 303 represents a die that requires extreme care, and the display of considerable ingenuity in hardening as the thin partition between the openings

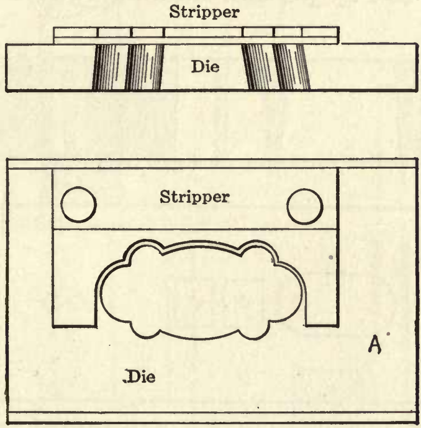


Fig. 302.

c c is liable to break away from the body of the die on account of its hardening so much more rapidly than the heavier portions, and as the heavier portions would continue to contract after the partition was hard and unyielding. To overcome this tendency the walls of the partition should be covered with oil by means of a small brush just before immersing the die in the bath, thus retarding the hardening and consequent contraction at this point. The stripper plate screw holes and stop-pin hole should be plugged with fire clay dough before the die is placed in the fire.

Hardening Redrawing Dies.—Redrawing dies and other articles that must have an extremely hard surface on the walls of the hole, and where a soft exterior is desirable may be satisfactorily hardened by heating to the proper temperature, then enclosing in the fixture shown in Fig. 304 and allowing a stream of water

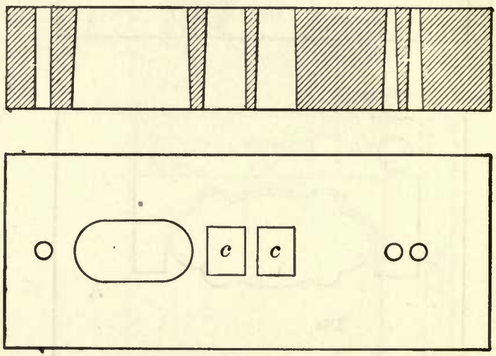


FIG. 303.

to run through the hole as shown. Do not allow the lower end of the fixture to enter any body of water as this would retard the flow of the stream through the hole, steam would form and poor results would follow.

Dies and other pieces having holes which go only part through them, whose walls must be hardened cannot be treated in a satisfactory manner unless some means is provided for forcing the liquid to the *bottom* of the holes. This is best accomplished by running a pipe nearly to the bottom of the hole as shown in Fig. 305 where one piece of pipe is fitted over another thus enabling one to use the device where holes of varying depths are encountered. In hardening pieces of this kind steam is the principal obstacle to be overcome, the water going down into the hole forces the steam out, and at the same time

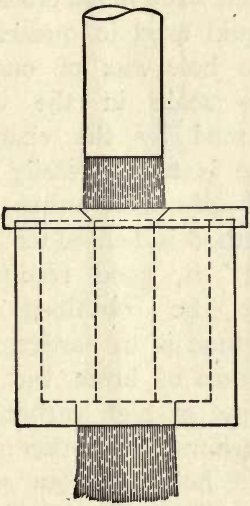


FIG. 304.

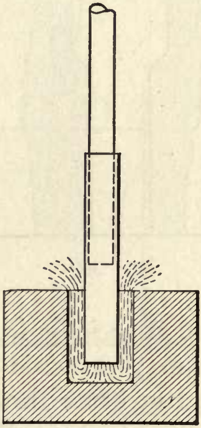


FIG. 305.

acts on the walls of the hole. When heating such pieces it is advisable to fill the hole with a mixture of 4 parts powdered charred leather and 1 part table salt before placing in the furnace to prevent oxidation of the surfaces and render them perfectly clean and ready for the action of the liquid.

In cases of the kind under consideration care should be exercised that the liquid does not enter the hole under too great pressure. The pressure should be just enough to insure the removal of steam and to carry the water out before it heats to any extent.

A die with a hole having two or more sizes as shown in Fig. 306 presents a problem that causes considerable perplexity at times. Unless the piece is heated in a manner that excludes all air from it, scale is apt to form, and while this scale *might* crack away and pass off with the liquid used in quenching if the hole was of one size, the scale in the corners formed by the change of size is not so easily gotten rid of and unless some method is devised for "striking" it, good results cannot be obtained. One method is to harden with a stream of brine, but many times, especially in the case of high carbon steel, brine may be considered too harsh. Another method is to run brine through the hole for a few seconds and then to immediately change to water as shown in Fig. 307. A method practiced with good results in one plant is to sprinkle a very small amount of powdered cyanide of potassium into the hole just before removing the die from the fire, then quench as shown in Fig. 304.

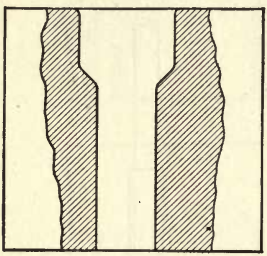


FIG. 306.

Where the condition of the hole under consideration exists care should be used in determining the velocity with which the liquid is projected into the hole. The size of the stream and the velocity should be graduated so that the water will not bound back and retard the water going into the hole or satisfactory results will not follow. In fact, the precaution just mentioned should be observed when quenching any die where the *walls* of the hole are the part desired hard.

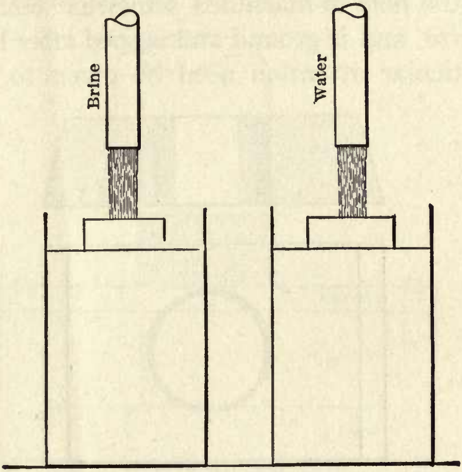


FIG. 307.

Burnishing Dies.—Fig. 308 shows a die used in burnishing the edges of a blank that had been previously punched from sheet steel. Burnishing is resorted to where edges must be highly finished, and of accurate diameters, and also furnishes a means of doing the work at a greatly reduced price as compared with polishing. As the walls of the hole taper, being smaller at the *bottom*, an immense strain tending to burst the die is given it. As a consequence the heat treatment must be such as to insure the greatest possible strength. Forcing a blank through a hole smaller than its own diameter also sets up a tendency to maximum wear of the walls of the hole necessitating an extremely hard surface. Dies of this class must have the surface of the holes highly polished in order to effectually burnish the work. When the hole is machined somewhat smaller than finish size, and is ground and lapped after hardening no particular attention need be given to retaining

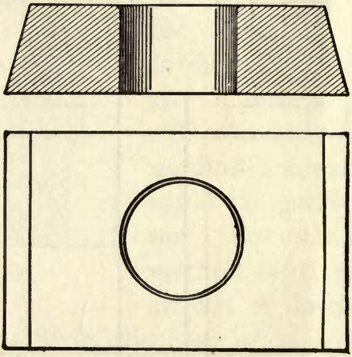


FIG. 308.

the finish of the hole, but where the working finish is given before hardening extreme care must be exercised to prevent even the slightest degree of oxidation.

Summing up the conditions just mentioned we find that the die must be hardened so as to produce the maximum of hardness and strength with freedom from oxidation. Work of this kind should always be enclosed in a box surrounded with a packing material composed of equal parts of charred leather and charcoal. Before placing in the box the walls of the hole should be coated with file maker's paste, which is made of charred leather, flour and salt, the exact proportions of which are given elsewhere. The die should be heated to a uniform red and hardened by running a stream of water through the hole. The die should be placed in a cage as

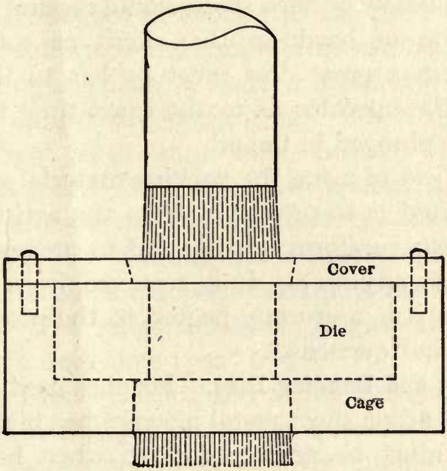


FIG. 309.

shown in Fig. 309 after taking from the box and before quenching. As the walls of the hole and a small portion of the top are the only parts hardened, any alteration in the size of the hole is not probable. The outer portions not being hardened are extremely tough and will resist the tendency to burst from the strains incident to forcing the pieces through. The paste is an added precaution against oxidation and protects the surfaces until the die is acted on by the water. In one shop that has come to the writer's notice the die is removed from the cage after the surface walls are thought to have been sufficiently hardened and immediately plunged in light oil. In this way the outer portion is somewhat stiffened. I am inclined to the opinion that this is not a safe practice especially if the pieces to be burnished are heavy, as heavy or hard stock would require a deeper penetration of hardness than light or soft stock. Then again a great deal must be left to the judgment of the operator as to the exact time the piece should be plunged in the oil.

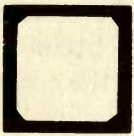
The object of using the packing material when the die is heated is to protect it from the action of the air, to secure uniform heating and to prevent decarbonizing in any way. It is removed from the box as soon as it is uniformly heated to the proper temperature and quenched.

Forming and Bending Dies.—For dies used in forming and bending sheet metal a somewhat higher temperature must be employed than when hardening tools used in cutting, as the particular condition to be overcome is a tendency to sink or cave in, and not only is a deeper penetration necessary than is the case with cutting tools, but the interior structure must be stiffer to withstand the tendency to sink. This condition can only be brought about by a higher temperature which causes the necessary changes in the steel.

Cutting or Dinking Dies.—Dies used for cutting leather, cloth, paper, etc., are called cutting, or dinking dies. They are many times made from "backed" steel, that is, the portion that bears the cutting edge is of hardening steel while the balance is of wrought iron. The two are welded together in the steel mill. When heating for hardening special furnaces, so designed that the cutting edge to the welded line is uniformly heated to the desired temperature are used in some shops. Many times a hard coal fire of fine coal is used in heating as the fire can be run so that a uniformly low temperature can be obtained. The cutting edge can be bedded down into the coals with no danger of overheating. When dipping, a bath of light oil or warm water is used. If cotton-seed oil is found to be too heavy a small amount of light mineral oil may be added to obtain the right consistency. In drawing the temper of cutting dies the material to be cut must determine the amount of drawing. The range, however, is generally from a brown to a dark blue (500° to 570° F.).

Curling Dies.—Curling and wiring dies and punches as shown in Fig. 310 should be quenched with their working faces uppermost, and by having a stream of water running down onto them. As such dies and punches are not, as a rule, made from steel containing a very high percentage of carbon they require a somewhat higher temperature than tools made from high carbon steel. As repeatedly stated the steel should not be overheated but simply given the proper temperature for desired results.

Taps.—As this class of tool has its cutting portions in the form of slender projections extreme care should be exercised when heating for hardening or the teeth will become overheated before the body of the tool reaches the desired temperature. A very good practice is to have a number of pieces of gas pipe somewhat larger and longer than the taps. Each tap may be placed in a pipe before it goes into the furnace. When heating as described there is less danger of overheating the teeth. A practice followed in some shops where screw die hobs are hard-



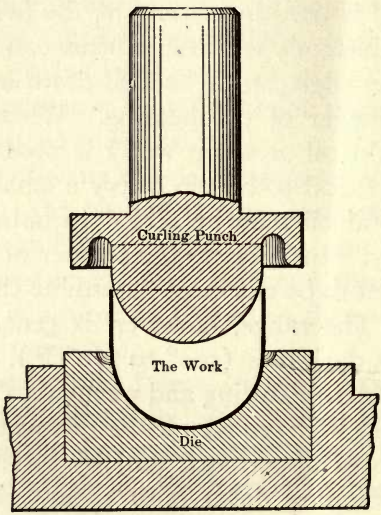


FIG. 310.

ened in quantities is to fill the teeth with the "file-maker's paste" described elsewhere. When the paste dries the hobs are placed in pipes and heated. While taps can be hardened in a still bath of brine, or water, better results follow the use of one of the type shown in Fig. 278 as the liquid is forced between the threads, thus insuring uniform cooling. Taps should not be quenched in very cold baths as a temperature of 70° to 80° F. gives better results. Taps larger than 1" diameter should be taken from the bath shortly after "singing" ceases and cooled in oil. While the temper of taps may be drawn to color more uniform results follow if an oil drawing furnace is used. If the temper is to be drawn to color the surface of the flutes may be brightened by grinding with some form of abrasive wheel making sure that a small amount is ground off the *face* of the cutting teeth. This is necessary as this surface is liable to contract in hardening more than that immediately back of it where there is sufficient stock to prevent contraction; as a result the cutting edge of the tooth is *slightly* lower, and while this amount is very small it is sufficient to cause the tap to bind when cutting, especially if it is used on metals where it cuts very close to its own size.

The temper to which taps should be drawn varies with the size and the use to which they are to be put. Those used for sizing, and which remove but a very little stock are sometimes left as they come from the hardening bath, more often though they are drawn to a pale yellow (430° F.). For ordinary use they are drawn to 450° to 460° F. Small taps used in screw machines are many times drawn to a brown yellow (500° F.), or to a light purple (530° F.), depending on the strains they are to receive. If quenching is necessary to keep the temper from running too much, *warm* oil should be used.

Steel for Taps.—In most small shops and also in some of considerable size a certain "temper" of crucible tool steel is used for most cutting tools.

While this practice does away with the mixing of various grades and the annoyance caused thereby, mixing is not necessary and seldom happens where a system of marking and keeping in separate racks is employed.

Maximum results follow the use of steels suited for the individual tool, or for tools to be used for a certain class of work. While "straight" carbon steels containing the proper percentage of carbon give good results on some classes of work, certain of the alloy steels give very much better results on other classes. For instance, 1.1 to 1.25 per cent carbon gives fair results when used for taps to work on brass and cast iron, yet a steel of this same carbon content with an addition of 2.0 per cent tungsten will under the same conditions do many times the amount of work. This addition of tungsten, however, calls for a higher hardening heat; the makers recommending 1525° F.

Vanadium steel made especially for taps, etc., gives excellent results so far as strength is concerned and is to be recommended where a slight change in pitch is not a serious matter. Straight carbon and tungsten steels when properly treated generally contract in length, but this contraction can be anticipated when the tool is threaded, but vanadium steels may either contract or expand and for this reason cannot be used where accuracy of pitch is essential.

Taps that are pack hardened do not, as a rule, change in pitch if the blanks are properly annealed and low heats are obtained when hardening.

High speed steel is especially suited to tap making, especially for those used on screw machines. It should be heated to about 2150° F. for hardening. In tempering they should be drawn to form 500° to 950° F. according to size and the shock they are to receive when in use.

Threading Dies.—Threading dies are made from a variety of steels. This is necessary on account of different demands on the tool resulting from the variety of metals to be threaded, and the opinions of men in charge of work. When the metal to be threaded is easily machined and free from grit, almost any good tool steel of the proper carbon content gives good results if properly treated. In shops where the screws are made from *iron* wire, or from stock that, on account of its composition, or from other causes, subjects the die to abrasive action, it is many times advisable to use a suitable alloy steel that will resist the tendency to wear from the causes mentioned. If alloy steels are used the treatment must correspond to the requirements of the metal; however, instructions usually accompany steels that require special treatment.

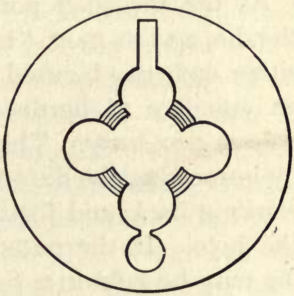


FIG. 311.

Threading dies are made in a variety of forms. The ordinary round, or button die shown in Fig. 311 is made either solid or adjustable. If a solid die is to be hardened the chief requirement is suitably hardened threads, this hardness extending out into the body of the tool for a distance that insures good results. In some shops it is customary to harden the whole die to as uniform a degree as possible and then draw back the portions that should not be as hard as the cutting portions. In other shops it is considered best practice to harden the threaded portions and for a distance out into the die leaving the balance soft, while the requirements in other places make it necessary to harden the portion just mentioned and stiffen the balance of the die in oil.

As the threaded portion is the essential part of the die, and as most "button" dies are so made that either end may be used in cutting, it is apparent that an equality of hardness throughout the threaded hole is necessary. This result can be accomplished by immersing the die edgewise in a still bath of brine working back and forth to force the liquid through the hole. If the outer portion is desired soft the die may be held in a fixture so constructed that the portion desired soft is covered.

Milling Machine Cutters.—Probably no one class of tool is a source of greater anonyance to the hardener than the cutters used on milling machines and generally known as "mills." The troubles experienced should not, in all cases, be attributed to the hardener. This form of tool is costly to produce and in many factories is used in large quantities. Efficiency is many times based on the length of life of the tool regardless of the quantity of work produced, and this has led to the use of slow speeds and fine feeds, where, under different conditions, namely, maximum speeds and feeds for properly designed tools, those considered would have been found sadly wanting and the hardener blamed because they would not do the things easily accomplished by properly designed tools hardened, and tempered exactly as these were. A mill with a great number of fine teeth where but few are required collects chips between its teeth and if coarse feeds are resorted to the teeth will break. As the cooling liquid cannot have free access to the teeth slow speeds must be resorted to or heating will result. If the mill is run at a high speed, which, under right conditions, would be easily possible it will heat and the temper will be drawn to a point that causes rapid dulling of the teeth, consequently, as the tool is too soft, and the teeth are too weak to stand up, the fault is usually put up to the hardener, and he, poor fellow, knowing nothing about tool design, does not know what to do to bring about correct results. The writer has seen mills having forty cutting teeth, which were being used in milling a semi-circular groove through a piece of work, that had to be run at a speed and feed that made it impossible to produce more than 30 pieces in ten hours. These were replaced by others made from steel of the same make and "temper," which contained 7 teeth and produced 125 pieces in the same time. Both were hardened and tempered by the same man and as nearly as possible in the same manner.

Slender teeth are conducive to weakness. Cutter teeth should always be made of a shape that insures maximum strength because if a tooth springs it cuts deeper into the work than it should, thus putting a breaking strain on the tooth. If the angle at which the tooth is backed off in grinding is not exact, trouble will follow. If it is backed off too much, the fine cutting edge does not receive the support it should and as a result flaxes off, or, on the other hand if it is not given sufficient angle the heel will rub, thus causing the tool to heat and dull quickly. These are conditions that the hardener is in no way responsible for, yet, unfortunately, he is many times scored for these and similar troubles, the cause of which he is entirely ignorant.

The writer's attention was called, a short time ago, to a batch of slotting mills made from a well-known brand of tool steel. These mills were to be used in cutting slots $\frac{1}{4}''$ deep in 0.30 per cent open hearth steel forgings that were well annealed. Several of the mills were tried, but could not be made to work as they would dull quickly and could not be forced into the stock. Examination showed that they were not given sufficient angle in backing off the cutting edges. After being reground to the proper angle they were pronounced highly efficient. In this case the opinion of those in authority had been divided, by some the hardener was considered at fault, while others claimed the steel was unfit for the purpose. The incidents mentioned in connection with milling cutters are characteristic of troubles that are met with frequently in many shops. If the cause of the trouble is not discovered what is more natural than to lay it to the steel, or the hardener.

If the hardener is blamed for troubles that originate outside of his department, and he hasn't sufficient knowledge of tool design to enable him to locate the trouble, he naturally changes his method of treatment of that class of tool with results that are not to his credit. Troubles of the character just mentioned are not peculiar to milling cutters, but undoubtedly are of more frequent occurrence with this class of tool than any other.

Steel for Milling Cutters.—Milling cutters are made from steel containing all the way from 1.00 to 1.60 per cent carbon. It may also contain varying proportions of tungsten and other elements. The varying proportions of these elements necessitates a variation of temperatures when heating for hardening in order to secure the best possible results.

Hardening.—The size and design of the tool also has a bearing on the hardening temperature. Extreme care should be exercised, when heating, that the teeth do not become overheated before the body of the tool has reached the desired temperature, which *must* be uniform *throughout* the piece. *Should any portion of any piece being heated for hardening become overheated the piece should be removed from the fire and allowed to cool*, after which it may be reheated and hardened. Although muffle furnaces are not generally used at the present time, on account of the comparatively high cost for fuel and maintenance, they afford an ideal method of heating tools of the character under consideration. In the absence of a muffle furnace the mill may be heated satisfactorily in an ordinary oven furnace by placing over it a piece of sheet iron bent so as to prevent the direct action of the heat. This protecting piece should not lie directly on the work, but should be far enough from it so that the heating will be from radiation. It is a good plan to surround the teeth with dry fire clay or some refractory material during the first stages of the heating to retard the action of the heat at these portions until the body of the tool has reached a low red when it may be raised and the material spread over the floor of the chamber and the mill allowed to rest on it. The mill should be turned over and around occasionally as it commences to get red to insure uniform heating. Toward the latter part of the heating operation it is well to raise the tool from the floor of the chamber by means of several small pieces of fire brick, that have been heated in the chamber thus allowing the heat to circulate around all parts of it. Tongs should seldom or never be used when quenching a mill as they prevent the water having free access to every part. A hook of the design shown in Fig. 312 answers the purpose very well. If a still bath is used long cutters should be immersed lengthwise and worked up and down and around in the bath, first in one direction then in another, alternating the movement frequently. If a bath of the design shown in Fig. 278 is used, where the liquid is projected uniformly against the teeth it is only necessary to work them up and down slowly to cause the liquid to pass through the hole. Thin mills should be dipped vertically to prevent springing,

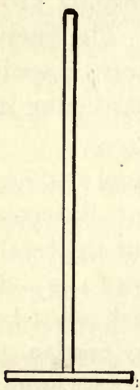


FIG. 312.

as shown in Fig. 313. A method employed by one very successful hardener when dipping thin mills consists in dipping vertically then rotating the mill slowly by means of a piece of wire thus bringing it constantly in touch with agitated water. Another method employed in a shop where many slotting

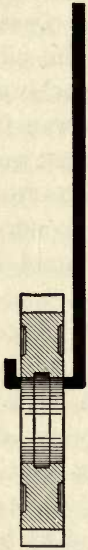


FIG. 313.

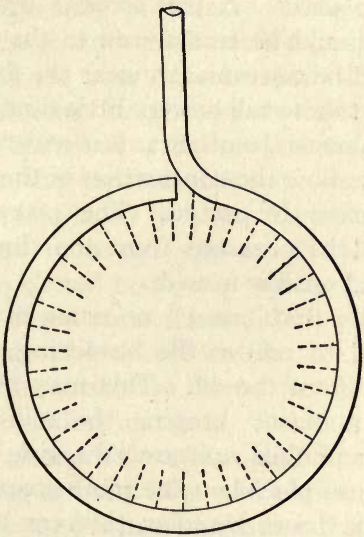


FIG. 314.

cutters, of from $\frac{1}{4}''$ to $\frac{1}{2}''$ thicknesses are made, consists of immersing in a bath of water having a supply pipe bent in the form of a circle as shown in Fig. 314. Numerous small holes are drilled on the inner portion of the circular pipe to project small streams toward a common center. The mill is held so that these streams will impinge against the teeth.

Mills that are $\frac{1}{2}''$ or more in length should be kept in the bath until the "singing" incident to the immersion of red-hot steel in water ceases and then be plunged into oil and left until cold. While some hardeners gauge the time of singing by the ear, it is better practice to gauge it by the vibration transmitted through the hook used in holding the piece, to the hand. A few seconds after this ceases the mill should be transferred to the oil. The oil bath should be conveniently near the first quenching bath so that there will be very little time lost in transferring from one to the other as it is never safe when quenching to allow the contraction of the metal to stop and expansion to set in. The process of contraction should be constant from the time the steel is immersed until it is cold.

Mills that are $\frac{1}{2}''$ or more in length should be heated to relieve the hardening strains as soon as taken from the oil. This may be done by holding over a blaze; keeping the mill revolving all the time and thus uniformly heating until a particle of moisture placed on the piece steams. If the temper is to be drawn by color, time can be saved by brightening the *backs* of several of the teeth and finishing the tempering operation at this time. Mills made from ordinary carbon steels and used for ordinary lines of work are tempered to a light straw color (430° F.).

If a quantity of mills are to be tempered, time will be saved and more uniform results obtained if they are drawn in an oil-tempering bath and the temperature gauged by a thermometer. In this way absolute uniformity of temper may be obtained, which is quite impossible where tools of irregular contour or ununiformity of size are treated by the color method.

If the mill *must* be tempered to color, a very common method consists in drawing on a heated plug. While this gives good results in cases where extreme care is exercised, it is a source of a great deal of trouble at times, especially in the case of large mills and those having large and small sections adjacent to one another. If the plug is to be used the mill should have several teeth brightened on their *backs*. It should then be held over a fire and heated until lard oil placed on the teeth *commences* to smoke. The mill may now be placed on the plug which has been heated almost to a red, and revolved. The brightened surfaces should be closely watched, when they show a light straw color it should be plunged into *warm* oil, but never into *cold* water.

Let us return for a moment to the subject of baths used in quenching milling cutters. The one most commonly used is clear, *cold* water. Right here we may get into trouble as extremely cold baths should seldom or never be used when hardening this class of tool. There are few cases where the water should be below 60° F. and many cases where 70° F. will give better results. The bath, however, should be of generous proportions, especially if it has no means whereby a constant supply of liquid is being fed into it. If it is provided with a supply pipe, this should have a steam pipe entering it so that the incoming water can be brought to the proper temperature before coming in contact with the work. A thermometer should be kept conveniently near in order that right temperatures can be readily obtained. Both the inlet and steam pipes should be provided with valves in order that the desired amount of liquid and the proper temperature may be had.

If brine is considered the proper quenching medium the bath may be provided with a storage tank and pump and a constant supply of this liquid of any desired temperature may be had. If oil hardening steels are used in making the mills a bath having a constant supply of oil of the proper temperature may be used. Both the oil and brine baths are illustrated and described under "Baths."

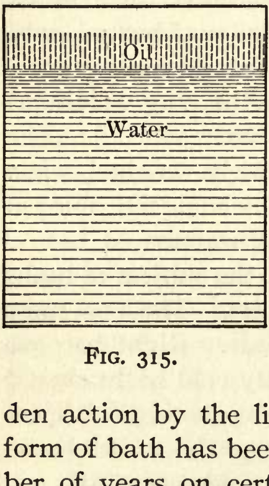


FIG. 315.

Many hardeners use a bath of water or brine with an inch or two of oil on the surface as shown in Fig. 315. The red-hot steel passing through the oil takes a thin coating of oil which prevents too sudden action by the lighter liquid underneath. This form of bath has been used by the writer for a number of years on certain classes of work, especially where the teeth of mills were cut with a sharp-pointed cutter. The oil lodging in these sharp cuts prevents the rapid action incident to a lighter fluid acting directly at these points.

Thin Cutters.—Screw slotting cutters, slitting saws and other forms of very thin cutters are hardened very nicely between flat plates. These plates may be so arranged that when the cutter is placed between them they will submerge in oil or water, or in the case of medium thin cutters the faces of the plates may be smeared with oil, or in the case of *very* thin cutters the plates alone will absorb the heat fast enough to produce desired results. Where but a few cutters are hardened at a time ordinary bench plates of convenient size may be used. This, of course, necessitates the services of two men, the hardener and a helper. Where the work is done in large quantities such practice would prove costly and a special device where the movable plate is operated by the foot may be employed, thus making it possible for one man to tend to the heating of the cutters and to operate the plate.

Troubles.—In an experience of over twenty years in looking into other peoples' troubles the writer has found that as many, if not more, difficulties are encountered by hardeners in treating milling machine cutters, as any class of cutting tool. Most of these troubles are directly traceable to comparatively few causes. The most common cause is ununiformity in heating. As previously stated, a piece of steel that is not uniformly heated is bound to cause trouble when it contracts in the operation of hardening. If any portion of a piece has been overheated and then allowed to cool in the furnace to the temperature of the balance of the piece, that portion has the same structure internally as would have been the case had it been hardened at that heat, and on account of this difference of grain structure cracks are liable to result. Improper handling when in the bath is more common than is generally known. In order that steel may harden satisfactorily it is necessary that it should contract uniformly. This, in the case of cutters of irregular shapes, means skillful handling in the bath. High heats are a source of more or less trouble, but not so frequently encountered at the present time as a few years ago on account of the better knowledge hardeners have of the effect of high heats on steel. Underheating is often found to be a source of trouble not generally considered as a piece of steel may be hardened so that it will be file hard and yet not be in condition to cut other metals. While steel should not be heated any higher than is necessary to produce desired results, it must be brought to the *right* temperature to get these results.

Draw Broaches.—This form of tool, if made from straight carbon tool steel should be hardened at a temperature that insures the greatest possible tensile strength, as the tendency is to pull apart when in use. As much trouble is experienced from insufficient chip space between the teeth, as from improper hardening. This is a defect over which the hardener has no control, and ignorance of the cause of the trouble may lead to constant changes in methods of treatment until the hardener loses confidence in his own ability. Very many forms of cutting tools show remarkable ability to stand up and retain a keen cutting edge when pack hardened, but draw broaches to be used for heavy cuts do not stand up as well as when heated in a tube and plunged in a light oil to which has been added a small amount of alum or borax, preferably the former. Larger broaches are usually quenched in luke warm water which has a thin coating of light oil on the surface, and the temper drawn to a full straw.

Rivet Sets.—The excessive strain and wear to which rivet sets are subjected renders necessary the exercise of extreme care in heating and quenching, and also a considerable display of ingenuity, at times, to determine the best method to pursue to get desired results.

Experiments are many times desirable, especially when using the so-called alloy steels to determine the exact heat treatment necessary to obtain good results. Steel makers' instructions regarding temperatures best suited to desired results are not always to be relied on when the steel is used for some specific purpose entirely out of the range anticipated by the steel maker. The writer recalls one particular steel that was used for rivet sets. This steel when hardened at the temperature called for in the instructions on the bar did not show even average results. When heated 150° F. higher, or to 1500° F. it gave remarkable results.

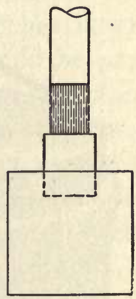


FIG. 316.

When quenching it is advisable to rest the sets on the plain end and send a stream of water directly into the impression as shown in Fig. 316.

Large Rings.—When heating large rings and similar pieces for hardening it is necessary to have a suitable furnace or satisfactory results cannot be obtained. Fig. 317 shows a gas-burning furnace especially designed for such pieces. This furnace being round in form will heat a round piece more uniformly

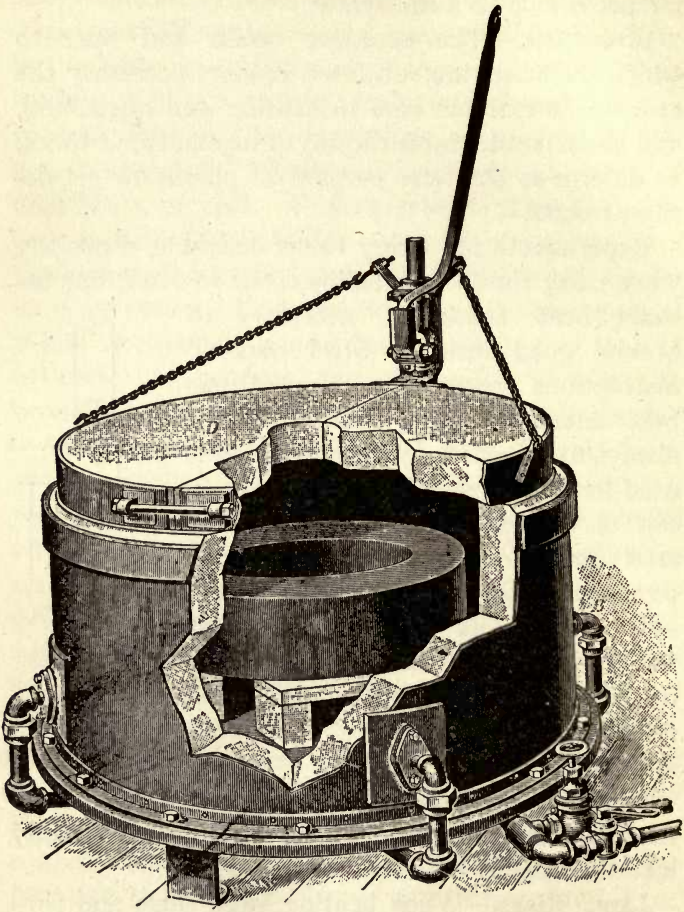


FIG. 317.

than one rectangular in form unless extra precautions are taken with the latter.

If it is necessary to use an ordinary case hardening furnace a piece of sheet steel, or sheet iron several inches larger each way than the piece should be placed on the floor of the furnace, on this should be several pieces of iron all of a uniform thickness, for the ring to rest on. After being placed in position the ring should be covered with granulated charcoal or with a mixture of charcoal and charred leather and gradually heated to a full red. The heating must not be carried on any faster than is consistent with a uniform temperature throughout the piece. If many pieces of a size are to be hardened it is advisable to make iron boxes several inches larger each way than the ring. The boxes should be provided with covers. In the bottom of each box place several inches of granulated charcoal; on this place the ring, filling the box with the packing material. After the cover is in position the box may be placed in the furnace and the ring gradually heated to the desired temperature.

As the red-hot ring would go out of shape if held in any but a horizontal position, and as all portions are desired hard, it is necessary to provide a special holder for use in dipping in the bath. This holder should be so designed that water can have free access to all portions of the ring. The supporting parts of the holder should be worked nearly to a sharp edge so as not to retard the action of the water.

The bath should be of the design shown in Fig. 278 having jets from the bottom and top and pipes up the sides to force water against the circumference of the ring. When the piece has cooled throughout to the temperature of the water it may be removed from the bath and immediately heated to remove hardening strains. While this heating is going on the piece may be brightened and the temper drawn the desired amount.

Spring Threading Dies.—Spring threading dies, hollow mills and similar tools having holes running *through* them, or part way through them, and whose cutting portions are on the end should be quenched in a bath of brine with the cutting end up to allow the steam to escape readily. They should be worked up and down in the bath to force the liquid to all portions of the hole.

For most work the cutting portions should be drawn to a full straw color (460° F.) and the balance drawn to a blue.

Spring Tempering.—Such articles as springs, screw drivers, etc., are hardened and tempered in such a manner that if bent they will return to their original shape when the strain is removed.

Small articles are usually hardened in oil preparatory to spring tempering, as water would cause brittleness that could not be done away with in the tempering process. Medium-sized pieces are many times hardened in warm, or even hot water, while extra large ones may be hardened in warm or lukewarm water.

The object of the hardening process in spring tempering is not to produce actual hardness, but stiffness, and the less brittleness produced by the operation, the better. Steel hardened in oil is much tougher than if hardened in water and it is advisable, whenever possible, to use oil, even though it is necessary to add some substance to it.

For most purposes special grades of spring steel give better results than tool steel. A good grade of open-hearth steel containing from .40 to .80 per cent carbon, if made into springs, will prove more satisfactory than a grade of tool steel costing five times as much.

In the selection of steel for springs to be subjected to but little strain almost any good grade of spring steel will answer. If, however, it is to be subjected to very rough, hard usage it is best to obtain directly from the steel maker the necessary information regarding the exact grade needed unless the user has had education or experience that enables him to rightly decide as to the quality needed.

When heating for hardening employ the lowest heats possible consistent with good results. As spring steel contains less carbon than ordinary tool steel it may be necessary to heat it a trifle hotter to obtain satisfactory results. This should always be determined by experiment before going ahead with a batch of work.

The nature of the spring must determine the character of the bath. For ordinary purposes sperm oil works well, at other times a good grade of lard oil, cotton-seed oil, fish oil or some of the commercial hardening oils may be found to answer the purpose.

It is necessary sometimes to add certain ingredients to the oil to obtain desired results. The following formula is used by a manufacturer who makes large quantities of springs about the size of ordinary clock springs:

Sperm oil..................	15 parts
Beef tallow................	2 parts
Resin......................	1 part

At times it has been found necessary to add a piece of bee's wax to the above to prevent a granular condition in the hardened steel.

Some hardeners use turpentine in place of resin in the above formula. Its use is not to be advocated unless extreme care is exercised as it is highly inflammable and serious burns may result.

Springs should never be heated in a furnace where oxidation of the surface takes place, as this oxidation may assume the form of blisters that would prevent the contents of the bath coming in intimate contact with the steel at those portions, and would result in soft spots that would be fatal to the spring. Resin in the bath has a tendency to strike any ordinary scale; but, it is best to do away, as far as possible, with oxidation.

Drawing Temper.—If but a few springs are tempered at a time, the temper may be drawn by heating until tallow, sperm or lard oil will catch fire (flash) from the heat in the steel. To determine this the spring must be removed from the fire when the oil on its surface starts to burn; if it continues to burn when away from the heat of the fire it has absorbed sufficient heat, if not, it should again be heated. Very heavy springs may have the oil flashed off two or even three times. The method just described answers when the steel from which the springs are made contains a fairly high percentage of carbon.

When low-carbon spring steels are used flashing cannot be resorted to as it leaves the springs too soft. In such cases they must be brightened and the temper drawn by color. The exact temper color cannot be stated arbitrarily as the carbon content of the steel must determine this, but usually it ranges from a light blue to a dark blue.

When work is done in quantities it is always best to place the pieces in a perforated pail which is immersed in a kettle of oil over a fire and the whole heated until the right temperature is reached. This is determined by means of a thermometer. The kettle should be so designed that a cover may be placed on it in case the oil catches fire. The cover should be provided with a long handle, in order that the operator will not be burned when putting it in position. It should be made high enough to receive the thermometer.

It is advisable to leave the thermometer in the oil and allow it to cool with the oil. If it is necessary to remove the thermometer place it where no draft of air can strike it, as sudden changes of temperature will cause the glass to crack.

Certain forms of springs are heated in a crucible of melted salt for hardening, while others are heated in melted glass. These provide excellent mediums for uniformly heating springs of unequal size in the various portions.

Heavy springs and screw drivers are tempered at times by heating in the fire and gauging the temperature by drawing a hard-wood stick or a hammer handle across a corner of the piece. If the shaving removed catches fire from the heat in the steel further heating is unnecessary. If there is a liability of the piece being heated too much, it may be checked when it reaches the proper temperature by plunging in *warm* oil.

Second Blue.—Springs made from high-carbon spring steel and tool steel are sometimes tempered to the *second blue*. This is done where the rich blue appearance is desirable when the springs are located where they can be seen on exhibition machines. To accomplish this the springs are polished after hardening, placed in a pan of sand and shaken over a fire until the proper temper color appears. The colors will show as stated in the Temper Color Chart. After the colors have all appeared as set forth the surface assumes a gray color followed by a blue which is called the second blue. When the second blue appears the spring should be immersed in *warm* oil to prevent the temper going too far.

The writer has found prolonged heats to be a common cause of poor results in hardening springs. Such heats not only tend to oxidation but also weaken the steel. The practice of raising a furnace to a given temperature and then allowing the springs to soak in the fire until they reach the furnace temperature cannot be condemned too severely. Anyone can convince themselves of the truth of this assertion by heating two springs, one by a method that insures uniform temperature as rapidly applied as possible, and the other by soaking, then testing in comparison with one another.

A manufacturing concern condemned some 0.60 per cent carbon spring steel being under the impression that it would not harden. Investigation showed that this steel was heated in a furnace with a temperature of nearly 1500° F., the springs being left in until they were of the same temperature as the furnace. Another batch heated quite rapidly and only exposed to the heat for about one-quarter of the customary length of time and quenched at a lower temperature hardened perfectly. When the temper was drawn these springs met every demand in the testing. As these springs had to stand very heavy strains the tests were correspondingly severe.

As in annealing prolonged heats in hardening should always be avoided as they change the structure of the steel and render it unfit for use.

Drop Forging Dies.—Drop forging dies, when made for general work, tax the ingenuity and resourcefulness of the hardener to a degree not experienced with any other class of tool. As they must be treated so as to produce a hard face and a depth of penetration sufficient to prevent sinking when in use the problem becomes difficult in proportion to the intricacy of the design of the impression and the resistance of the stock to be forged. The producing of the necessary hardness and penetration without warping the die complicates the problem. Forging dies are of two general classes, namely *hot* forging dies and cold dropping dies. The former in shops doing general jobbing work are generally made from open hearth steel containing 0.60 to 0.80 per cent carbon. In other plants they are made from crucible steel containing about the same proportion of carbon.

Cold dropping dies are usually made from crucible steel containing a higher percentage of carbon in order to obtain a deeper penetration and a stiffer backing to the bottom of the impression as the tendency to sink is greater where cold metal is struck. All portions of a die block that are to be machined should first be rough machined then thoroughly annealed before the impression is finished and the tang machined to size. This annealing heat should be about 50° F. higher than the heat employed in hardening.

In shops where the volume of business warrants the outlay continuous furnaces are used in heating the block for hardening. These furnaces are so designed that the portion where the die enters is not very hot, while the portion at the opposite end and where the die leaves the furnace is of the temperature the die is to be heated. The use of this furnace, of course, insures ideal conditions. Such furnaces, however, are not in general use and the hardener in the average plant finds it necessary to produce satisfactory results by the use of an ordinary furnace. This can be done by the exercise of ingenuity and extreme care. When possible the die should be placed in the furnace before it is heated very much and the temperature raised gradually to prevent overheating of the edges and corners.

Dies should be placed in shallow boxes with the face embedded in charred leather, or animal charcoal. To accomplish this a layer of one of these materials about 2″ deep should be placed on the bottom of the box and the face of the die laid on this. The box should be filled with the packing material extending up at least 1″ beyond the depth of the impression. Where a general line of work is done it is necessary to have boxes of various sizes and depths to satisfactorily accomplish the desired results. The writer has advocated for years filling

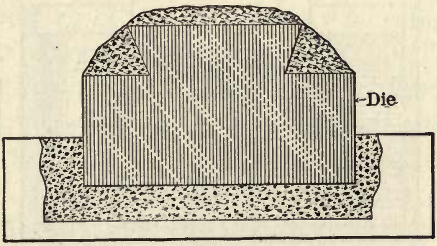


FIG. 318.

in the sides of the tang with fire clay dough as shown in Fig. 318, and placing a layer of the same on top of the tang, also, as shown. This prevents the hot gases acting directly on the steel at these portions. Many experienced hardeners do not consider this necessary, but results have proven this precaution to be of value entirely out of proportion to the expense involved, which is slight. The furnace should be heated gradually, and at no time should the temperature be allowed to exceed the temperature to which the die is to be heated, or some portion will become overheated and cracks will result.

In order to successfully harden dies of this character a bath adapted to the work must be used. It is folly to attempt to obtain good results unless a plentiful supply of water that can be projected against the die is available. A form of bath that gives excellent results is shown in Fig. 319. It will be noticed that the overflow pipe is telescoped in order that any desired level of water may be maintained in the bath as this should be somewhat above

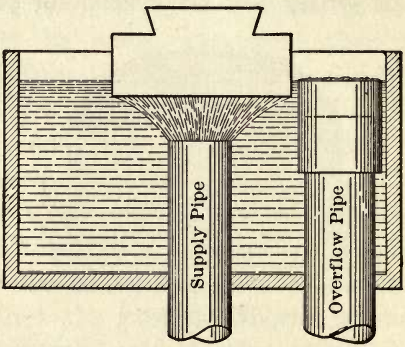


FIG. 319.

the deepest part of the impression when the die is face down in the bath.

In some shops it is customary to partially harden the tang before hardening the face. This tends to prevent the die from springing when the irregular surface of the face is hardened and is done by placing the die on the supporting wires in the bath with the tang *down*, then opening the valve in the supply pipe and allowing the water to play against the tang. The overflow pipe should be adjusted so that the contents of the bath will come about 1″ up the *body* of the die. The water should be allowed to play against the tang until the red has disappeared from the portion under water, then the position of the die is reversed and the flow of water is allowed to come against the face. In the meantime water should be poured from a dipper or some convenient retainer onto the tang to keep it from drawing back until the surface of the face is below a red. When the face has lost every trace of red cease turning water on the tang and allow the red in the body of the die to work back through the tang. When the die has cooled to the temperature of the bath it may be removed and heated to remove hardening strains. There are several methods of doing this. One method consists in placing in a continuous furnace timing the travel of the die so that it will reach a temperature of 250° or 300° F. as it comes out. It may then be taken to the tempering fire and the heating process continued until the temper is drawn the right amount, if it is necessary to temper it further than removing strains. Another method consists in taking directly from the bath to the tempering fire and relieving strains there. This is an uncertain method as the die, unless turned frequently, is not heated uniformly and if the heat enters one portion while the balance of the block is cold and unyielding it is very apt to break.

A method employed with very good results in a number of hardening plants is to place the die in a steam box on wire rods. When the box is closed steam is turned on and the die is gradually brought to a temperature of 212° F.

Another method is to have a tub of water with a steam pipe entering at some convenient point. The die is placed in the water, the steam turned on, and everything brought to the boiling point. The boiling is kept up until the die is uniformly heated. It is a mistake to immerse dies of intricate design, or with projecting portions from the face directly into boiling water as is sometimes done, as the slender portions when subjected to the high temperature expand faster than the balance of the piece and, as a result, are cracked or broken off.

When hardening dies having projections from the face, or which have delicate portions that would be liable to crack from the unequal contraction in the bath, it is a good plan to cover such portions with heavy oil, or soap just before immersing in the hardening tank, making sure that there is a generous supply of the substance at the point where the projection joins the block. This will retard the hardening at these points thus producing a more uniform contraction. The water from the supply pipe will wash the oil or soap away in time to produce sufficient hardness.

A method of quenching employed at times necessitates the use of a bath of the design shown in Fig. 320. In this case the die is lowered into the bath until it rests on the supporting wires with the tang well back toward the wall of the tank. The jets of water playing against the face cools it very nicely. In the case of dies with impressions that might cause steam to pocket in them this form of bath works well as the steam can readily escape.

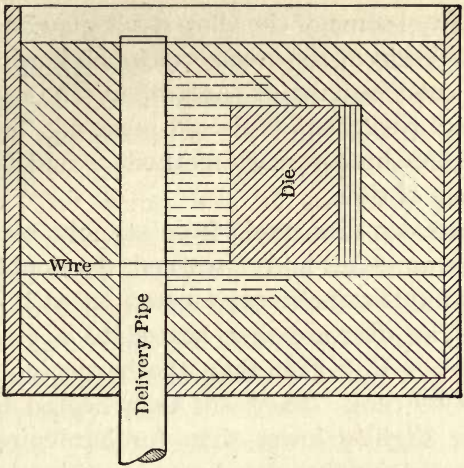


FIG. 320.

Another method is to lay the die on wires in a tank from which the water can escape without coming up around the die and from an overhead pipe allow the water to play against the face which is, of course, uppermost as shown in Fig. 321.

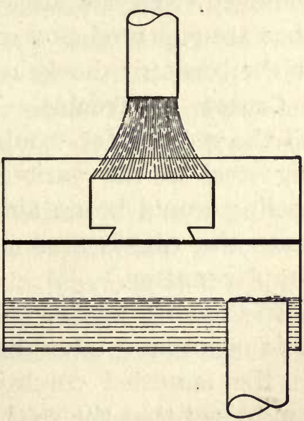


FIG. 321.

The writer is inclined as a result of experience to favor the first method described for the majority of work. Realizing, however, that there are cases where special methods of quenching must be resorted to to accomplish certain desired results.

Dies from some of the alloy steels may be hardened in oil; certain of the steels *require* oil hardening, but in such cases instructions accompany the steel stating the exact treatment it should receive. To attempt to describe these various methods would be a needless waste of time.

When worn dies made from straight carbon steel are to be annealed and re-worked, the double annealing process is sometimes resorted to with good results. The dies are first heated to a temperature 75° to 100° F. higher than the hardening heat and allowed to cool. They are then heated to a temperature slightly lower than for hardening. Some hardeners claim that dies heated in this way are less liable to go to pieces when hardened.

Reworked dies should have sufficient stock reremoved from the face to get beneath the portions that are ruptured as a result of the compression due to the constant shocks received when in use.

Causes of Trouble.—To attempt to enumerate all the reasons for troubles experienced when treating steel in the various processes of heating and cooling would be an almost impossible task, but to state the causes *commonly* experienced is a much simpler matter.

In the shop having the ordinary furnace capacity it is considered advisable to purchase all tool steel in the annealed condition. While it is generally considered that the steel maker knows better how to anneal the product of his mill than the average man in a heat-treating plant, he cannot anticipate everybody's requirements. As a result mill annealed steel may or may not be in the best possible condition for hardening. Then, again, a considerable proportion of the annealed steel purchased from a local steel warehouse is not annealed at the mill, but by some local concern equipped with suitable furnaces. The writer was at one time connected with a concern that regularly annealed about two tons of tool steel a day for local steel houses. We could not anticipate the uses to which the steel was to be put, as a result we attempted to get it as soft as possible without in any way injuring the metal.

As previously stated softness is not the only requirement. There are many other things to be considered but some of these cannot be anticipated until one knows what is to be made from the steel. Strains cannot be successfully removed from steel unless it is blocked out somewhere near to the finished shape. This is especially true of such tools as dies, milling cutters, gauges, etc. As a result, steel to be made into such tools *should* be carefully annealed after roughing out, even though it has been previously annealed.

Steel that has been *over annealed* is in no condition for hardening, and should be re-annealed to remove strains and to refine the grain previous to the hardening heats. Many tools are ruined in the process of hardening, because the steel was not in condition to harden.

As commercial bar steel has a decarbonized surface occasioned by the action of the oxygen in the air on the carbon in the surface of steel during the process of rolling and hammering in the steel mill, it is necessary to remove this exterior portion for a depth sufficient to get beneath the affected metal. The surfaces of forgings are decarbonized in the same way. In order to get good results when hardening an equal amount of surface stock should be removed from all parts of the piece so that there may not be left at any point metal that does not contain as much carbon as the balance of the piece or unequal contraction or ununiformly hardened surfaces will result. It is always better to remove a trifle more surface stock than not quite enough.

Pieces that are to be hardened should *never* be straightened when cold. If a piece of steel that is to be made into a tool is bent, heat it red hot, straighten, and then anneal. If steel is straightened when cold it is almost sure to return to its original form when heated for hardening.

Overheating is a common cause of trouble. The steel is weakened because the interior structure is coarsened. Overheating also has a tendency to cause steel to crack in a direction corresponding to the axis of the piece.

Ununiform heating of steel, when hardening, is the most common source of trouble experienced by the hardener, and manifests itself in cracks, or breaks, the direction of which corresponds to the line of ununiformity of temperature.

Long-continued heating (soaking) renders steel weak, and should always be avoided. On the other hand heating should never be carried on more rapidly than is consistent with a uniform temperature throughout the piece.

Steel as it comes from the mill sometimes contains laps or seams. If either of these defects are noticed the steel should be returned to the party from whom it was purchased, as any tools made from such stock are almost sure to go to pieces when hardened. Such defects, however, are not common at the present time, as the inspection of ingots and bars is much more thorough than it was at one time. Such defects may be so located that they cannot be seen until the piece breaks. If the steel contained a seam its walls will generally have a much different appearance than the walls of a crack which took place in the bath. In the latter case they will be clean except for such stains as the contents of the bath may have caused.

Piping is a defect not very often seen in commercial tool steel. When the ingot of steel is cooling in the mold the portion near the center remains fluid much longer than that near the walls of the mold, as a result the center portion contracts more than the balance, leaving a depression at the center at the top of the ingot. This defective portion is cut away (cropped). At times the defect extends into the ingot for a greater distance than the operator is aware of, and, as a result, it is not all removed. When the ingot is heated for rolling the walls of these defective portions become oxidized and do not weld together, the defect extending through a number of bars. Ingots and bars are subjected to a very rigid inspection in all first-class mills and if "pipes" are discovered the bars are cut up and remelted. No reputable steel maker would knowingly allow a piped bar to get out of the mill, yet once in a while one will get by. When discovered such bars should be returned, as any tool made from them, unless the piped portion was cut away, is almost sure to go to pieces when hardened. The writer knows of a number of concerns using immense quantities of tool steel who have every bar that is to be made into costly tools inspected and tested before it is placed in the stock rack. This is done in a very systematic manner. A thin piece is cut from each end of the bar by means of a power saw and the surface is carefully inspected under a powerful microscope for imperfections. If none can be found the pieces are hardened and then broken as nearly as possible across the center. The fractured surfaces are then inspected under the microscope, if no defects appear one or more of the pieces are tested with a "Shore Scleroscope." If the steel shows up all right under the inspection and test the bar is marked O.K. and placed in the steel rack.

At times a bar of steel will be found that shows disintegration of some element. This is caused by the particles of the element separating from the steel and pocketing at some point. It is almost impossible to detect this defect until the piece is machined, and even then the removal of material may not uncover the pocket, and the piece may be finished and turned over to the hardener. In all probability it will go to pieces in the bath. If the bar from which a piece containing a defect of this kind can be located it should be condemned and returned to the party from whom it was purchased. Defects of this kind are rare, and for this reason but little understood by the men engaged in heat-treating steel.

Hardened pieces, especially those that are round or oval in form, sometimes show soft spots on the surface. At one time it was considered by many hardeners, and by a number of writers on the subject of hardening, to be almost, or quite impossible to avoid this trouble. At the present time it is considered unnecessary to have such spots. They are caused by scale forming on the surface while the piece is being heated, and while most of the scale will "strike" (drop off) when the piece is placed in the bath small particles may remain on the piece and prevent, or retard hardening. This can be prevented by heating in a manner to prevent oxidation of the surface, and also by using a strong salt solution in a bath of the description shown in Fig. 278. Another cause for soft spots is the pocketing of steam at certain points. The bath shown in Fig. 278 will prevent the steam collecting at any portion and insure uniformly hardened surfaces.

It is sometimes necessary to make a tool from a piece of steel that is not of sufficient diameter for the purpose. In such case the steel is given the proper diameter by upsetting. If such practice is necessary select steel enough smaller than finished size so that the process of upsetting is *very thorough*. The upsetting should be accomplished by blows sufficiently heavy to reach to the center of the piece, or unsatisfactory results will follow when the piece is hardened. It is poor practice to upset a portion of a piece that is to be hardened *allover*, as the flow of the stock occasioned by the working of the bar in the mill will be in one direction, while that occasioned by the upsetting will be at right angles to the first, thus creating the worst possible condition for hardening. Unless all portions of a piece can be thoroughly upset it is unwise to attempt to increase its diameter. As a rule upsetting a piece of tool-steel that is to be hardened is not advisable; but, where it *must* be resorted to be sure that the precautions mentioned are closely observed.

Pack Hardening.—The term Pack Hardening was applied to the superficial carburizing of tool steel surfaces about twenty-five years ago while the writer was in charge of a heat-treating department doing a large jobbing business. We were hardening a great many punch-press dies of unusual size and complex design, milling machine cutters, and various other tools.

At that time there was a shortage of skilled help versed in the heat treatment of steel. The volume of business, and the requirements of the tools we were hardening forced us to experiment along lines that would enable us to successfully harden tools that were made from steels the make and composition of which we were many times ignorant of.

This was before the modern oil-hardening steels were made, or, at least, generally used. We reasoned that as thin pieces of steel hardened in oil seldom cracked or warped to any extent, it would be advisable to treat ordinary tool steel tools so that they would satisfactorily harden in oil. As bone contains a considerable percentage of phosphorus and this element is highly injurious to steel, especially steel made into cutting tools, we adopted leather as the carburizing agent. An experience of a quarter of a century has failed to convince me that any packing material that I have experimented with is better suited to this work than a good grade of charred leather. Although several satisfactory commercial carburizers have been analyzed and found to contain a high percentage of leather, none of these worked better than leather alone.

Although this method is used very extensively in several large plants, its use is no where near as general as it should be, because if properly done breakage is almost entirely eliminated, and warping is reduced to the minimum.

High-carbon as well as low-carbon steels respond to this treatment, although if the steel contains more than 1.25 per cent carbon, charred hoofs, or a mixture of charred hoofs and horns, should be used instead of leather.

An argument sometimes advanced against this method is its high cost. When we consider that quite a number of tools can be packed in a box and a number of these boxes can be treated at a time it will be seen that the actual cost is in this way considerably lessened. Even though the cost were greater its use is to be advocated when we consider that dies treated by this method will last many times longer than those hardened by the ordinary fire and water method. Milling-machine cutters will be found to run considerably faster and stand up many times longer between grindings. Taps and dies will wear much longer, and other classes of tools will show an increased efficiency overbalancing the extra cost of treating and is therefore to be advocated.

There are several classes of tools that, under certain conditions, do not prove as efficient when pack hardened. For instance, draw broaches doing extremely heavy work in proportion to their diameter; slender piercing punches used on stock whose thickness exceeds the diameter of the punch and other tools that are slender in cross-section that are subjected to excessive tensile or crushing strains, but the classes of tools that do not satisfactorily respond to this treatment are few in comparison to those that are wonderfully helped by it.

Temperature.—The temperature to be employed should be determined by test wires and pyrometer, and should rarely exceed the critical range of the steel which runs from 1375° to 1400° F. The length of time the pieces should be held at the red heat depends on the size and character of the piece. Before packing in the box each piece should be wired with *iron* binding wire for use in drawing from the box and dipping in the bath. Packing in the boxes is carried out the same as for case-hardening except that charred leather is used in place of the other carburizing materials.

Time.—The length of time the pieces should be left in the box after reaching the critical temperature depends on the size and character of the tool. Small taps $\frac{1}{8}''$ to $\frac{1}{4}''$ should be left in the box one-half hour; those $1''$ diameter two hours; reamers of the same size fifteen to thirty minutes longer; milling machine cutters from two to four hours according to size and the use to which they are to be put; and punch-press dies from two to four hours according to thickness of the walls. Swaging dies are one of the most pronounced examples of the advantages of pack hardening. If they are to be subjected to very severe duty the heat employed should range from 30° to 50° higher than for milling cutters, that is, from 1400° to 1430° F. This is to secure a deeper penetration and a more solid backing for the surface receiving the rough usage. Stay-bolt taps should be packed in a pipe, never in a box, as drawing the red-hot tap through the packing material in removing it from the box would be sure to bend it.

Gauges.—Pack hardening provides the most satisfactory method of hardening gauges of all kinds. It also makes possible the use of lower grades of steel than would be possible if the ordinary methods were employed. Ring gauges and other forms having holes passing through them, where the walls of the holes are to be subjected to wear, should be hardened in a bath having a jet of oil projected by a pump, the jet passing through the hole under considerable pressure forces all vapors away and allows the oil free access to the surfaces desired hard. If the outer portion of the gauge is irregular in form so that there is a heavier wall of steel at one side of the hole than the other, it is a good plan to encase it in fire clay, which may be wired on to prevent it from cracking, and breaking away. This should be done before the gauge is placed in the hardening box and may be removed after it is taken from the bath.

This, of course, leaves the outer walls soft, and applies only to pieces where the walls of the holes are the only portions desired hard.

TABLE OF APPROXIMATE TEMPERATURES.

FORGING AND HARDENING CARBON STEEL TOOLS.

Approximate Carbon Content.	Approximate Forging Temperature.	Critical Range.	Approximate Hardening Temperature.
0.60 per cent	1600°–1800° F.	1340°–1380° F.	1480° F.
0.70 per cent	1600°–1700° F.	1340°–1375° F.	1470° F.
0.80 per cent	1600°–1700° F.	1340°–1365° F.	1465° F.
0.90 per cent	1600°–1650° F.	1340°–1360° F.	1460° F.
1.00 per cent	1600° F.	1340°–1360° F.	1450° F.
1.10 per cent	1550° F.	1340°–1360° F.	1440° F.
1.20 per cent	1500° F.	1340°–1360° F.	1425° F.
1.30 per cent	1500° F.	1340°–1360° F.	1410° F.
1.40 per cent	1500° F.	1340°–1360° F.	1400° F.

Case Hardening.—In the process of case hardening, a hard surface is produced over a soft center, or core. The metals commonly treated are wrought iron, low-carbon steel, and cast iron.

The process is a modification of the cementation process of converting wrought iron into blister steel and differs from it essentially in that it is not carried so far. In the cementation process the carbon is charged to the center of the iron, while in case hardening it is stopped when a case of hardening steel deep enough to answer the purpose is produced.

The proper selection of stock to use for articles that are to receive this treatment should be given a great deal more consideration than is generally the case. In practice, any low-carbon stock whose initial cost is low, and which machines easily, is many times selected without regard as to whether the core is strong enough to resist any strains it may receive. If a hard surface is the only consideration, a stock low in carbon is selected, usually one that does not contain more than 0.20 per cent. If bending, breaking or other strains are to be encountered it is necessary to select one that contains a higher percentage. In some instances it is necessary, in order to obtain needed strength, to use steel containing 0.60, 0.80 or 1 per cent carbon. In case the high carbons are used it is advisable in most cases to avoid water baths in dipping, using instead, a bath of oil. In this way a very hard surface with a soft, strong core is obtained.

Probably no one branch of hardening has received more intelligent study in the last twenty-five years than the one under consideration; yet, in some shops, the subject is given no thought and, as a result, an inferior article is being turned out, which, if certain parts were properly case hardened, would be a satisfactory product.

Quick Case Hardening.—It is necessary at times to case harden a few small screws, or other small articles, and depth of penetration is not a factor to be considered. Under such circumstances the necessary hardness may be produced by heating the pieces to a red and applying a small amount of cyanide of potassium, re-heat the pieces to a red and plunge in clean, cold water. The depth of penetration may be increased by several applications of the cyanide, reheating after each application. Always make sure that the direct blast does not strike the pieces, as the resulting oxidation would decarbonize the surface and undo what is attempted.

If colors are desired it will be necessary to polish the surfaces and have them free from grease of any kind. The pieces should be heated in a tube, or covered, when in the fire, with a piece of sheet iron to protect them from the direct action of the flame. They should rest, when heating, on a clean surface, usually a piece of fire brick or iron. The quality of the colored surfaces may be bettered by introducing air into the water at the location of dipping. This may be accomplished by taking a piece of $\frac{1}{4}''$ pipe and placing one end in the bath $3''$ or $4''$ below the surface, then blowing on upper end and passing the pieces through the air bubbles in the water.

Yellow prussiate of potash was formerly used quite extensively in quick case hardening either alone, or in a mixture of 2 parts prussiate of potash, 1 part sal-ammoniac and 1 part salt. At the present time it is nearly impossible to get the potash. There are several quick case hardening compounds on the market. Some of these give very good satisfaction, most of them have this to their credit, they are not poisonous, while cyanide of potassium is a violent poison and should be kept under lock and key when not in use.

Carburizers.—To get good results when doing case hardening on a large scale one must understand the selection of stock from which articles are to be made, the effect of different carbonizing materials, and the effect of different temperatures on the stock. He must know what results are desired in the finished product and how to obtain these results. There are a number of carburizers used in charging carbon into iron and steel. Granulated raw bone is more commonly used than any other material. It comes in several different sizes of granules. The coarser grades are used for long runs, while the finest is used for short exposures. Raw bone is rich in phosphorus, and as this causes brittleness when present in steel this form of bone should not be used for articles that are to be subjected to shock or blow unless they are of a form that insures the desired strength.

Charred Bone.—Bone that is burned sufficiently to remove the phosphorus and grease may be procured commercially, or it may be charred in the hardening furnace by filling hardening boxes with raw bone, placing the covers in position and setting the boxes in the furnace at the end of the day when the furnace has been run for several hours. At the time of placing the boxes in the furnace the fire should be shut off as there will be sufficient heat in the walls of the furnace to char the bone. However, should the walls of the furnace be light in construction and not hold the heat long enough to accomplish the desired result, the fire may be run very low for a time then shut off. The boxes may be left in until morning. When removed the material is ready for use.

Animal Charcoal.—Thoroughly burned, specially treated bone known as animal charcoal may be procured commercially and is used for the finer grades of work. Another form of burned bone, known as hydrocarbonated bone, is used for certain fine grades of work. This is animal charcoal treated with oils.

Wood Charcoal.—Hard-wood charcoal is used as a carburizer either alone, or mixed in various proportions with other carbonizing materials and should be granulated before using. Granulated charcoal may be procured commercially, or it may be granulated and sorted to size by sifting. To do this economically on a large scale special grinding and sifting machines should be used. Wood charcoal is not a satisfactory packing material when the work is to run for a long period.

Leather.—Charred leather provides the very best material for use on the finer grades of work. As it is more expensive than bone it is not used when bone will answer the purpose. It may be procured commercially but should never be bought from any but dealers whose reliability is known, as there is a tendency on the part of some to use any scrap leather they can get.

Leather may be charred in the shop by getting the scraps that soles and heels of shoes are punched from as this gives a heavy scrap. Old belting that has passed its usefulness is also used. The leather should be cut in 3″ or 4″ pieces and packed in the box as was explained under Charring Bone. Care should be exercised, or the leather will be charred too much. This process should be carried on only long enough to char the leather until it can be crushed in the hand.

Barium Carbonate.—A mixture of 35 parts barium carbonate and 65 parts granulated wood charcoal is used with excellent results in a number of shops.

The proportions given need not be accurately observed but may be varied to meet requirements.

Mixtures.—Various mixtures of carbonaceous materials are used in packing work. Materials that have no direct action on the steel are many times used with the direct-acting cements. Two parts common salt added to 8 parts granulated hard-wood charcoal materially increases the action of the latter, or the salt may be added to mixtures containing charcoal, with good results.

Mixtures for Short Runs.—Where pieces are not to be run for a great length of time the following mixtures may be used: 1. Granulated hard-wood charcoal, 6 parts; lamp black, 2 parts; granulated charred leather, 2 parts. The charcoal and leather should be ground fine or the lamp black will settle to the bottom of the mass. 2. Finely granulated raw bone, 7 parts; animal charcoal, 2 parts; powdered charred leather, 1 part. 3. Powdered wood charcoal, 4 parts; sawdust, 5 parts; salt, 1 part. 4. Hydrocarbonated bone, 1 part; charred leather, 4 parts; charcoal, 4 parts; salt, 1 part.

The formulas for dozens of mixtures could be given but a study of the effects of the various ingredients used will enable one to adapt the quantities, and select the carburizers to meet the various requirements. It should be borne in mind that *raw* bone should not be used where extreme toughness is necessary, and that leather is a safe carburizer for all steel containing less than 1.25 per cent carbon.

The Boxes.—Articles to be case hardened are packed in boxes or tubes completely surrounding each piece with the carbonizing material. Small pieces and those that are long and slender, especially the latter, should be packed in tubes as more uniform temperatures can be obtained, and there is always danger of springing long slender pieces when drawing them through the packing material in a box when they are red hot. As such pieces must be dipped vertically in the bath they canot be dumped into the bath, but must be handled individually. The tubes may be pieces of iron pipe having one end closed tightly by means of a cap, or a plug may be driven in and securely pinned in place. When the tube is filled,

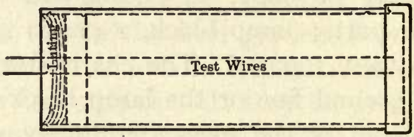


FIG. 322.

the opposite end may be closed by a loosely fitting plug which sets below the end of the tube, giving room for the fire clay used in sealing (luting) as shown in Fig. 322.

Boxes of various sizes and shapes, made from one of a number of materials may be used. Those to be used for small work should themselves be small in order that the pieces near the center may be heated to a red nearly as soon as those nearer the walls. Boxes that are larger in size give best results if rectangular in form. At times the shape of the piece necessitates the use of a square box. Round boxes work well for small pieces but are not so easily handled as other forms; *small, round boxes*, however, are very desirable at times.

The box used more than any other is rectangular in form and has ribs at its upper edge as shown in Fig. 323. These not only provide a means of handling

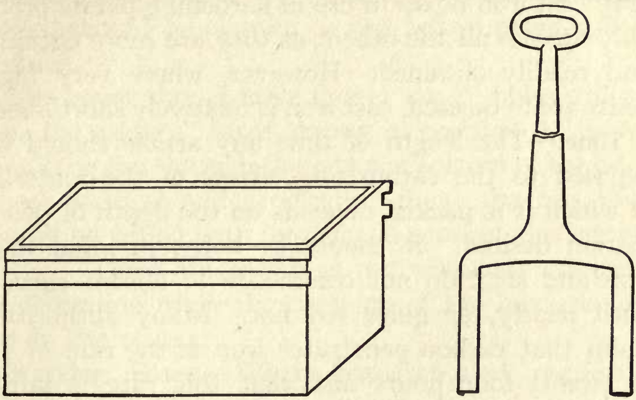
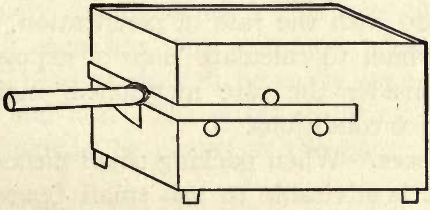


FIG. 323.



Design of Case Hardening Box Used in some Plants.

with the grappling iron, or dumping fork, as it is many times called, but tends to keep the boxes from warping. Round boxes are generally handled with special tongs made to fit the box.

The material used in making boxes may be sheet iron, low-carbon sheet steel, malleable cast iron, or gray cast iron. Boxes made from sheet iron and sheet steel will last much longer than those made from the other materials mentioned, while malleable iron is more durable than gray iron. The number of gray cast-iron boxes in use in hardening plants probably exceeds all the others, as they are more cheaply and readily obtained. However, where very high heats are to be used, cast iron is relatively short lived.

Time.—The length of time any article should be exposed to the carburizing effects of the material in which it is packed depends on the depth of penetration desired. It should be borne in mind that iron and steel do not commence to absorb carbon until nearly, or quite red hot. Many authorities claim that carbon penetrates iron at the rate of $\frac{1}{8}''$ in twenty-four hours and that this rate is fairly constant. The character of the metal being charged, and the temperature to which it is raised has considerable to do with the rate of penetration, but as a basis on which to calculate time of exposure, it is safe to consider the rate mentioned, making due allowance for conditions.

Small Pieces.—When packing small pieces for carburizing it is advisable to use small boxes. First, place a layer of packing material $1''$ or $1\frac{1}{2}''$ deep in the bottom, on this a layer of work, making sure that they are $1''$ from the walls of the box and $\frac{1}{4}''$ to $\frac{1}{2}''$ from one another, on this spread a layer of packing material, then one of work and so continue until the box is filled to within $1\frac{1}{2}''$ of the top. After each layer of packing material is laid, tamp lightly with a block of wood. There should be a layer of packing material at least 1″ thick between the top layer of work and the cover. After placing the cover in position, seal the space between it and the box with fire clay mixed with water to the consistency of dough. This sealing, or luting, as it is many times called, should be allowed to dry before placing in a furnace.

The cover should have five or six $\frac{1}{4}''$ holes drilled near the center. After placing in position $\frac{3}{16}''$ wires should be run through these to the bottom of the box. These wires should project 1″ above the top, and should be sealed with fire clay to prevent the escape of gas. These are known as test wires and are used to determine when the contents of the box are red hot to the center.

Marking Boxes.—Where boxes of work requiring different time exposures are to be heated in a furnace, it is necessary to mark the boxes so that they can be easily distinguished. This may be done by numbering each box with common white marking crayon. These marks can be easily seen when the boxes are red hot. The boxes requiring the longer exposures should be placed at the back of the furnace.

Testing.—When, in the judgment of the furnaceman, a box has been exposed long enough to be heated to a red, one of the test wires should be drawn by means of long tongs and examined. If it is red, the time should be noted and recorded on a tally sheet, or slate, together with the number of the box, what it contains, time it should be removed from the furnace, highest temperature it received and any other facts those in charge think best to keep.

Below is a sample tally sheet:

Box No.	Contents.	Furnace No. 1. Date, May 6, 1918.		
		Red Hot.	Remove.	Highest Pyrometer Reading.
1	Links.......	10.10	10.45	1450
2	Binders.....	10.25	11.25	1450
3	Binders.....	10.30	11.30	1455
4	Bolts.......	10.50	2.50	1470
		Furnace Operator, John Smith.		

The above is an abbreviation of a form of tally sheet used in several factories. It may be varied to meet requirements. There are a number of advantages derived from the use of a standard tally sheet. They enable those in charge to keep closely in touch with the treatment each box receives. If the results show that the pieces were not given the proper temperature or time exposure, note may be made of the fact, and the practice varied with the next batch. It obviates difficulties that arise when the operator's memory is relied on as to what is in a given box, when it should be removed from the furnace, and also tends to cultivate carefulness on the part of the operator.

The man in charge of the heat-treating department should be able to differentiate between work not requiring much care, and that requiring the utmost care and attention. For instance, a batch of ordinary machine nuts and several long, slender shafts, or spindles may be received at the same time.

The nuts may be packed in raw bone and run at fairly high heats, while the spindles should be packed in tubes with charred bone, leather, or some mixture that will not give off phosphorus, run at a low temperature, and will probably require a definite time exposure.

The Quenching Bath.—The design and contents of the hardening bath do not receive the attention they should in some shops. A batch of work may be packed all right, receive the proper time exposure and temperature and yet not give desired results, because the quenching bath was not deep enough, or had no means of separating the pieces from one another, or the liquid was not what it should have been. When the character of the work is such that a barrel of water that is provided with no means of agitation will produce desired results, it is folly to go to the expense of rigging up an expensive bath, but when such a bath is necessary to get definite conditions, it is worse than folly not to provide it. The tank should be deep enough so that the pieces will cool below a red before they reach the bottom, if the box of work is dumped. Where the pieces are taken singly from the box and worked around in the bath until cold a very deep bath is not necessary. Large, heavy work is seldom dumped.

Tank with Separating Wires.—In cases where the work is dumped directly into the bath from the box it is well to provide some means of separating the pieces or ununiform results will follow. To effect this, wires may be provided as shown in Fig. 279, making sure that no two consecutive rows of wires are directly in line. By this arrangement the work is not only separated but is turned over and over as it bounds from one wire to another and descends. The bottom of the tray (*a*) should be of wire netting or thoroughly perforated sheet metal in order that the water may circulate freely about the work, and should be in the form of a tray. It should be provided with handles to facilitate its removal. Directly under this should be a pan (*b*) also provided with handles to receive the packing materials.

If bone is the carburizer used, it may be removed from the pan and dried on top of the furnace, or in some convenient way and used for work such as screws, etc., that do not require a strong material. For certain classes of work it may be used in connection with fresh bone, in proportions varying according to the requirements of the pieces.

This bath should be provided with a supply pipe as shown, and also with an overflow pipe. It is well to arrange a hood over most baths where work is dumped. This hood should have a pipe running into a chimney, or into the atmosphere to conduct the steam, smoke, sparks, etc., away, as they are extremely annoying and tend to injure the eyesight and health of the workmen.

While shafts, spindles, small axles and similar pieces are many times dipped one at a time vertically, excellent results, in many instances, follow the use of a bath of the form shown in Fig. 280 where inclined shelves are provided to allow the pieces to go down into the bath with a rolling motion. These shelves should be thoroughly perforated to allow the liquid constant contact with the steel. This is a modification of the so-called "Coffin" method of treating car axles and, as a rule, produces good results.

The bath shown in Fig. 278 having perforated pipes up the sides, is adapted to work that is to be dipped rather than dumped. For certain kinds of work a

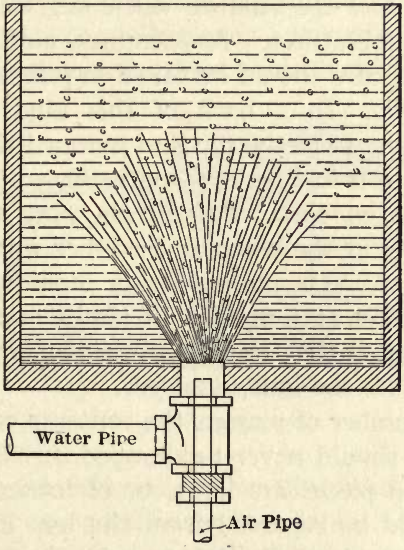


FIG. 324.

bath having pipes coming in from the sides and one or more from the bottom is desirable. In fact, when the work is done in quantities that warrant it, the bath should be designed to give the best possible results with the pieces being hardened.

Fig. 324 shows a bath designed for colorcase hardening which has an air pipe entering the water-supply pipe. A bath of this description should be in every plant where color work is done.

Oil Baths.—Where oil is the quenching medium employed, some means should be provided for cooling it, because, unless used in large bodies it becomes heated quickly and uniform results cannot be obtained as some pieces will enter the bath while the oil is cold and the balance will enter while it is at various temperatures. As extremely cold oil seldom works well, care should be taken in planning for the cooling coils. In a bath of this kind the oil is usually taken from the top and pumped through the coils as shown in Fig. 277 and returned to the tank at any desired part. For certain work the supply should enter at the bottom; for other work the inlet should be at one or more sides, or pipes may be provided to enter at a number of places and furnished with valves so that the entry may be where it will work best for the individual job.

For a number of reasons the contents of the hardening box should never be dumped *directly* into the oil. If the pieces are large, or of intricate design, they should be removed from the box individually and immersed in the bath by means of tongs, a hook, or wire and worked around until cooled considerably below a red when they may be lowered to the bottom and allowed to remain until cold. If they can be hardened all right by dumping, the bath should be provided with an inclined wire cloth dumping screen as shown in Fig. 325 onto which the contents of the box should be dumped. The packing material will pass through the screen into the iron pan below while the work will roll down the incline into the oil. The packing material, if dumped into the oil, will set it afire, and also dirty the oil, rendering it useless. Some hardeners always use this dumping screen even when quenching in water.

Examples of Case Hardening.—*Small Screws.*—As the stock used in making machine screws varies, it is necessary to vary the treatment at times. If they are made from Bessemer screw wire, bone that has been used once for short runs gives better results

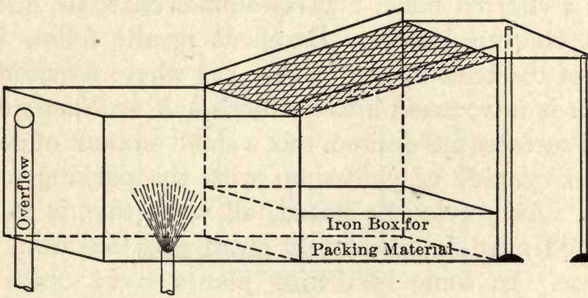


FIG. 325.

than raw bone, especially on small slotted screws. If no partially expended bone is available, it is advisable to char some as raw bone will phosphorize the screws and make them extremely brittle and no amount of tempering will remove this brittleness. Screws larger than $\frac{3}{8}''$ do not show the effects of brittleness as much as the smaller sizes as there is a large, soft core that is not affected.

Nuts.—Machine nuts, if small, and a deep penetration is not necessary, may be packed in small boxes with equal parts of charcoal and raw bone and run from three to five hours according to size and depth of hardness desired. If the nuts are to be polished after hardening a little longer exposure will be necessary. Nuts $\frac{3}{8}''$ and larger may be packed in raw bone and charcoal of equal parts, run from five to seven hours and dumped into the bath. If colors are desired, the flats and tops of the nuts must be polished and the packing material should be some mixture especially suited to the work. For general purposes the following works well. Eight parts No. 1 charred bone, 2 parts animal charcoal, and 1 part charred leather. Excellent results follow the use of the bath shown in Fig. 324 where a quantity of air is introduced into the bath. If *brilliantly* colored surfaces are desired, mix a small amount of powdered cyanide of potassium with the packing mixture. As previously stated, all work that is to be colored must be absolutely clean and free from all grease. In some hardening plants every operator packing work of this character wears gloves to prevent the moisture of the hands getting on the work. It is advisable to observe this precaution if good results are desired.

All case hardened work should be thoroughly washed in hot soda water, then in boiling water and then thoroughly dried. Colored work should be oiled. All this should be done immediately on removing from the quenching bath.

Deep Penetration.—Where very deep penetration is desired, it is necessary to expose the work to the influence of the carbonizing material for a long period. The writer has in mind some nuts that were about 16″ across flats. Instructions called for a depth of carbon penetration of at least $\frac{1}{8}$″. They also stated that the walls of the holes and the stock immediately around the holes must be soft as the nuts were to be threaded *after* hardening, and that the flats and tops must be nicely colored. Test pieces of steel made from the same billet as the nuts, came with them. These were to be treated the same as the nuts, and broken to determine the depth of carbon penetration.

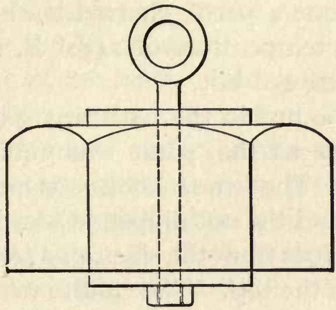


FIG. 326.

On account of their size it was considered advisable to pack but one nut and its test piece in a box. The packing material used was the coarser grades of raw bone. Before packing, a round plate of cast iron $\frac{1}{2}$″ diameter larger than the hole, was provided to cover each end of the hole, as shown in Fig. 326. These were provided to prevent the carbon gas acting on the walls of the hole. The plates were bolted in place and an eye bolt provided for use in handling. Three $\frac{1}{16}$″ vent holes were drilled in each upper plate; these were covered with fire clay.

While carbon will penetrate iron and steel when in contact with carbonaceous materials, it is a known fact that the material gives off all of its available carbon in a few hours; the length of time depending on the size of the kernels. In the case of the nuts, it was considered best to run them fifteen hours, let them cool off, repack in fresh material and run for an equal length of time, making thirty hours that they were exposed to carburization, at a temperature of 1700° F. They were packed again in a mixture of charred bone 4 parts, charred leather 1 part and exposed to a temperature of 1450° F. for four hours after they were red hot.

Dipping the nut in the bath was a comparatively simple matter as the plant was equipped with a small crane. The crane hook was passed through the eye bolt and the nut dipped in a large bath having six delivery pipes from the sides, one from the bottom and one from the top. The results were all that was expected as the penetration was over $\frac{1}{8}''$ and the surfaces were nicely colored.

At times, the ingenuity of the hardener is taxed to the limit. Results that are, apparently, beyond the range of human possibility are demanded and no method for producing these results is advanced. I have in mind an instance where the man in charge of a heat-treating plant was told that certain pieces being case hardened must show an increase of 25 per cent in breaking strength, and, at the same time, show the same hardness test as formerly. He accomplished the desired result by dropping his charging heat 50° F. and quenching in water heated to about

115° F. The bath was supplied with water from an artesian well. Several pipes carrying live steam entered the supply pipe, each pipe being provided with a valve making it possible to get a range of temperature from about 50° F. to 150° F. He might have attained the desired *strength* by quenching in oil, but as the pieces had but a short time exposure to the carburizer they would not show the necessary hardness when tested.

Local Case Hardening.—This term is applied to the practice of hardening one or more portions of a piece leaving the balance soft, and is accomplished by a number of methods. One method consists in charging carbon into a piece of work then cutting away the carbonized surface where hardness is not desired. Another method is to protect, by some means, the portions desired soft, so that the carbon will not penetrate. A third method consists in charging carbon into all surfaces, then protecting the portion desired soft by means of holders, or special tongs. As an example of the first method we will consider the block shown in Fig. 327 where the projecting ring (*a*) is the only portion desired hard. The block was rough machined, the ring was machined to within grinding size on top and to within $\frac{1}{64}''$ of finish dimension for thickness and $\frac{1}{32}''$ depth.

When packed for carburizing a thoroughly expended bone was placed in the box to a depth of 2″ and on this the block was placed with the ring uppermost. The hole was filled with expended bone, and the same material was placed around the block to within $\frac{1}{2}''$ of the top. Raw bone of medium size granules, mixed with an equal amount of wood charcoal, was then put in, covering the ring to a depth of 1″. The balance of space was filled with expended bone. The block was then subjected to a temperature of 1750° F. for eight hours after it was red hot. The box was then removed from the fur-

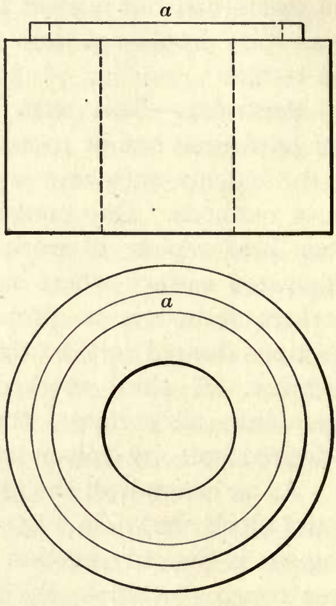


FIG. 327.

nace and allowed to cool. After cooling the block was machined to finish dimensions, then reheated to 1480° F. in a box with no packing material, except that the ring was covered on top and sides with dry fire clay, to a thickness of ½″ to prevent oxidation of the surfaces.

When the piece was uniformly heated to the temperature mentioned (1480° F.) it was placed on a specially prepared holder and a large stream of water projected against either end, as shown in Fig. 283. The purpose of the stream against the bottom of the block was to cause, so far as possible uniform contraction of the piece. It had been found, by experience, that satisfactory results were not obtained by immersing in a tank as the vapors formed did not allow the water free access to the ring. In the open air with a large, strong jet of water these vapors were easily taken care of.

By the second method mentioned, the portions desired soft are protected from the action of the carbon gas by covering with sheet iron or steel. These covers may be wired in position. Or the portions may be covered with wet fire clay, wound with wire to prevent its cracking away or a mixture of fire clay and asbestos may be used. Where local case hardening is done in large batches special cast-iron covers are made to protect certain portions desired soft. Or the portions may be plated with either nickel or copper, this is costly and seldom resorted to where any of the other methods will answer.

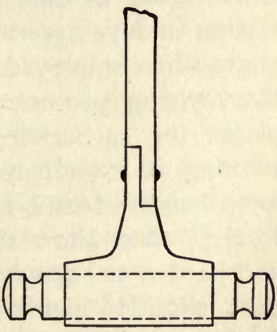


FIG. 328.

As an example of the third method we will consider the piece shown in Fig. 328 where a pair of tongs is used to protect the portion desired soft from the action of the bath. Under certain conditions it may be advisable to cool the ends in water until the red has disappeared, then to remove them from the water bath and drop the piece from the tongs into a bath of oil. This will stiffen and toughen the center portion without actually hardening it. Special holders are many times used instead of tongs.

Fine Grain.—The process of case hardening, as ordinarily practiced, tends to produce a coarse grain in the carbonized portion. For many purposes this does not injure the product. As the size of the grain is directly proportional to the temperature given the steel, *extremely* coarse texture may be avoided by employing low heats in charging. In many cases this is objectionable on account of the time necessary to secure a desired penetration, as carbon penetrates faster at high heats. To secure rapid penetration and yet get a compact grain two heats are many times employed. This is a modification of the Harveyizing process, and consists in packing the pieces for carburizing in the usual manner and running at a temperature of 1750° F. to 1850° F. for a length of time necessary to give desired penetration, then allow the pieces to cool, and reheat and harden as though they were of tool steel, except that slightly higher temperatures are employed (about 1475° F.) than for high-carbon tool steels.

Under some conditions two quenchings are made, the first at a high temperature 1650° to 1750° F., and then a second at 1400° to 1450° F. Unless this method is necessary to produce desired results its use is not to be advocated on account of the expense involved. The writer does not wish to be understood as advocating the exact temperatures mentioned, as they must be adapted to the materials used, the design of the piece, and the use to which it is to be put.

As modern manufacturing conditions demand a higher grade of case-hardened product than was formerly the case, dumping into the bath directly from the charging heat is not practiced to as great an extent as it was at one time. In some shops a very large proportion of case-hardened work is given two heats, i.e., the first for charging and the second for hardening. This practice is especially desirable where a pronounced line of demarkation, at the point where the hardened portion joins the soft core, is objectionable.

The depth of penetration of carbon should be no greater than is necessary to produce desired results. It is folly to run work, in the process of carburizing, for eight hours, when an exposure of five hours will give a penetration sufficiently deep.

Under some conditions it is necessary to draw the temper after case hardening, this practice is resorted to where it is necessary to use a comparatively high-carbon steel in order to get a strong core.

Case Hardening Brazed Articles.—At times it is desirable to case harden articles that have been brazed. Where possible such pieces should be brazed with a fairly high-temperature spelter, but the hardener seldom has anything to say about what shall be done to articles before they reach his department. For this reason it is advisable to heat one of the pieces in an open fire and see if the brazing starts at a *full* red heat, if it does not it is safe to pack the pieces in a box with a desirable carburizer and run at a *low* red heat, making sure that this temperature is not exceeded at any time, and proceed as in any ordinary case hardening. When quenching work of this kind it is not advisable, generally speaking, to dump. The pieces should be quenched singly in such a manner as not to bring any strain on the brazed joint.

The writer has case hardened many thousand pieces of brazed work. In some cases the object sought was a hard surface; in others it was to stiffen the stock so it would stand a high torsional, or other strain.

Carburizing with Gas.—There have been many changes and advances made during the past twenty-five years in the process of case hardening, none of which are of more importance to the manufacturer who finds it necessary to produce a *deep* penetration of carbon than the method of carbonizing with gas.

Armor-plate manufacturers were handicapped when treating the plates by means of solid carbonizers, and experimented with, and perfected, a process whereby the carbonizing could be accomplished by means of carbonaceous gas. The success of this method has led manufacturers of heating furnaces to place on the market muffle furnaces using gas as a carburizer. By this method more uniform results are obtained, especially where deep penetration is desired, than by the use of solid carbons. As the gas can be constantly fed to the heated pieces any desired depth of penetrations can be obtained without the bother and expense of repacking. A gas carbonizing machine is shown in Fig. 329.

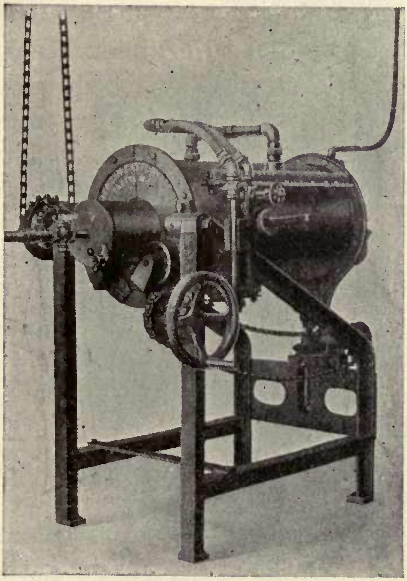


FIG. 329.

Baths of Cyanide of Potassium.—Gun frames, parts of apparatus and scme forms of tools where highly colored surfaces are desired, are case hardened by heating in a crucible of red-hot cyanide of potassium and then dipping in cold water. As in all methods of producing color work the surfaces must be nicely polished and absolutely clean before case hardening.

The work must be suspended in the crucible in such manner that it is entirely submerged in the cyanide and so it does not touch the crucible at any point. This is usually accomplished by means of hooks suspended from rods placed across the top of crucible.

For most small work a Cyanide Hardening Furnace of the type shown in Fig. 330 answers very well. Where the pieces are of a size and form that does not make possible the use of one of the commercial types, a furnace and crucible designed to meet the requirements can be built. Cast-iron crucibles work nicely in heating cyanide as the temperatures employed are never extremely high when producing colors. The exact temperature depends on the character of the work, generally from 1375° to 1450° F.

The pieces should be left in the cyanide until uniformly heated, and as much longer as is necessary to produce the desired depth of penetration. If colored surfaces with slight penetration is desired the pieces should be removed and quenched when uniformly heated to the proper temperature.

Any form of moisture must not be allowed to enter the crucible as the resulting steam would cause particles of the melted cyanide to fly, these produce painful burns which, on account of the poisonous nature of the chemical, are slow in healing. For this reason the operator should always wear goggles to protect the eyes and long gloves to cover the hands and arms.

Hooks and tongs should be dried after use in quenching before using again. For this reason a plentiful supply of hooks, and several pairs of tongs must be provided. Furnaces are sometimes designed with a drying chamber so located that the

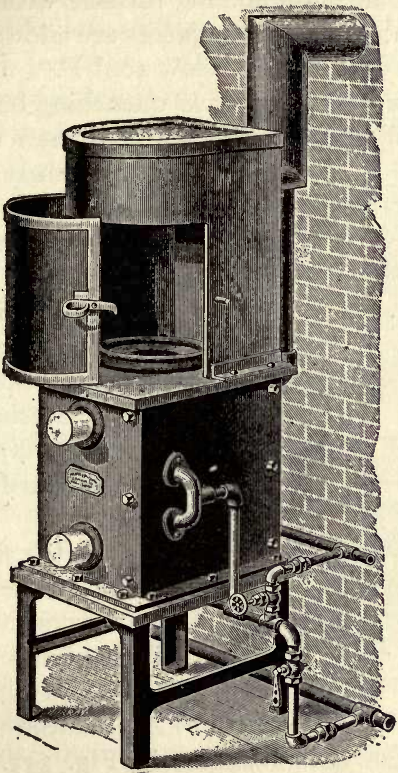


FIG. 330.

operator can place the hooks and tongs in it, and remove them without loss of time.

Articles made from tool steel, and other high-carbon steels, are many times hardened by this method in order to get the brilliantly colored surfaces. In case the resulting hardness is too great the temper may be drawn the desired amount by means of an oil-tempering furnace without injuring the colors; provided the pieces are allowed to remain in the oil until cooled below 400° F.

As a rule extremely *cold* quenching baths produce more brilliantly colored surfaces than those whose temperature is above 50° F. For this reason it is customary in some hardening plants to keep ice in the tank in warm weather unless the water is from an artesian well or some supply that insures the desired temperature.

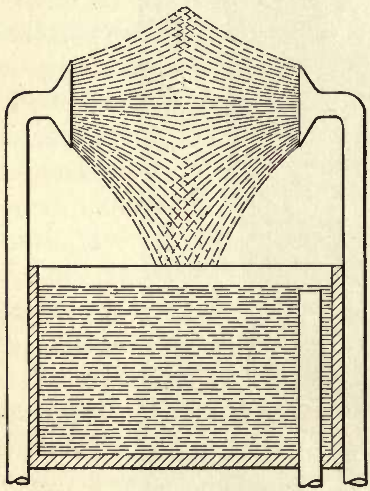


FIG. 331.

If the fine vine-like bluish lines sometimes observed on high-grade case-hardened work are desired they may be produced by using a bath of the design shown in Fig. 331. The ends of supply pipes which are located above the tank are so constructed that the water comes from them in the form of spray. The heated pieces are passed through this spray then into the bath where they are worked around in the water until cool.

Many forms of dies, especially those having engraving on the working faces, molds used in forming various substances to shape and numerous other articles are heated in red-hot cyanide for hardening; but in such cases colors are not sought. Molten cyanide provides an excellent means of heating pieces that must be free from oxidation, and which would not prove satisfactory if heated in lead.

Melted cyanide gives off poisonous fumes which are harmful if inhaled. Furnaces used for the purpose under consideration should be provided with some means of getting rid of these fumes, the one shown in Fig. 330 has a pipe connected with the chimney.

HIGH SPEED STEEL

Forging High-Speed Steel.—For tools to be used in taking medium and light cuts, tool bits for use in tool holders are advocated as they answer every purpose and are much cheaper than forged tools. The desired shape can be produced by grinding, one holder answering for the various forms of tools used on a machine. This applies, of course, to tools used on lathes, planers, etc., particularly the former.

In the case of milling cutters, blanks can be procured of a size that allows for the necessary machining. Punches are best made from bar stock even where considerable turning or other machining is necessary as such pieces, especially if round in form, are liable to burst from forging strains of a nature that cannot be removed by annealing.

At the present time there is comparatively little trouble experienced when forging the ordinary forms of lathe tools. Smiths have become familiar with the higher temperature necessary for high-speed steel than is employed for carbon and the *ordinary* alloy steels. To get satisfactory results it is absolutely necessary that the steel be uniformly heated throughout. If the interior is hotter than the outer portion, cracks will develop near the center from uneven contraction when cooling. These defects are not easily detected as the exterior may be perfectly sound. If the exterior is much hotter than the interior surface checks will result. High-speed steel should not be hammered when it is below a full red heat, the temperature range recommended by several manufacturers is 1650° to 1850° F., although in no case should it be hammered when it gives a metallic ring. The objection to *high* heats is that tools so treated do not stand up as well.

Most steel makers furnish general directions for forging and hardening which are many times given in colors and it is rather difficult to determine just what is meant, because one authority's understanding of the temperature corresponding to a certain color is liable to differ materially from that expressed by another. For this reason, the smith when possible should ascertain by experiment the temperature that gives the best results with the steel he is using and the tools he is forging. A heat that may insure ease in forging may not put the tool in the best condition possible for producing the greatest amount of work in a given time. The smith should always bear in mind the fact that his office is not to produce the greatest number of tools in a given time, but rather to produce tools that will turn out the maximum amount of woik in a given time. Unfortunately, it is the custom in some establishments to judge a smith's ability by the number of passable tools he turns out rather than by the amount of work these tools produce in a given time.

Form of Tools.—The form of a tool must depend on the character of the work and the condition of the metal it is to be used on. If a tool is to be used on work requiring coarse feeds it must be given an angle of inclination with the cut that will insure sufficient clearance below the cutting edge so that the work will not rub on the tool below the cutting edge; this amount of clearance would not be absolutely necessary if fine feeds were to be employed. If the exact amount of feed is not known it is best to give sufficient inclination so that the tool will answer in any case.

The writer's attention was at one time called to several tools that "fell down" in a competitive test. The concern handling the steel was not satisfied with the results of the test and ordered an investigation. An examination of the tools showed that there was very little angle on the side of the tool as shown in Fig. 332, and as coarse feeds were employed in the tests it was impossible for the tools to cut. They were heated and bent to a greater angle as shown in Fig. 333. In the second test they stood No. 1 instead of being at the bottom of the list. An intelligent study of tool angles is just as essential for the smith as a study of temperatures.

As a rule tools to be held in tool posts should be made from annealed stock and as this can be purchased at prices less than that of unannealed stock plus the cost of annealing in the average shop it is not wise to attempt the annealing of bars in shops having the ordinary furnace equipment. If the stock *is* bought in the unannealed condition it must be heated to cut to length.

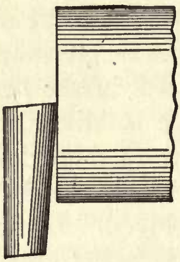


FIG. 332.

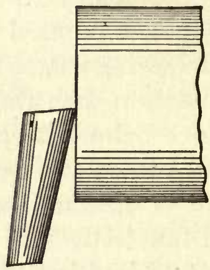


FIG. 333.

Annealing.—High-speed steel can be annealed so it is nearly as soft as carbon-tool steel. To accomplish this, however, the proper facilities must be at hand and the steel must be *slowly* heated to the proper temperature and allowed to remain at this temperature for a time that insures an absolutely uniform heat, then cooled very slowly. Long continued soaking should be avoided as it is apt to produce a coarse grain and set up strains that are liable to cause the steel to crack when hardened. The steel may be annealed in the bars by packing in iron pipes having one end tightly closed by means of a cap or plug. The pipe should be somewhat longer than the bars in order that the open end may be closed with a loosely fitting plug and securely sealed with fire clay. Several small holes should be drilled through this plug to allow gas to escape or the clay lutting will be blown away. The bars when in the pipe should be surrounded with green coal dust, powdered charcoal, powdered coke or some substance that will give off a gas that prevents oxidation of the surface. The pipes when packed may be placed in the furnace and gradually brought up to low red (1400° to 1450° F.). The steel should be uniformly heated and should *not* be soaked in the fire, as long-continued heats produce a coarse structure and tend to increase the liability to rupture when the steel is hardened.

When the bars are uniformly heated to the temperature mentioned the heat may be shut off and the whole allowed to cool. Any openings in the furnace should be closed as cold air, if it enters the furnace, chills the steel and retards the annealing operation.

Box Annealing.—When annealing forgings, tool blanks, etc., it is advisable to pack in boxes of convenient size using as packing materials powdered charcoal, coal, coke, or something that gives off a non-oxidizing gas. However, some parties claim good results from the use of asbestos, ashes, lime or sand. The writer has had good results from the use of finely powdered dry fire clay. A space of $1\frac{1}{2}''$ should be left between the top of the packed work and the cover which should be filled with the packing material. The cover, which has three or four small holes drilled at the center to allow gas to escape, should be placed in position and sealed.

When a box of the description shown in Fig. 334 is used sealing with wet fire clay is not necessary. The groove is quite a little wider than the cover flange, this allows a packing of finely sifted ashes, or dry powdered fire clay between the flange and walls of groove thus preventing air entering the box. The interior of the box may be lined with fire brick if this seems advisable. As a rule, however, a cast-iron

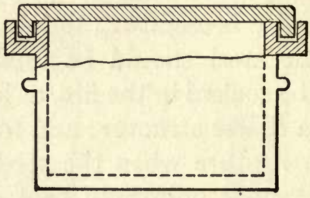
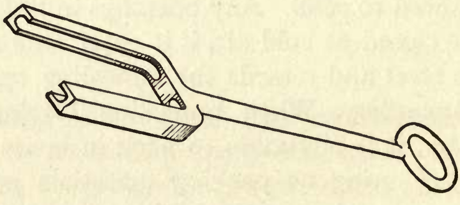


FIG. 334.



Dumping Fork for Fig. 334.

box with reasonably thick walls and no lining will be found satisfactory.

If possible the boxes should be placed in the furnace at such a time that the completion of the run will come at about the time of shutting off the furnaces at night, so that the boxes can be left in until morning. This arrangement, however, is not always possible, and they must be removed from the furnace when heated long enough and buried in very hot sand or ashes.

Pieces 2″×1″×6″ should be held at the annealing temperature for about three hours. If very much larger than 2″×1″ the time should be increased somewhat, always avoiding long heats from the time the pieces are uniformly heated to the proper temperature. Always avoid *overheating*. If the temperature is raised much above 1500° F. hardness results, as it is approaching the temperature where the changes take place in the steel that produces hardness even if slow cooling is resorted to. Nevertheless, if the heats do exceed 1500° F. *slower* cooling must be resorted to.

To Anneal Without Discoloring.—If it is necessary, or desirable to anneal articles having polished surfaces without oxidizing or discoloring them, it may be done by taking a piece of gas pipe of convenient size and length and thread both ends. On one end permanently screw a cap having one or two $\frac{1}{32}$″ holes drilled through it. The cap to go on the other end should be drilled and threaded to receive a $\frac{1}{8}$″ gas pipe. The articles to be annealed should be placed in the pipe, the cap screwed on and the whole placed in the furnace with the end that is to receive the $\frac{1}{8}$″ pipe towards the front. The small pipe should be screwed to place and connected with an illuminating gas supply, as shown in Fig. 335. When the gas is turned on it should be immediately lighted at the opposite end of the pipe as it escapes from the small holes.

The furnace heat should be turned on and the operation carried on as in ordinary annealing of high-speed steel. When the pieces have been heated for the proper length of time the furnace heat may be shut off but the gas should be allowed to pass through the tube and burn until the pieces are cooled to below 400° F.

The gas passing through the pipe mixes with the air in the pipe and carries it out before an oxidizing temperature is reached, after which the flow of gas excludes all air, and as oxidation cannot take place unless air is present the surfaces will be clear and free from oxide.

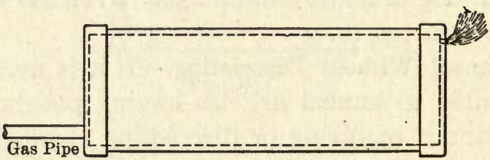


FIG. 335.

A modification of the process just described consists in placing a small quantity of resin in the bottom of the hardening box, packing the work in the box surrounding each piece with powdered charcoal and then placing another small amount of resin on top. The cover should have a few small holes drilled through it to allow the gas to escape and should be securely sealed and the process carried on as in ordinary annealing. This method is also employed in annealing articles made from carbon steel and when discoloration of surfaces is undesirable.

Quick Annealing.—While fairly good results are sometimes obtained by rapid annealing, the practice is one the writer does not advocate, but like a number of other practices which cannot be encouraged there are times when it must be resorted to. A tool may be heated very slowly to a low red and buried in lime, ashes, asbestos, or sand that has been heated very hot and allowed to cool very slowly. A method employed by an acquaintance consists in heating as described above and plunging in water at a temperature of 200° F.

Lathe, planer, and similar tools should be annealed after forging and before hardening. As the object of this annealing is to overcome forging strains which otherwise would manifest themselves when the piece is hardened, it may be accomplished by allowing them to cool down to a black after forging then re-heating to a low red and placing in a warm dry place and leaving until cold.

Hardening High-Speed Steel.—There are many makes of high-speed steels on the market, some of which require special treatment in hardening. The majority, however, respond to the same treatment and it is with this class we shall deal when considering the treatment necessary to obtain good results. The furnace used has a great deal to do in obtaining the right temperature. In some instances those designed for use in heating carbon steels can be used with good results in treating high-speed steel, but as a rule specially designed furnaces should be used.

Coke furnaces properly made and tended are used with good results in some shops, but generally those burning gas or oil give best results and do not have the interruption necessary when cleaning and replenishing coke fires. As extremely high heats are necessary two or more furnaces should be used. The pieces should be pre-heated before placing in the high temperature furnace, or the steel will be weakened or ruptured. The pre-heating should be comparatively slow, and to a temperature of about 1500° F., when the pieces should be transferred to the high temperature furnace and rapidly heated the desired amount. This temperature necessarily varies according to the character of the tool. Taps, milling cutters, and other tools having slender projecting teeth cannot be heated to as high a temperature as ordinary lathe, planer, and similar tools. For the former, if made from most of the standard American high-speed steels, a temperature of 2250° to 2450° F. is recommended. While most lathe, planer and similar tools to be used for rough, heavy work, and whose design allows of grinding after hardening, should be heated nearly to the melting point; in fact in many cases it is advisable to heat until the edges and corners "drip," melting does not occur, in most high-speed steels, below a temperature of 2550° F. Where grinding is not allowable after hardening slightly lower heats must be observed.

Fig. 336 shows a furnace provided with a preheating chamber immediately above the high-temperature chamber. The waste gases from the lower chamber heat the upper one, effecting a considerable saving in fuel. After the furnace has been in operation for some time the upper chamber may become too hot for pre-heating extremely complicated tools in which case the tools may be placed on top of the furnace and transferred to the pre-heating chamber afterward.

Fig. 337 shows a furnace having three chambers, the upper one being used in drawing the temper of tools or for cold steel until heated somewhat, and

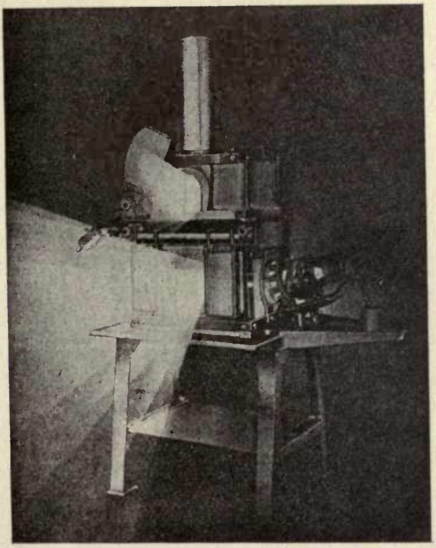


FIG. 336.

before placing in the second, or pre-heating chamber.

Electric Furnaces.—Excellent results are claimed by some from the use of electrically heated furnaces, especially in the treatment of certain classes of small tools. The cost of operating this type is apt to be rather high.

Lead Pot.—Lead heated white hot in a crucible was formally used very extensively in heating high-speed steel. Its use has given way to the barium

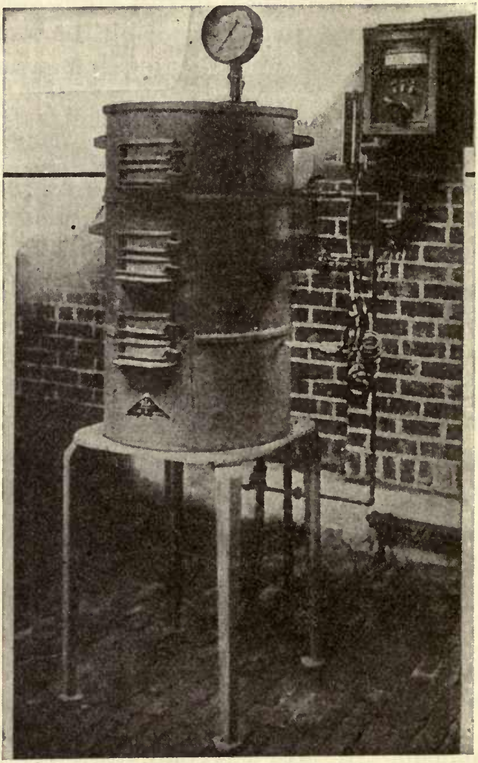


FIG. 337.

chloride process of heating in a few plants, and to the especially designed high-speed steel furnaces in most shops. However, it is employed in a few places in getting the final heats on milling cutters and similar tools. The tendency of the lead to rapidly oxidize at high temperatures may be overcome to a degree by keeping the surface covered with finely broken wood charcoal. A very serious objection to the use of the lead bath is the poisonous gases given off by it. As these gases are heavier than air it is difficult to conduct them away by any ventilating system that will not cool the lead.

Salt Baths.—Various salts are used as heating baths for high-speed steel. These salts are held in crucibles in some form of specially designed furnace using coal, gas, coke or oil as fuel. Generally speaking, gas and oil give best results as a more uniform heat can be obtained. Specially designed electrically heated furnaces are used in connection with salt baths and excellent results are claimed by the makers, and by some users. Before deciding to install any electrically heated furnace the reader is advised to get in touch with parties who have had them in constant use on a commercial basis for some time and get their opinions as to their relative value and cost of maintenance. When making such inquiries it is well to bear in mind the fact that an electric furnace can be operated much more economically by a firm generating electricity on a large scale, or by one having a constant water power used for generating purposes.

It is undoubtedly true that electrically heated furnaces can have their temperatures more accurately controlled than those heated by other means, especially when heating small articles. Some users, however, claim that the temperatures of such furnaces fluctuate more when *large* pieces are immersed than is the case when gas or oil is used as fuel. It is also claimed by some that under certain conditions steel heated in electrically heated baths shows a decided tendency to pitted surfaces.

When it is necessary to use two *separate* furnaces in heating they should, if possible, be located near each other to avoid cooling of light sections and the oxidation resulting from exposing the steel to the air when transferring from one to the other.

As a rule it is advisable to anneal articles made from high-speed steel before they are heated for hardening. This is especially true of lathe, planer, and similar tools. Annealing relieves forging and other strains which are liable to manifest themselves when the piece is hardened. It is always best to anneal reworked tools before hardening. In one factory it was found that tools used in removing stock from the inside of projectiles when worn below size could be heated to a forging temperature flatted and ground to size and re-hardened, but their life was only about 40 per cent of that shown by new tools. Investigation showed that after being flatted they were ground and hardened without annealing. Orders were given to anneal after forging, as a result the tools were found to be 95 per cent efficient.

At the present time the customary method of cooling high-speed steel when hardening is to dip in an oil bath rather than to cool in a blast of air. Cotton-seed oil, or fish oil works well as a quenching medium for some classes of tools, while others show better results if dipped in one of the lighter oils.

Kerosene used alone, or added to some of the heavier oils is used in some hardening plants with excellent results. Extreme care should be exercised if kerosene is used. The heated steel should be passed down through the surface so that all portions of the heated steel are *completely* covered to prevent the oil catching fire. If this bath is used precautions that will prevent burns and fires should be observed.

Pack Hardening High-Speed Steel.—While lathe, planer and similar tools show *best* results when heated to the highest temperature possible without melting, and, in fact, when it can be done the temperature should be high enough to cause the edges to drip. Such heats are not possible when treating taps, formed milling cutters, punch-press dies, forming tools and similar articles. Experience shows that such tools give excellent results when pack hardened. When employing this method the tools should be packed in charred leather and run at a temperature ranging from 1750° to 2200° F. according to the character of the tool and the use to which it is to be put.

Milling cutters and similar tools whose design allows of grinding after hardening and which are to be used for heavy roughing cuts may be heated higher than the temperatures mentioned above, the heats ranging from 2250° to 2350° F., while those to be used for light and finishing cuts may not require more than 2100° F. Threading dies, taps, reamers and other tools to be subjected to torsional (twisting) strains, require a temperature of 1950° to 2150° F., chisels, some classes of piercing punches and other tools that are to receive repeated shocks should not be heated above 1800° F. and in case of very severe usage not above 1750° F.

Cooling.—Pack-hardened high-speed steel tools should not be quenched in an air blast, but in oil. For many tools a light lard oil works well, but for general use cotton-seed oil, or a commercial hardening oil is best.

The pieces should be worked around well in the bath and allowed to remain until cold. The cause of failure many times can be traced to insufficient movement of the piece in the bath. This is especially true of large tools, milling-machine cutters, and punch-press blanking dies where the vapors are liable to lodge and prevent the oil reaching the essential portions.

As the melting point of cast iron is comparatively low it is not advisable to use boxes made from this material when pack hardening high-speed steel as they are liable to give out quickly. The most satisfactory box is one made from boiler plate, or similar material.

The length of time pieces should be exposed to the temperatures mentioned varies from one to four hours according to the size of the piece and the use to which it is to be subjected. Tools hardened by this method give better results in use than if heated in the open fire.

TABLES.

TABLE I.

Circumferences and Areas of Circles.

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
1/4	.7854	.0490	3	9.4248	7.0686
5/16	.9817	.0767	1/8	9.8175	7.6699
3/8	1.1781	.1104	1/4	10.210	8.2958
7/16	1.3744	.1503	3/8	10.603	8.9462
1/2	1.5708	.1963	1/2	10.996	9.6211
9/16	1.7671	.2485	5/8	11.388	10.321
5/8	1.9635	.3068	3/4	11.781	11.045
11/16	2.1598	.3712	7/8	12.174	11.793
3/4	2.3562	.4417	4	12.566	12.566
13/16	2.5525	.5184	1/8	12.959	13.364
7/8	2.7489	.6013	1/4	13.352	14.186
15/16	2.9452	.6902	3/8	13.744	15.033
1	3.1416	.7854	1/2	14.137	15.904
1/16	3.3379	.8866	5/8	14.530	16.800
1/8	3.5343	.9940	3/4	14.923	17.728
3/16	3.7306	1.1075	7/8	15.315	18.665
1/4	3.9270	1.2272	5	15.708	19.635
5/16	4.1233	1.3530	1/8	16.101	20.629
3/8	4.3197	1.4849	1/4	16.493	21.648
7/16	4.5160	1.6230	3/8	16.886	22.691
1/2	4.7124	1.7671	1/2	17.279	23.758
9/16	4.9087	1.9175	5/8	17.671	24.850
5/8	5.1051	2.0739	3/4	18.064	25.967
11/16	5.3014	2.2365	7/8	18.457	27.109
3/4	5.4978	2.4053	6	18.850	28.274
13/16	5.6941	2.5802	1/8	19.242	29.465
7/8	5.8905	2.7612	1/4	19.635	30.680
15/16	6.0868	2.9483	3/8	20.028	31.919
2	6.2832	3.1416	1/2	20.420	33.183
1/16	6.4795	3.3410	5/8	20.813	34.472
1/8	6.6759	3.5466	3/4	21.206	35.785
3/16	6.8722	3.7583	7/8	21.598	37.122
1/4	7.0686	3.9761	7	21.991	38.485
5/16	7.2649	4.2000	1/8	22.384	39.871
3/8	7.4613	4.4301	1/4	22.776	41.282
7/16	7.6576	4.6664	3/8	23.169	42.718
1/2	7.8540	4.9087	1/2	23.562	44.179
9/16	8.0503	5.1572	5/8	23.955	45.664
5/8	8.2467	5.4119	3/4	24.347	47.173
11/16	8.4430	5.6727	7/8	24.740	48.707
3/4	8.6394	5.9396	8	25.133	50.265
13/16	8.8357	6.2126	1/8	25.525	51.849
7/8	9.0321	6.4918	1/4	25.918	53.456
15/16	9.2284	6.7771	3/8	26.311	55.088

TABLE I—(*Continued*).
Circumferences and Areas of Circles.

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
8½	26.704	56.745	16¼	51.051	207.39
⅝	27.096	58.426	½	51.836	213.82
¾	27.489	60.132	¾	52.622	220.35
⅞	27.882	61.862	17	53.407	226.98
9	28.274	63.617	¼	54.192	233.71
⅛	28.667	65.397	½	54.978	240.53
¼	29.060	67.201	¾	55.763	247.45
⅜	29.452	69.029	18	56.549	254.47
½	29.845	70.882	¼	57.334	261.59
⅝	30.238	72.760	½	58.119	268.80
¾	30.631	74.662	¾	58.905	276.12
⅞	31.023	76.589	19	59.690	283.53
10	31.416	78.540	¼	60.476	291.04
⅛	31.809	80.516	½	61.261	298.65
¼	32.201	82.516	¾	62.046	306.35
⅜	32.594	84.541	20	62.832	314.16
½	32.987	86.590	¼	63.617	322.06
⅝	33.379	88.664	½	64.403	330.06
¾	33.772	90.763	¾	65.188	338.16
⅞	34.165	92.886	21	65.973	346.36
11	34.558	95.033	¼	66.759	354.66
⅛	34.950	97.205	½	67.544	363.05
¼	35.343	99.402	¾	68.330	371.54
⅜	35.736	101.62	22	69.115	380.13
½	36.128	103.87	¼	69.900	388.82
⅝	36.521	106.14	½	70.686	397.61
¾	36.914	108.43	¾	71.471	406.49
⅞	37.306	110.75	23	72.257	415.48
12	37.699	113.10	¼	73.042	424.56
¼	38.485	117.86	½	73.827	433.74
½	39.270	122.72	¾	74.613	443.01
¾	40.055	127.68	24	75.398	452.39
13	40.841	132.73	¼	76.184	461.86
¼	41.626	137.89	½	76.969	471.44
½	42.412	143.14	¾	77.754	481.11
¾	43.197	148.49	25	78.540	490.87
14	43.982	153.94	¼	79.325	500.74
¼	44.768	159.48	½	80.111	510.71
½	45.553	165.13	¾	80.896	520.77
¾	46.338	170.87	26	81.681	530.93
15	47.124	176.71	¼	82.467	541.19
¼	47.909	182.65	½	83.252	551.55
½	48.695	188.69	¾	84.038	562.00
¾	49.480	194.83	27	84.823	572.56
16	50.265	201.06	¼	85.608	583.21

TABLE I—(*Continued*).

Circumferences and Areas of Circles.

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
27½	86.394	593.96	38¾	121.737	1179.3
¾	87.179	604.81	39	122.522	1194.6
28	87.965	615.75	¼	123.308	1210.0
¼	88.750	626.80	½	124.093	1225.4
½	89.535	637.94	¾	124.878	1241.0
¾	90.321	649.18	40	125.664	1256.6
29	91.106	660.52	¼	126.449	1272.4
¼	91.892	671.96	½	127.235	1288.2
½	92.677	683.49	¾	128.020	1304.2
¾	93.462	695.13	41	128.805	1320.3
30	94.248	706.86	¼	129.591	1336.4
¼	95.033	718.69	½	130.376	1352.7
½	95.819	730.62	¾	131.161	1369.0
¾	96.604	742.64	42	131.947	1385.4
31	97.389	754.77	¼	132.732	1402.0
¼	98.175	766.99	½	133.518	1418.6
½	98.960	779.31	¾	134.303	1435.4
¾	99.746	791.73	43	135.088	1452.2
32	100.531	804.25	¼	135.874	1469.1
¼	101.316	816.86	½	136.659	1486.2
½	102.102	829.58	¾	137.445	1503.3
¾	102.887	842.39	44	138.230	1520.5
33	103.673	855.30	¼	139.015	1537.9
¼	104.458	868.31	½	139.801	1555.3
½	105.243	881.41	¾	140.586	1572.8
¾	106.029	894.62	45	141.372	1590.4
34	106.814	907.92	¼	142.157	1608.2
¼	107.600	921.32	½	142.942	1626.0
½	108.385	934.82	¾	143.728	1643.9
¾	109.170	948.42	46	144.513	1661.9
35	109.956	962.11	¼	145.299	1680.0
¼	110.741	975.91	½	146.084	1698.2
½	111.527	989.80	¾	146.869	1716.5
¾	112.312	1003.8	47	147.655	1734.9
36	113.097	1017.9	¼	148.440	1753.5
¼	113.883	1032.1	½	149.226	1772.1
½	114.668	1046.3	¾	150.011	1790.8
¾	115.454	1060.7	48	150.796	1809.6
37	116.239	1075.2	¼	151.582	1828.5
¼	117.024	1089.8	½	152.367	1847.5
½	117.810	1104.5	¾	153.153	1866.5
¾	118.596	1119.2	49	153.938	1885.7
38	119.381	1134.1	¼	154.723	1905.0
¼	120.166	1149.1	½	155.509	1924.4
½	120.951	1164.2	¾	156.294	1943.9

TABLE I—(*Continued*).

Circumferences and Areas of Circles.

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
50	157.080	1963.5	62½	196.350	3068.0
¼	157.865	1983.2	63	197.920	3117.2
½	158.650	2003.0	½	199.491	3166.9
¾	159.436	2022.8	64	201.062	3217.0
51	160.221	2042.8	½	202.633	3267.5
¼	161.007	2062.9	65	204.204	3318.3
½	161.792	2083.1	½	205.774	3369.6
¾	162.577	2103.3	66	207.345	3421.2
52	163.363	2123.7	½	208.916	3473.2
¼	164.148	2144.2	67	210.487	3525.7
½	164.934	2164.8	½	212.058	3578.5
¾	165.719	2185.4	68	213.628	3631.7
53	166.504	2206.2	½	215.199	3685.3
¼	167.290	2227.0	69	216.770	3739.3
½	168.075	2248.0	½	218.341	3793.7
¾	168.861	2269.1	70	219.911	3848.5
54	169.646	2290.2	½	221.482	3903.6
¼	170.431	2311.5	71	223.053	3959.2
½	171.217	2332.8	½	224.624	4015.2
¾	172.002	2354.3	72	226.195	4071.5
55	172.788	2375.8	½	227.765	4128.2
¼	173.573	2397.5	73	229.336	4185.4
½	174.358	2419.2	½	230.907	4242.9
¾	175.144	2441.1	74	232.478	4300.8
56	175.929	2463.0	½	234.049	4359.2
¼	176.715	2485.0	75	235.619	4417.9
½	177.500	2507.2	½	237.190	4477.0
¾	178.285	2529.4	76	238.761	4536.5
57	179.071	2551.8	½	240.332	4596.3
¼	179.856	2574.2	77	241.903	4656.6
½	180.642	2596.7	½	243.473	4717.3
¾	181.427	2619.4	78	245.044	4778.4
58	182.212	2642.1	½	246.615	4839.8
¼	182.998	2664.9	79	248.186	4901.7
½	183.783	2687.8	½	249.757	4963.9
¾	184.569	2710.9	80	251.327	5026.5
59	185.354	2734.0	½	252.898	5089.6
¼	186.139	2757.2	81	254.469	5153.0
½	186.925	2780.5	½	256.040	5216.8
¾	187.710	2803.9	82	257.611	5281.0
60	188.496	2827.4	½	259.181	5345.6
½	190.066	2874.8	83	260.752	5410.6
61	191.637	2922.5	½	262.323	5476.0
½	193.208	2970.6	84	263.894	5541.8
62	194.779	3019.1	½	265.465	5607.9

TABLE I—(*Continued*).
CIRCUMFERENCES AND AREAS OF CIRCLES.

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
85	267.035	5674.5	93	292.168	6792.9
½	268.606	5741.5	½	293.739	6866.1
86	270.177	5808.8	94	295.310	6939.8
½	271.748	5876.5	½	296.881	7013.8
87	273.319	5944.7	95	298.451	7088.2
½	274.889	6013.2	½	300.022	7163.0
88	276.460	6082.1	96	301.593	7238.2
½	278.031	6151.4	½	303.164	7313.8
89	279.602	6221.1	97	304.734	7389.8
½	281.173	6291.2	½	306.305	7466.2
90	282.743	6361.7	98	307.876	7543.0
½	284.314	6432.6	½	309.447	7620.1
91	285.885	6503.9	99	311.018	7697.7
½	287.456	6575.5	½	312.588	7775.6
92	289.027	6647.6	100	314.159	7854.0
½	290.597	6720.1			

TABLE II.

Temperatures to which Hardened Tools should be Heated to Properly "Draw the Temper," together with the Colors of Scale appearing on a Polished-steel Surface at those Temperatures, and other Means of Detecting Proper Heating.

Kind of Tool.	Temperature, Fahr.	Color of Scale.	Action of File.	Other Indications.
Scrapers for ordinary use.	200°			Water dries quickly.
Burnishers. Light turning and finishing tools.	430°	Very pale yellow.	Can hardly be made to catch.	Lard-oil smokes slightly.
Engraving-tools. Lathe-tools. Milling-cutters. Lathe- and planer-tools for heavy work. Taps. Dies for screw-cut'g. Reamers. Punches. Dies. Flat drills.	460°	Straw-yellow.	Can be made to catch with difficulty.	
Wood-working tools. Plane-irons. Wood-chisels. Wood-turning tools. Twist drills. Sledges. Bl'ksmiths' ham'rs.	500°	Brown-yellow.		
Cold-chisels for very light work.	530°	Light purple.	Scratches.	
Axes. Cold-chisels for ordinary use.	550°	Dark purple.		
		Blue, ting'd slightly with red.		
Stone-cutting chisels Carving-knives. Screw-drivers. Saws.			Files with great difficulty.	
Springs.	580° 610° 630°	Blue. Pale blue. Greenish blue.	Files with difficulty.	Lard-oil burns or flashes.

TABLE III.

Decimal Equivalents of Fractions of One Inch.

From Kent's Mechanical Engineer's Pocket-book.

1/64	.015625	33/64	.515625
1/32	.03125	17/32	.53125
3/64	.046875	35/64	.546875
1/16	.0625	9/16	.5625
5/64	.078125	37/64	.578125
3/32	.09375	19/32	.59375
7/64	.109375	39/64	.609375
1/8	.125	5/8	.625
9/64	.140625	41/64	.640625
5/32	.15625	21/32	.65625
11/64	.171875	43/64	.671875
3/16	.1875	11/16	.6875
13/64	.203125	45/64	.703125
7/32	.21875	23/32	.71875
15/64	.234375	47/64	.734375
1/4	.25	3/4	.75
17/64	.265625	49/64	.765625
9/32	.28125	25/32	.78125
19/64	.296875	51/64	.796875
5/16	.3125	13/16	.8125
21/64	.328125	53/64	.828125
11/32	.34375	27/32	.84375
23/64	.359375	55/64	.859375
3/8	.375	7/8	.875
25/64	.390625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	.421875	59/64	.921875
7/16	.4375	15/16	.9375
29/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375
1/2	.50	1	1.

TABLE IV.

Weights of Bar Steel per Lineal Foot.

The weight given in the table is for a bar of steel 1 foot long and of the dimensions named.

(From Jones & Laughlins.)

Size in Inches.	Rounds, Weight in Lbs.	Squares, Weight in Lbs.	Size in Inches.	Rounds, Weight in Lbs.	Squares, Weight in Lbs.	Width in Inches.	Thickness in Inches.											
							1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
3/16	.094	.120	2 1/8	12.06	15.36	1	.21	.43	.638	.850	1.06	1.28	1.49	1.70	2.12	2.55	2.98	
1/4	.167	.213	2 1/4	13.52	17.22	1 1/8	.24	.48	.720	.955	1.20	1.43	1.68	1.92	2.39	2.87	3.35	3.88
5/16	.261	.332	2 3/8	15.07	19.19	1 1/4	.27	.53	.797	1.06	1.33	1.59	1.86	2.12	2.65	3.19	3.72	4.25
3/8	.375	.478	2 1/2	16.70	21.26	1 3/8	.30	.59	.875	1.17	1.46	1.76	2.05	2.34	2.92	3.51	4.09	4.68
7/16	.511	.651	2 5/8	18.41	23.44	1 1/2	.32	.64	.957	1.28	1.59	1.92	2.23	2.55	3.19	3.83	4.47	5.10
1/2	.668	.851	2 3/4	20.21	25.73	1 5/8	.35	.69	1.04	1.38	1.73	2.08	2.42	2.77	3.46	4.15	4.84	5.53
9/16	.845	1.076	3	24.05	30.62	1 3/4	.38	.75	1.11	1.49	1.86	2.23	2.60	2.98	3.72	4.47	5.20	5.95
5/8	1.044	1.329	3 1/4	28.23	35.94	2	.43	.85	1.28	1.70	2.12	2.55	2.98	3.40	4.25	5.10	5.95	6.80
3/4	1.503	1.914	3 1/2	32.74	41.68	2 1/4	.48	.96	1.44	1.91	2.39	2.87	3.35	3.83	4.78	5.75	6.69	7.65
7/8	2.046	2.605	3 3/4	37.57	47.84	2 1/2	.53	1.06	1.59	2.12	2.65	3.19	3.72	4.25	5.31	6.38	7.44	8.50
1	2.672	3.402	4	42.77	54.45	2 3/4	.59	1.17	1.75	2.34	2.92	3.51	4.09	4.67	5.84	7.02	8.18	9.35
1 1/8	3.382	4.306	4 1/2	54.83	69.81	3	.64	1.28	1.91	2.55	3.19	3.83	4.46	5.10	6.38	7.65	8.93	10.20
1 1/4	4.175	5.316	5	66.82	85.08	3 1/4	.69	1.38	2.07	2.76	3.45	4.15	4.83	5.53	6.91	8.29	9.67	11.05
1 3/8	5.052	6.432	5 1/2	80.85	102.94	3 1/2	.75	1.49	2.23	2.98	3.72	4.47	5.20	5.95	7.44	8.93	10.41	11.90
1 1/2	6.012	7.655	6	96.22	122.51	3 3/4	.80	1.60	2.39	3.19	3.99	4.78	5.58	6.38	7.97	9.57	11.16	12.75
1 5/8	7.056	8.984	6 1/2	112.92	143.78	4	.85	1.70	2.55	3.40	4.25	5.10	5.95	6.80	8.50	10.20	11.90	13.60
1 3/4	8.183	10.419	7	130.97	166.75	4 1/2	.96	1.92	2.87	3.83	4.78	5.74	6.70	7.65	9.57	11.48	13.39	15.30
1 7/8	9.394	11.961	7 1/2	150.34	191.42	5	1.07	2.13	3.19	4.25	5.31	6.38	7.44	8.50	10.63	12.75	14.87	17.00
2	10.69	13.61	8	171.04	217.78	5 1/2	1.17	2.34	3.51	4.67	5.84	7.02	8.18	9.35	11.69	14.03	16.36	18.70
						6	1.28	2.55	3.83	5.10	6.38	7.65	8.93	10.20	12.75	15.30	17.85	20.40
						7	1.49	2.98	4.46	5.95	7.44	8.93	10.41	11.90	14.87	17.85	20.83	23.80
						8	1.70	3.40	5.10	6.80	8.50	10.20	11.90	13.60	17.00	20.40	23.80	27.20

COURSE OF EXERCISES IN FORGE WORK.

What is suggested as a standard course of exercises is given below.

A short talk should first be given covering the calculation of stock for simple bent work, rings, links, eyes, etc.

The starting of the fire and fitting of tongs is then explained.

Exercise 1. Stock $\frac{1}{2}'' \times \frac{1}{2}'' \times 6''$ is drawn out to $\frac{1}{4}''$ round, and this round stock is used to make the two following pieces of work.

Exercise 2. Fig. 338. Eye Bend.

Exercise 3. Fig. 339. Double Eye Bend.

Exercise 4. Fig. 341. Twisted Gate Hook.

Exercise 5. Fig. 342. Square Point and Eye Bend.

Exercise 6. Fig. 377. Twisted Scriber. Before giving this exercise a short talk should be given on the effect of high heats on tool steel. The scriber should be forged from an old file in order to give practice in the drawing out of tool steel. The scriber is tempered later in the course.

Exercise 7. Fig. 342. Weldless Ring.

Exercise 8. Fig. 355. Chain Hook.

Exercise 9. Fig. 351. Bracket with Forged Corner.

Exercise 10. Practice Weld. This should be a sort of a faggot weld made by doubling over the end of a piece of scrap, the object being simply to determine the welding heat.

Exercise 11. Fig. 357. Chain of Three Links.

Exercise 12. Fig. 348. Flat Lap Weld.

Exercise 13. Fig. 349. Angle Weld.

Exercise 14. Fig. 347. Welded Ring. This and the hook made in Ex. 9 should each be joined to the chain by extra links, making a chain of five links with the hook on one end and the ring on the other.

Exercise 15. Fig. 373. Welded Rings shrunk together.

Exercise 16. Fig. 358. Planer Bolt, make welded head.

Exercise 17. Fig. 352. Hexagonal Head Bolt, upset head.

Exercise 18. Fig. 354. Ladle.

Exercise 19. Fig. 367. Taper Machine Key.

Exercise 20. Fig. 368. Lever Arm.

Exercise 21. Figs. 370, 371, or 372. Tongs.

Exercise 22. Hardening Tool Steel. The student should be given an old file or piece of scrap tool steel to determine the proper hardening heat. This is done by drawing out the steel to about $\frac{1}{4}''$ square and hardening the end, which is then snapped off and the condition of the steel determined from the fracture. This should be repeated until the hardening heat can be hit upon every time.

Exercise 23. Fig. 313. Cold Chisel.

Exercise 24. Fig. 380. Center Punch.
Exercise 25. Fig. 397. Cape Chisel.
Exercise 26. Figs. 382 or 383. Thread Tool.
Exercise 27. Fig. 384. Round Nose Tool.
Exercise 28. Fig. 381. Side Tool.
Exercise 29. Fig. 387. Boring Tool.
Exercise 30. Fig. 385. Diamond Point.
Exercise 31. Figs. 393, 394, 395, 396, or 399. Hot Chisel, Cold Chisel, Set Hammer, Flatter or Pattern-maker's Hammer.
Exercise 32. Fig. 400. Spring.
Exercise 33. Fig. 375. Brazed Ring.

Many students will be able to cover much more ground than outlined above, and for such cases additional drawings are given. These additional exercises may be interpolated where the instructor sees fit.

Additional drawings are also given in order that the course may be varied somewhat from term to term.

No more than three pieces of stock should ever be allowed for any one exercise, and as a general rule the student should do the work with one. When more than one piece is used the work should be graded down accordingly.

Talks should be given on Brazing, Case Hardening, Metallurgy of Bessemer, Open Hearth, and Crucible Steels and Wrought Iron.

Considerable work should also be done in making sketches and stock calculations for large machine forgings, the sketches to show the different steps in the forging process.

When a steam or power hammer is available old hammers, tools, etc., may be drawn out into bar stock for center punches, small chisels, etc.

The tongs shown in the drawings may be made to good advantage under a steam or power hammer.

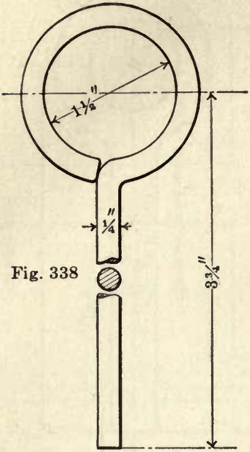


Fig. 338

EYE BEND

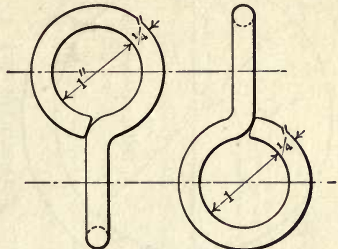


Fig. 339

DOUBLE EYE BEND

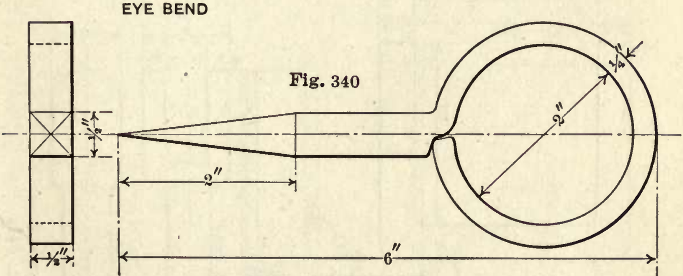


Fig. 340

SQ. POINT AND EYE BEND

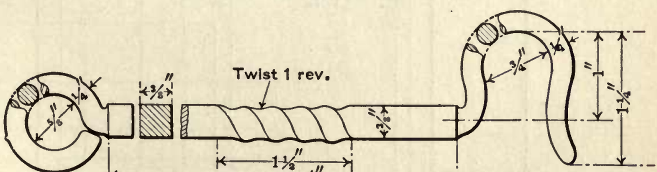
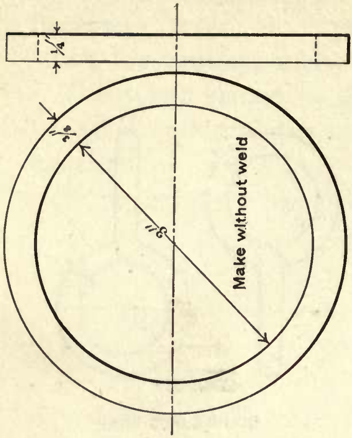
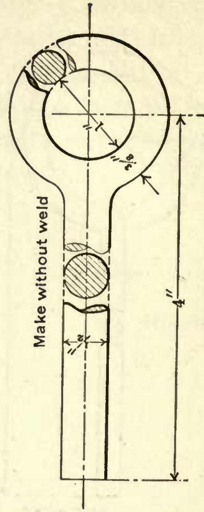


Fig. 341

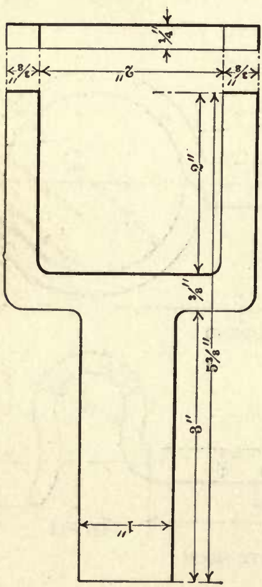
TWISTED GATE HOOK



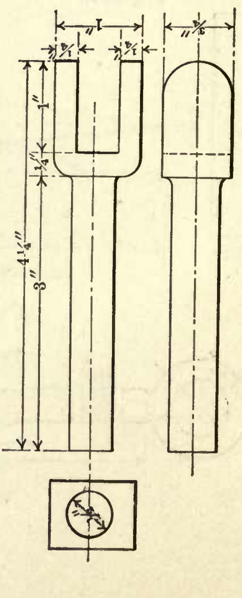
WELDLESS RING
Fig. 342



FORGED EYE
Fig. 344



FORK
Fig. 343



KNUCKLE
Fig. 345

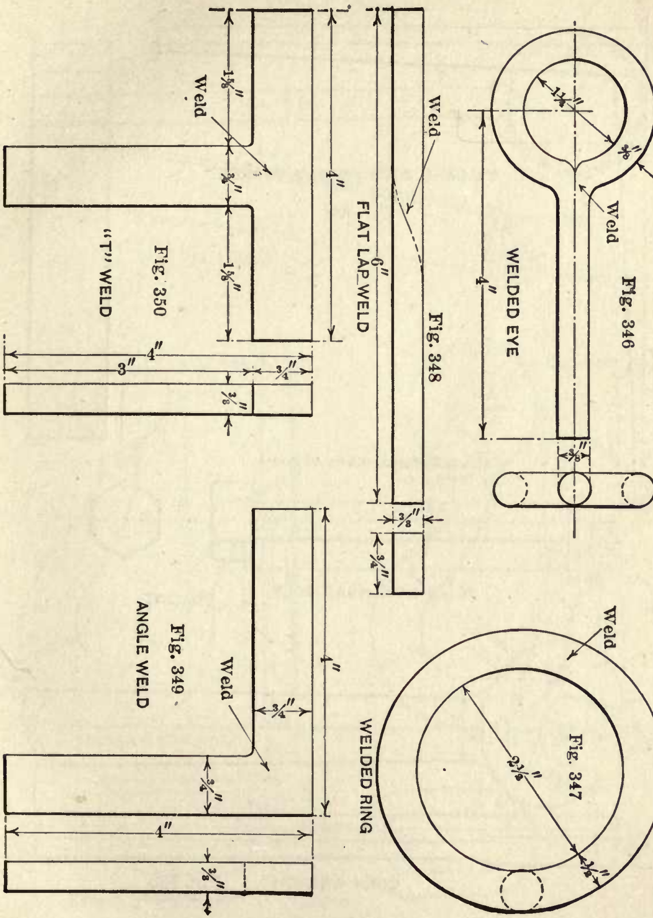


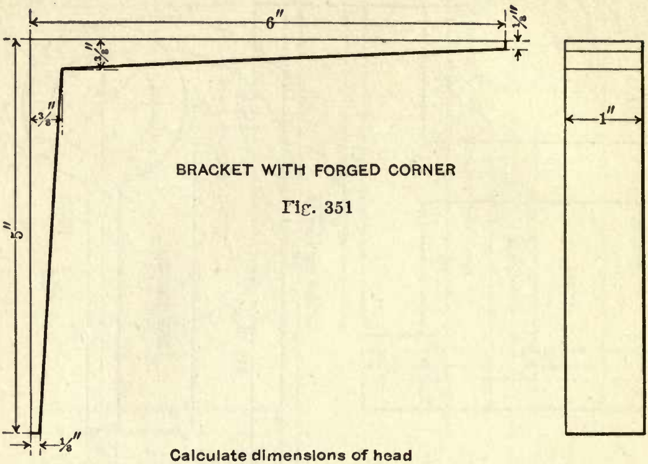
Fig. 346 WELDED EYE

Fig. 347 WELDED RING

Fig. 348 FLAT LAP WELD

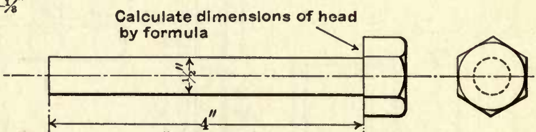
Fig. 349 ANGLE WELD

Fig. 350 "T" WELD



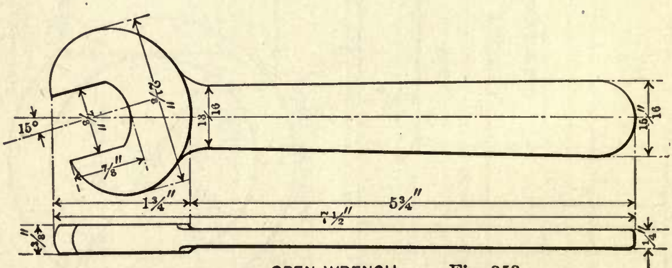
BRACKET WITH FORGED CORNER

Fig. 351



1/2" x 4" HEX. HEAD BOLT

Fig. 352



OPEN WRENCH

Fig. 353

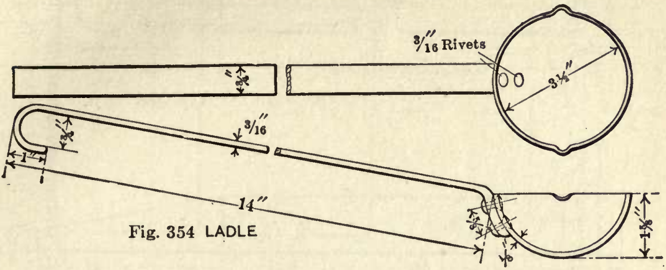


Fig. 354 LADLE

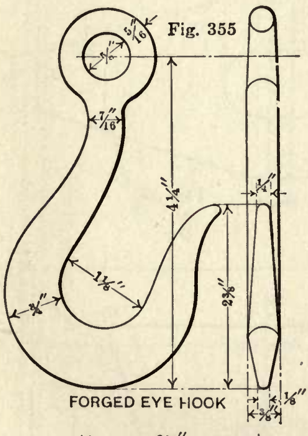


Fig. 355

FORGED EYE HOOK

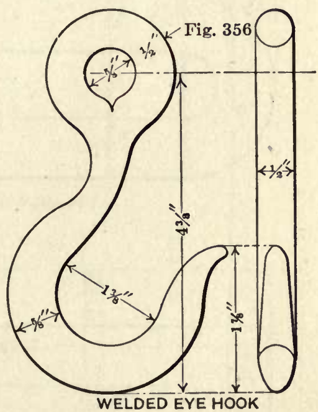
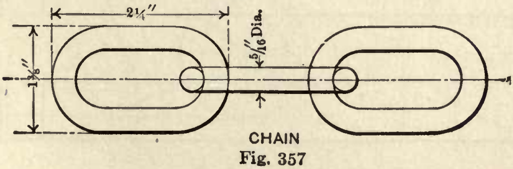
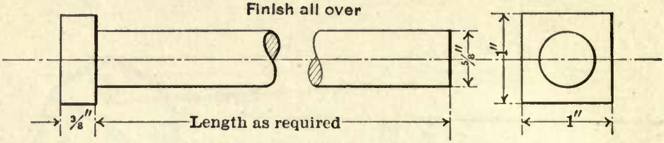


Fig. 356

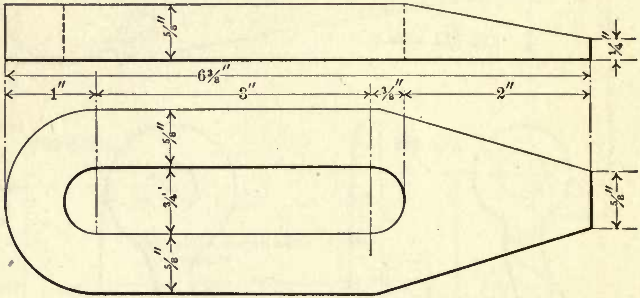
WELDED EYE HOOK



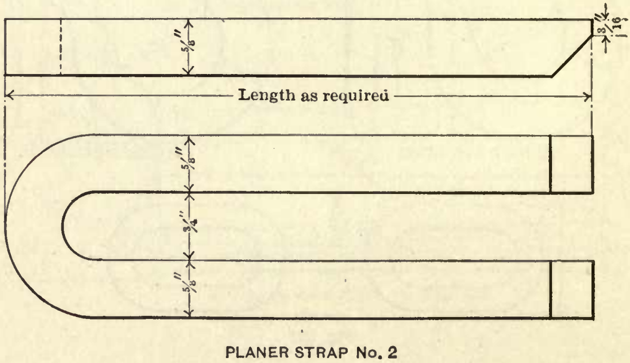
CHAIN
Fig. 357



PLANER BOLT Fig. 358



PLANER STRAP No. 1 Fig. 359



PLANER STRAP No. 2

Fig. 360

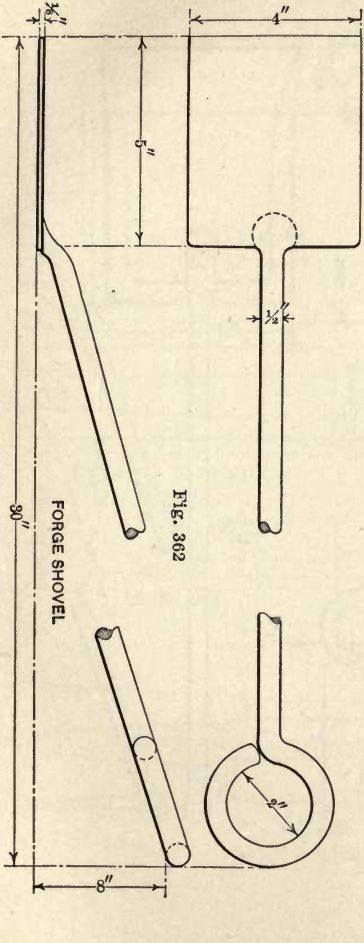


Fig. 362

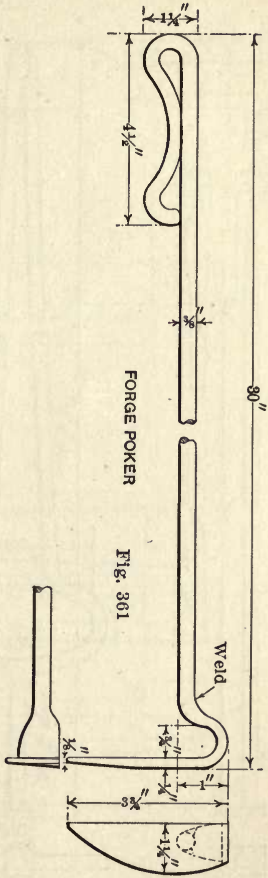


Fig. 361

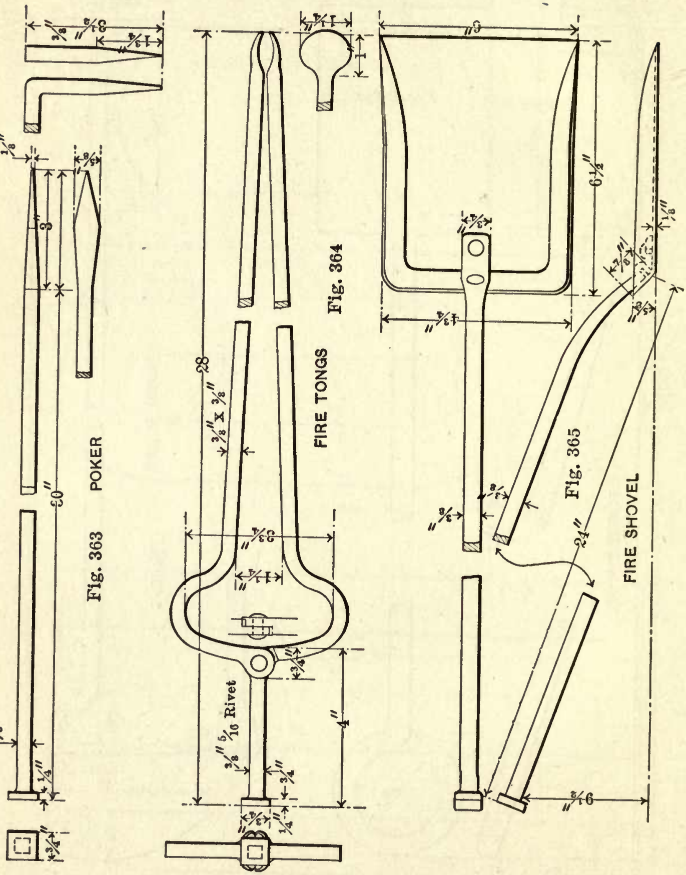


Fig. 363 POKER

Fig. 364 FIRE TONGS

Fig. 365 FIRE SHOVEL

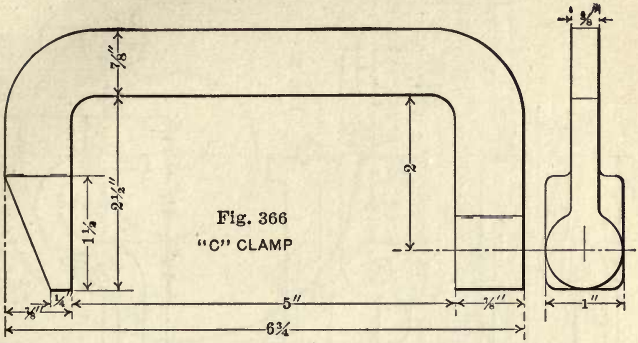
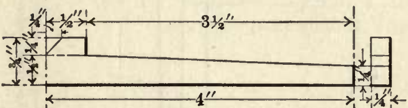
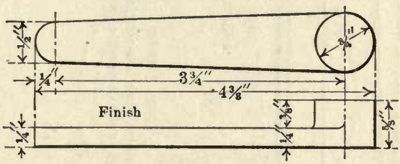


Fig. 366
"C" CLAMP



TAPER KEY Finish all over
Fig. 367

Fig. 368
LEVER ARM



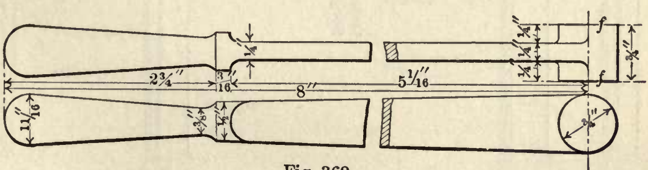
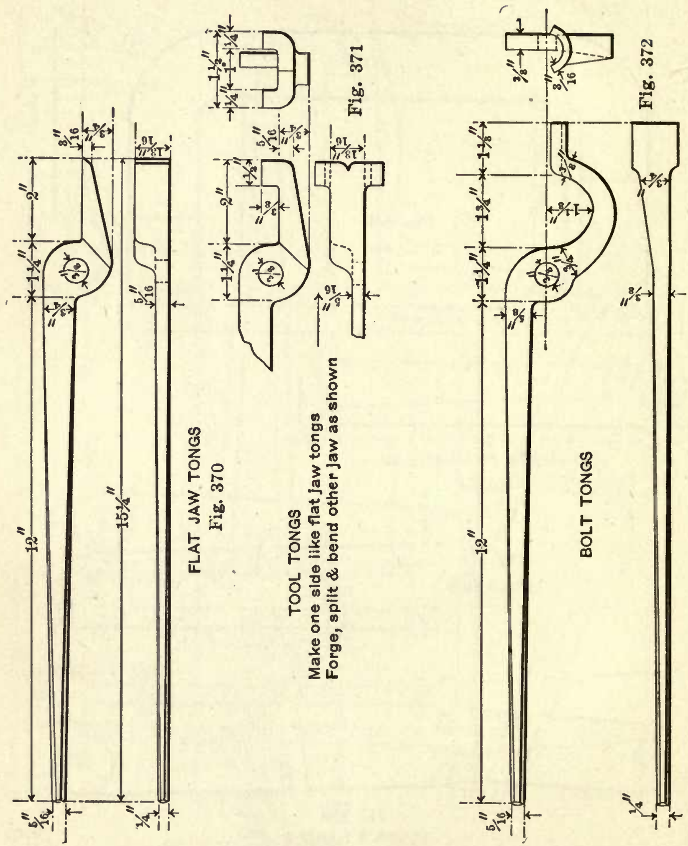


Fig. 369
LEVER & HANDLE



FLAT JAW TONGS
Fig. 370

TOOL TONGS
Make one side like flat jaw tongs
Forge, split & bend other jaw as shown
Fig. 371

BOLT TONGS
Fig. 372

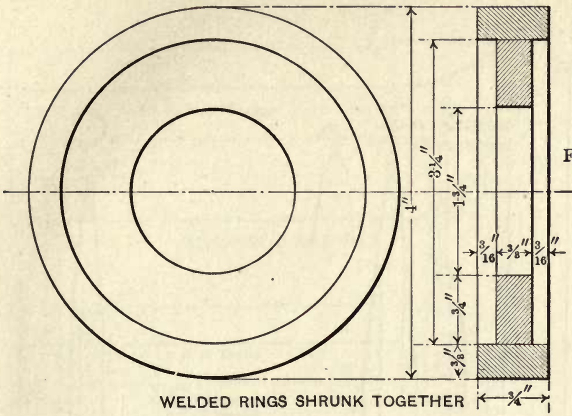


Fig. 373

WELDED RINGS SHRUNK TOGETHER

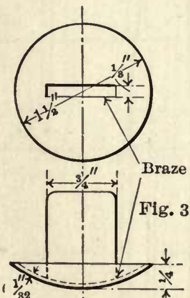
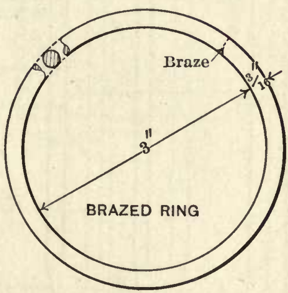


Fig. 374

BUTTON SLICK



BRAZED RING

Fig. 375

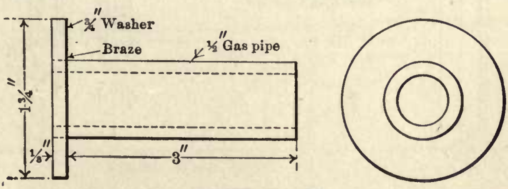


Fig. 376

BRAZED FLANGE

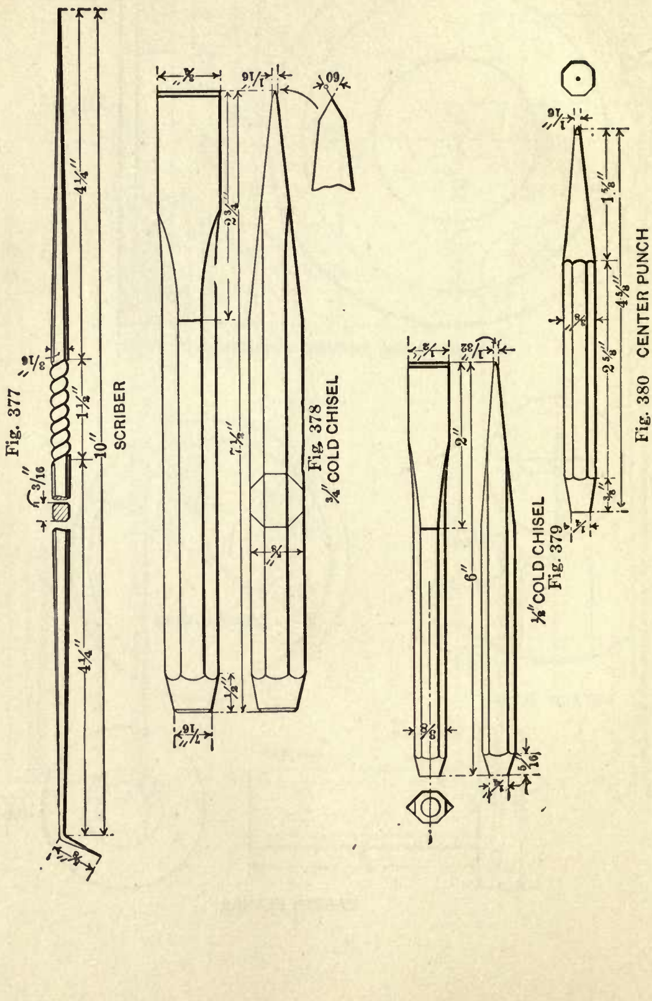


Fig. 377 SCRIBER

Fig. 378 ¾″ COLD CHISEL

½″ COLD CHISEL Fig. 379

Fig. 380 CENTER PUNCH

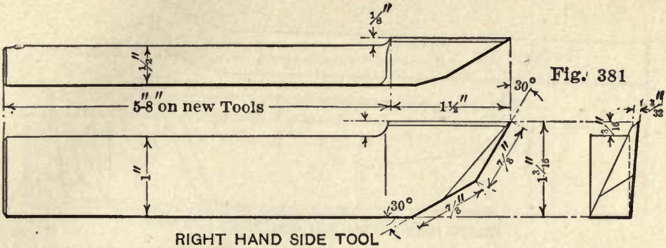


Fig. 381

RIGHT HAND SIDE TOOL

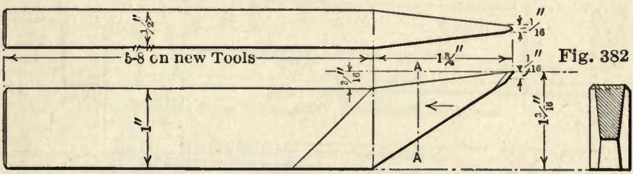


Fig. 382

THREAD TOOL No.1

SECTION A-A

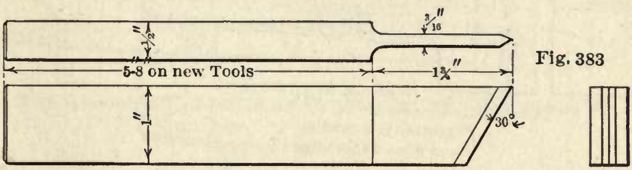


Fig. 383

THREAD TOOL No.2

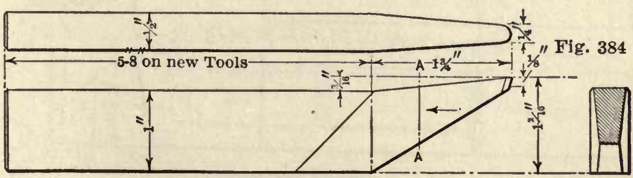


Fig. 384

ROUND NOSE TOOL

SECTION A-A

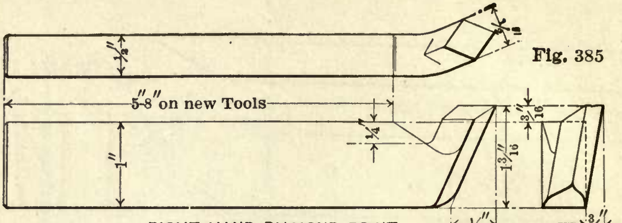
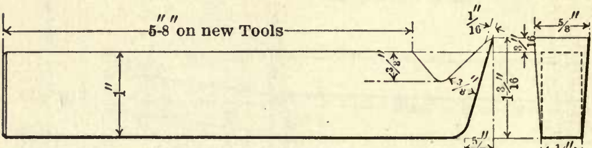


Fig. 385

RIGHT HAND DIAMOND POINT



FINISHING TOOL

Fig. 386

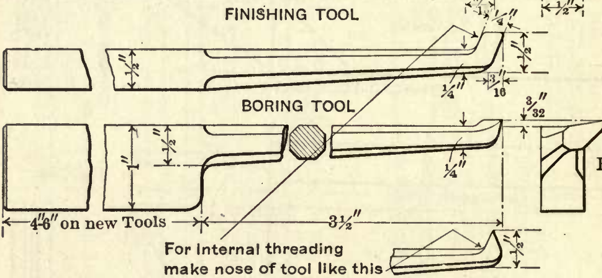


Fig. 387

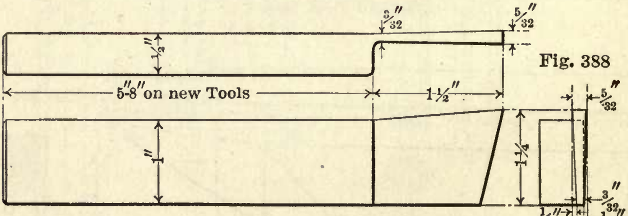
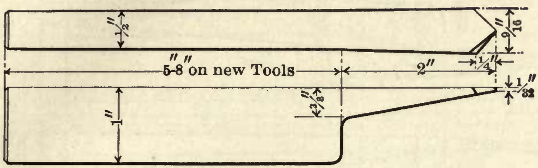
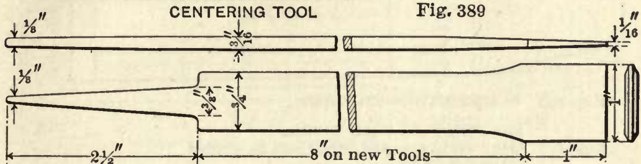


Fig. 388

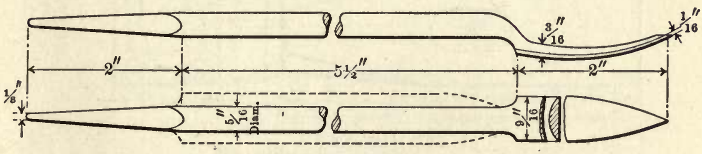
CUTTING OFF TOOL



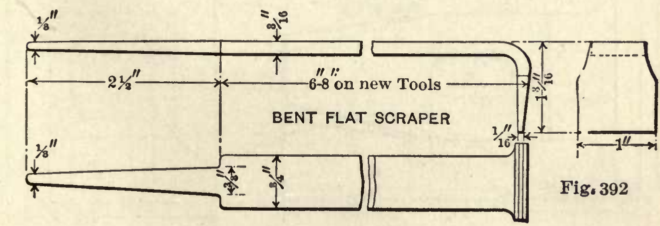
CENTERING TOOL Fig. 389



FLAT SCRAPER
(May be made from old file) Fig. 390



HALF ROUND SCRAPER Fig. 391
(May be made from old half round file as shown by dotted lines)



BENT FLAT SCRAPER

Fig. 392

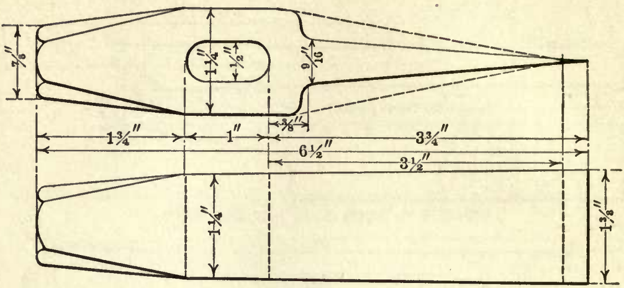
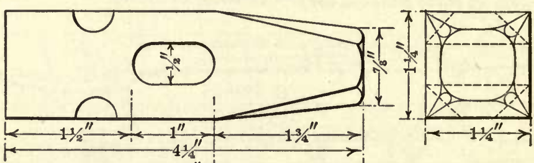


Fig. 393 BLACKSMITH'S HOT CHISEL

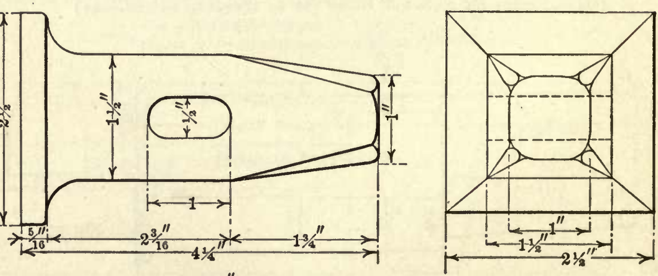
BLACKSMITH'S COLD CHISEL

Fig. 394 Make same way but shape end as shown by dotted line.



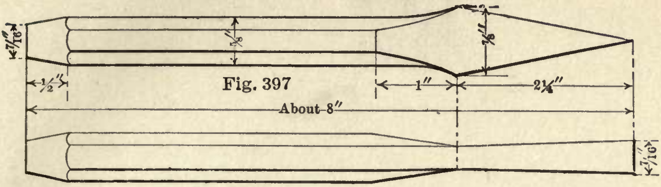
1 1/4″ SET HAMMER

Fig. 395

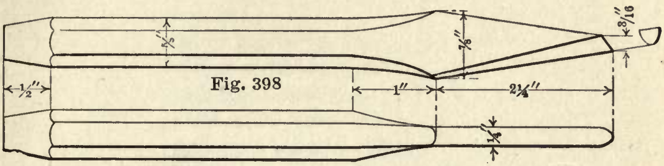


2 1/2″ FLATTER

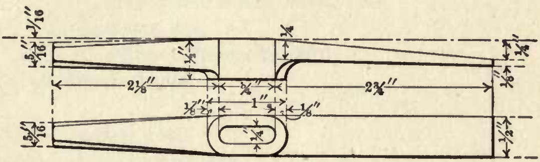
Fig. 396



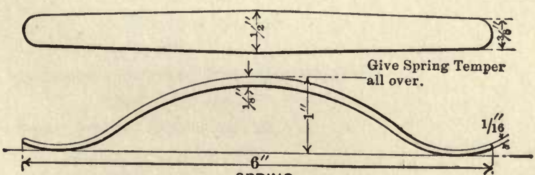
CAPE CHISEL



ROUND NOSE OR CENTERING CHISEL



PATTERN MAKER'S HAMMER
Fig. 399



SPRING
Fig. 400

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