PART I

CHAPTER 1

THE BLACKSMITH'S EQUIPMENT

Forge equipment consists of the Hearth, the Blast, the Anvil and the Bench and Vice.

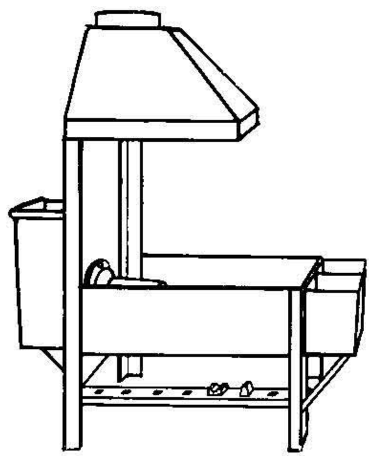


Fig. 2

THE HEARTH

As cast iron is resistant to corrosion it is an ideal material for a hearth in constant use, but where the work is intermittent, a hearth made of mild steel plate is satisfactory. The Rural Development Commission can supply drawings of a steel hearth (Fig. 2) which is simple to make, either by riveting or arc welding. It is important that the hearth should be well proportioned to allow the fire to form its own bed amongst the burned cinders and ashes. In addition to the place for the fire, a water trough and a container for fuel are needed. The most convenient arrangement is shown in Fig. 2, where the water and fuel troughs are made in one piece and fitted to the front of the hearth.

THE BLAST

An important feature of the hearth is the Blast Pipe, called the *tuyere* or *tue iron*. The most efficient tuyere is water cooled (A in Fig. 3) so that it

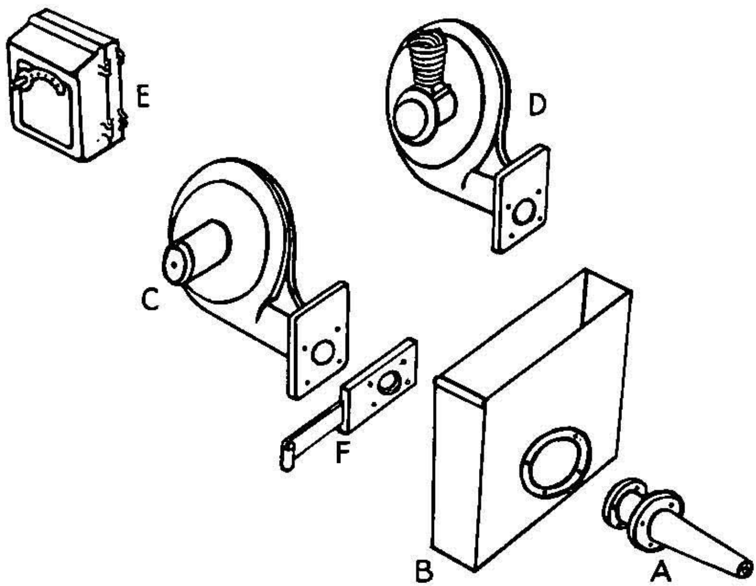


Fig. 3

can stick well out into the fire without the nose getting burned. In a well designed hearth, the tuyere passes through a cast-iron backplate which is detachable. The cooling water which circulates through the tuyere is contained in an open-topped tank just behind the hearth or, if space is short, it can be piped to a tank in a convenient position. The tank should have a lid to keep out dirt and reduce evaporation; it is wise to use rain water to avoid scaling up the inside of the tuyere. For general repair work a tuyere 16″ long with a ¾″ air hole is suitable. It is set horizontally on the centre line of the hearth-back with the hole 3″ below the level of the top of the side plates.

The blast is produced by either a bellows or a hand- or power-driven blower. The electrically driven blower (C in Fig. 3) is by far the most convenient, and a size suitable for the average hearth will consume less than a unit of electricity per day. The normal size will blow a second fire for occasional jobs. If electricity is not available, the same type of blower fitted with a petrol engine (D in Fig. 3) can be obtained. One type of set, driven by petrol engine, is fitted with a dynamotor and battery which makes it self-starting, and also provides 12-volt lighting for the shop. Although it may be possible to vary the speed of an electrically driven blower by a regulator (E in Fig. 3) or an engine driven set by the throttle, a valve is essential for accurate control of the blast. This may be a sliding shutter (F in Fig. 3), a butterfly valve, or an ordinary full-way rotating plug-cock. Whatever type is used, the control should work perfectly smoothly and be within easy reach of the blacksmith's free hand.

THE ANVIL

A good quality anvil is made of wrought iron or steel with a hardened steel top and is well worth the extra cost. Working on a bad anvil is like jumping on a heap of sand, whereas working on a good anvil set on a proper foundation is like jumping on a springboard—the rebound from one blow helps towards the next. Anvil patterns may vary for different purposes, but for general work it should have a long and finely tapered bick as shown in Fig. 4 which is a 'London Pattern' anvil standing on a welded angle steel

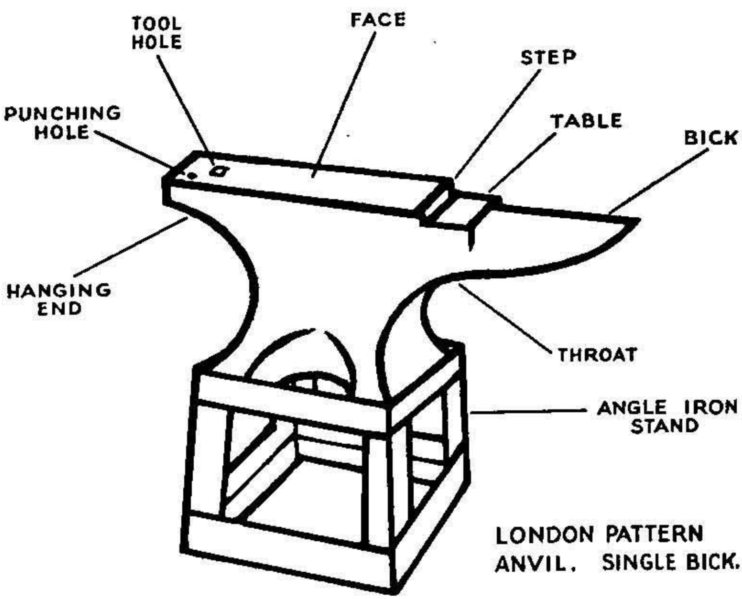


Fig. 4

stand. Although the face or top of the anvil is hardened, the bick and table, which is the square part between the bick and the face, are usually left soft. When cutting off with a chisel, the work should always be moved to the table before the final blow to avoid damaging the chisel edge. On a new anvil the front and back edges of the face are left sharp and it is advisable to round these off carefully with a carborundum file or a portable grinder in the places shown in Fig. 5. There are two holes in the face of an anvil; the square or hardy hole and the round or punching hole. It is a good plan to chamfer the edges of the square hole so that the hardy sits tight to the anvil face; this is also a convenience when using the hole for setting slightly curved bars. The liveliness or spring of an anvil is much improved by mounting it on a wooden block, preferably made from a squared-up trunk of elm. This should be sunk at least 3′ into the ground with the grain standing vertically. The disadvantage of setting up an anvil like this in the modern agricultural engineering shop is that the block cannot be moved out of the way. It may be more convenient to have a fabricated steel or cast-iron stand but, where space permits, it is a distinct advantage to have a wooden block.

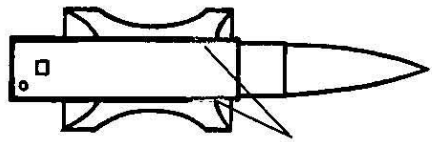


Fig. 5

THE BENCH

A well designed and strongly built bench is essential and it should be planned and designed to save time and labour. The one illustrated in Fig. 6 has a heavy wooden top bolted to an angle-iron frame; two vices are fitted, a leg vice nearest the hearth for heavy blacksmith's work, and an engineer's vice at the opposite end. It is more convenient to keep tools in boxes on a shelf under the bench than in drawers; the additional weight will help to stabilize the bench. To keep the bench clear of tools when working, a shelf of the type shown in Fig. 6 should be fitted to the wall above the bench. Close against the wall is a strip of wood with $\frac{1}{2}''$ and $\frac{3}{4}''$ holes bored alternately at 2″ intervals to take small tools which would not stand upright in a slot. In front of this is a $\frac{1}{2}''$ slot for the longer tools such as files and screwdrivers, and in front of this again is a broad shelf for tools in current use. The $\frac{1}{2}''$ holes drilled horizontally in the front edge of the broad shelf are for pencils, scribers, centre punches, etc. To keep these holes clear of dirt $\frac{3}{4}''$ holes can be drilled from the underside of the shelf as shown inset in top left corner of Fig. 6. A rack for pliers, shown inset on the right, can be made from two bars of $1'' \times \frac{3}{16}''$ iron about $\frac{3}{4}''$ apart and

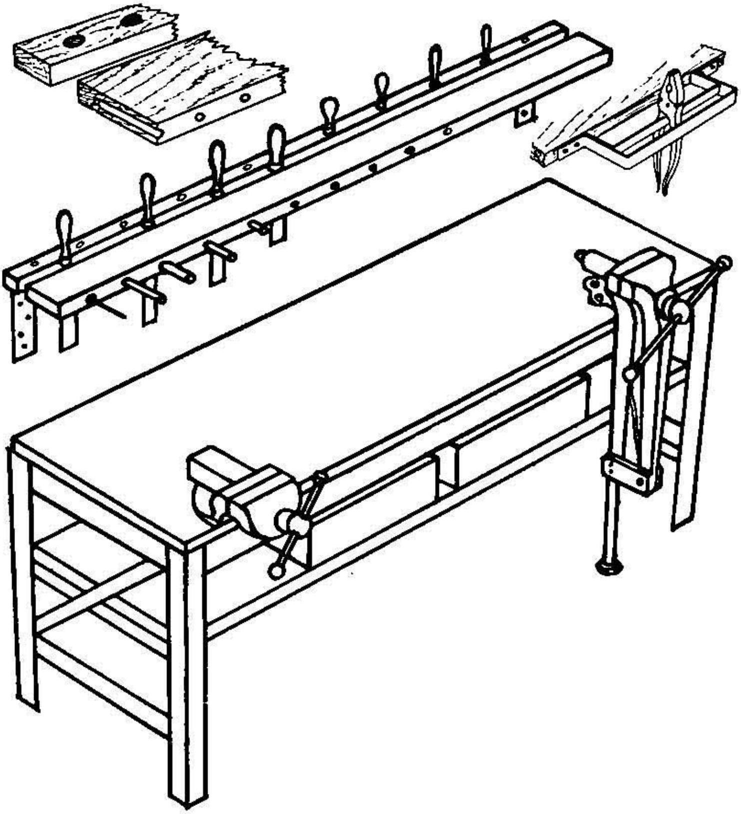


Fig. 6

fixed to the front of the shelf or in any other convenient place. Where space permits, the bench should be backed against the wall on the working side of the hearth and receive natural light from either a window or a sky-light. It does not matter if the shelf cuts across the window as the bench will still get the light and, in addition, the tools can be seen easily. If the smith cannot afford to install fluorescent lighting, which is ideal but expensive, ordinary electric lamps for the bench and machines should be fitted on adjustable brackets to give light where it is most needed.

THE VICES

A steel leg vice (Fig. 6) is still the best for smithing. Heavy bending or hammering should always be done in the leg vice, as the strain and shock on the jaws are taken by the leg which is usually let into a steel socket set in the concrete floor.

The parallel jaw or engineer's vice should also be made of steel, and it is an advantage to have a quick release action for the jaws. A cast steel engineer's vice will stand almost anything, but the cheaper malleable variety should only be used for fitting and precision work; it is not designed for heavy hammering or excessive strains on the jaws, and must not be used for these purposes.

TOOL RACKS

One type of rack for taking hardies and anvil swages is shown fitted beneath the hearth in Fig. 2.

Chisels, punches and drifts can be kept within reach of the anvil in another type of rack which is made by drilling a series of $\frac{7}{8}''$ holes in a piece of $2'' \times 2''$ timber secured to the wall or other convenient place with a piece of $2'' \times 1''$ below it, as shown in Fig. 7. In this type of rack both ends of each tool can always be seen; nothing can be lost down the holes, and dirt cannot block them.

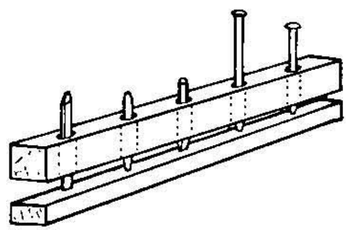


Fig. 7

TONG RACKS

These can be made of round or flat bar and are usually bolted or hung on the water trough where they are near the hearth.

FLOOR MANDREL

The Floor Mandrel (Fig. 8) is a hollow cast-iron cone, often standing breast high, which is used for rounding up small tyres, rings and hoops.

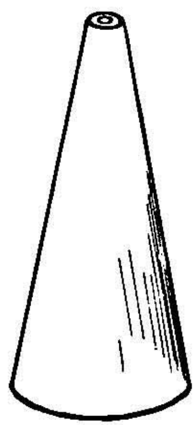


Fig. 8

THE SWAGE BLOCK

The swage block (Fig. 9) is a rectangular block of cast iron with different sizes of half round and V-shaped notches on all four sides and various shaped holes through the face. It is best mounted on a stand which enables any of the edges or the face to be used at a convenient height.

This completes the essential equipment of a blacksmith's shop. No heights for the bench and anvil have been given because individual craftsmen vary so much in their own heights and opinions. It is a useful guide to know that, when standing normally, you should be able to rest your elbow on the top of the vice.

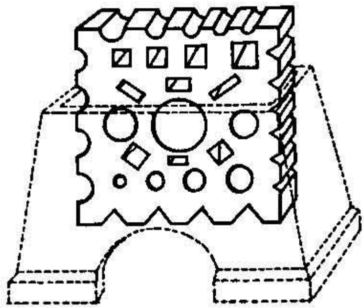


Fig. 9

Make up your mind what height suits you best and see that you have it right. It is all too easy to accept the height of a forge, an anvil or a vice as you find it and go on putting up with it without realizing that a small alteration will make life and work much easier for all time.

CHAPTER 2

THE BLACKSMITH'S TOOLS

The blacksmith, unlike many other craftsmen, is able to make most of his own tools, particularly when one is required for a special job.

The principal hand tools are hand and sledge-hammers, a great variety of chisels, punches, drifts and a selection of tongs with differently shaped bits or jaws. For shaping and cutting metal a smith needs tools which fit into the hardy hole in the anvil and others for use under the sledge-hammer. For measuring and marking off, he will want calipers, dividers, a set square and a rule, which should be made of brass; a steel rule soon becomes rusty through being in constant contact with heat and water. Smith's calipers, which have one arm each side and a long handle beyond the joint, are particularly useful.

HAMMERS

For everyday forging, blacksmiths use ball-peened hammers varying from $1\frac{3}{4}$ lb. to 3 lb. in weight. Some prefer short hafts and some very long ones, but it is vital to have a hammer whose balance suits *you.* Do not use one just because it happens to be handy. When you have found a suitable hammer, it is wise to keep a spare which matches it as closely as possible both as to head and haft. Then, if the haft breaks in the middle of an important job, you will not be inconvenienced by suddenly having to use a hammer with a different balance. Although the blacksmith does not usually make his own hammer heads, most smiths have certain special hammers (Fig. 10) for special purposes which they either make themselves or adapt from standard patterns. Car axle half-shafts are suitable material for making special hammer heads.

Fig. 10

TONGS

The beginner must acquire several pairs of ready-made tongs (Fig. 11) for a start. The making of tongs is dealt with in Lesson 37.

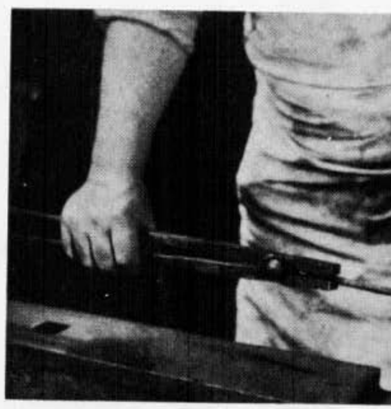


Fig. 11

COLD CHISELS

Chisels for cutting cold iron (Fig. 12) are made short and thick and are ground a little more acutely than a right angle. They are needed in various widths with both straight and convex cutting edges.

They are made from steel containing about 0·875 per cent carbon; a lower carbon content than the steel used for taps and dies but higher than that used for picks. Steel of the right kind is commonly sold in octagonal (eight sided) bars; it is wise to buy octagonal steel because it cannot be confused with any other metal even if an end of a bar gets rusty and dirty. It does not pay to make cold chisels out of any odds and ends of steel which come to hand, but it is worth stocking several sizes of the proper steel from $\frac{3}{8}''$ to $\frac{7}{8}''$ across the flats.

The smith may be asked to make cold chisels for special purposes such as chipping castings in preparation for welders or for other tradesmen, particularly bricklayers. These chisels are made in a variety of shapes and tempered to suit particular needs.

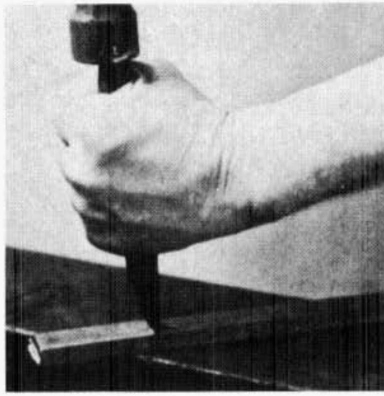


Fig. 12

HOT CHISELS

Chisels for cutting hot iron (Fig. 13) should, by contrast, be made long to keep the hand away from the heat of the job, and slender so that the chisel may be driven into the soft metal like a knife into butter. As the chisel becomes hot it is quenched in water after every three or four blows. A wide variety of shapes and sizes should be kept as a great deal of time can be saved by using hot chisels intelligently.

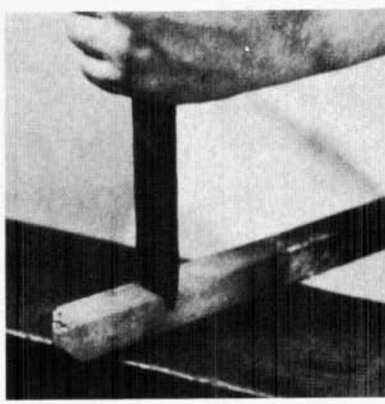


Fig. 13

Some smiths use a sharp cutting edge, but others prefer to leave the edge about $\frac{1}{16}''$ thick.

Hot chisels should be made from steel containing less carbon than cold chisels—0·75 per cent is correct—or preferably from special alloy steels which are now sold for the purpose. Either of these steels can be had in bars $1'' \times \frac{1}{2}''$ with rounded edges. Again it is worth while having this special section so that there is no mistaking it. Although these tools get hot in use, most smiths find it an advantage to temper them.

COLD SETS

Cold sets (Fig. 14) are made for use under a sledge-hammer. They are like cold chisels but are even shorter and thicker and are fitted with a handle at one side.

Usually a groove is forged round the middle of the set and either a twisted hazel or an iron rod wrapped round a couple of turns, the ends being left long enough to form a handle. The ends of the hazel rod have an iron ring slipped over them to keep them together; the ends of the iron rod are best welded together in a loop.

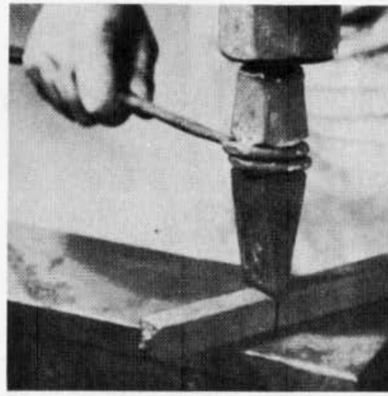


Fig. 14

Some cold sets are hafted like hammers which give better control on fine work, but the very severe jars they get in normal service are apt to break the haft or sting the hand.

They can be made from a lower carbon steel than cold chisels, the grade used for swages being quite suitable. The grading of steel is described in Chapter 5.

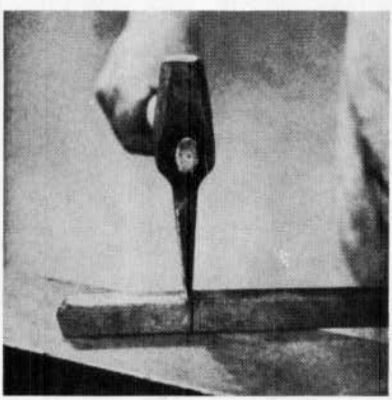


Fig. 15

HOT SETS

Hot sets (Fig. 15) are the sledge-hammer version of hot chisels and are made from similar material. They are used with more precision than cold sets, so are best hafted like hammers, as the hot iron on which they are used absorbs the shock to a large extent.

HARDIES

Hardies are chisels which fit into the square hole in the anvil, the work being driven down onto them (Fig. 16). Some smiths make one fairly stout hardie and use it for both hot and cold work, but it is better practice to have two separate ones suitably shaped and tempered for each purpose.

Fig. 16

PUNCHES FOR HOT WORK

Punches used for hot work (Fig. 17) can be round, square or any other shape to suit requirements. Like hot chisels, they should be long enough to keep the hand away from the heat, or if large, they can be rodded like sets. A slot punch makes a long narrow hole with rounded ends and removes the minimum amount of metal. This hole can be enlarged or opened out by using a drift (see below) without weakening the bar. Round-ended punches called 'bob' punches are used for forming scarfs.

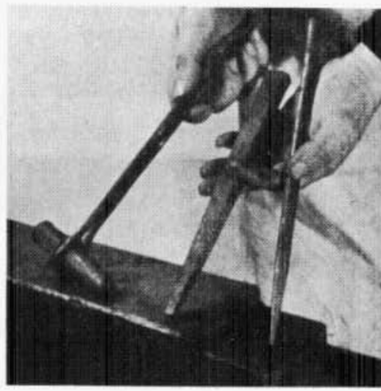


Fig. 17

DRIFTS

Drifts (Fig. 18) are pieces of steel of any required section with a long taper at one end and a short taper at the other; they are driven right through punched holes to enlarge, shape and smooth them.

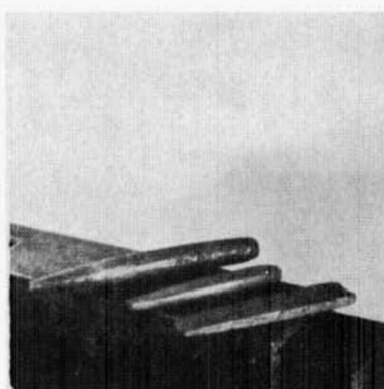
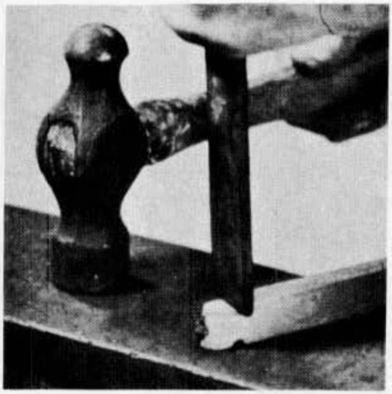


Fig. 18

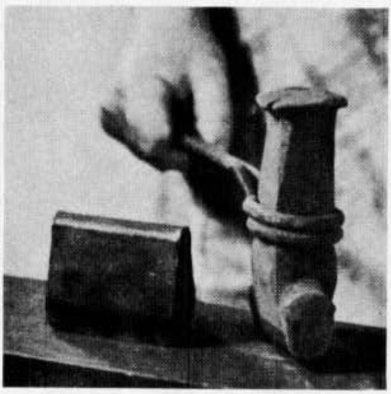


FULLERS

These tools are like chisels and sets but with rounded noses. They are used for making shoulders before drawing down pins and tenons, for forging special shapes and for drawing the metal in one particular direction.

Small Fullers (Fig. 19) are used in the hand.

Fig. 19



Large Fullers (Fig. 20) are rodded.

Bottom Fullers (Fig. 20) fit in the hardy hole of the anvil.

Fig. 20

FLATTERS AND SET HAMMERS

These are placed on the work and struck with a sledge. They may have flat or convex faces with sharp or rounded edges, according to the purpose for which they are required (Fig. 21).

Fig. 21

SWAGES

Swages are top and bottom tools between which the iron is worked to shape (Fig. 22). The bottom swage fits into the square hole in the anvil and the top swage is handled, and is struck with a sledge- or power-hammer. Swages may be of any form required and are made of the lowest carbon tool steel. A bar of $1\frac{1}{2}''$ square should be kept especially for this and is also suitable for making large sets.

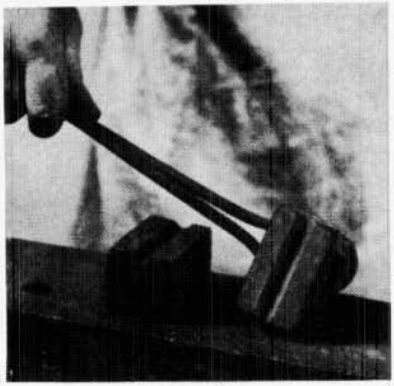


Fig. 22

HAND MANDREL

This tool (Fig. 23) is used either on the face or over the edge of the anvil for drawing out and rounding up small rings and collars.

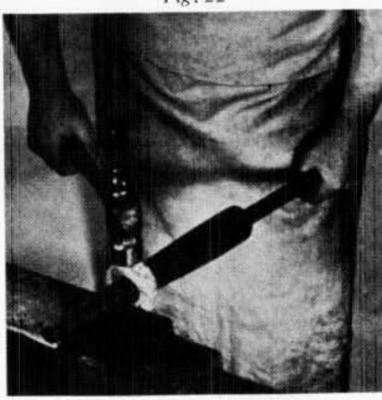


Fig. 23

BOLSTER FOR HARROW TINES

Fig. 24 shows the special bolster used for forming the shoulders on harrow tines. On one side the holes, used for forming the round threaded part, are slightly countersunk to prevent a sudden change of section. The edges of the square holes are raised slightly to produce a concave shoulder on the tine; the prominent edges of these shoulders will then bear hard on the harrow bars when the tine is tightened, thus making a rigid job.

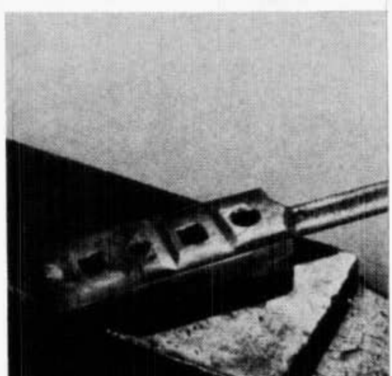


Fig. 24

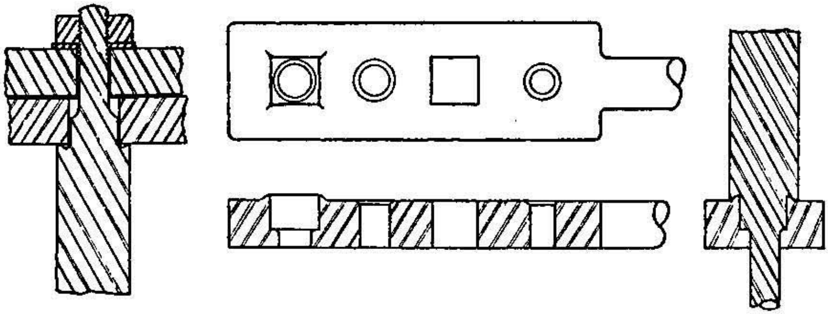


Fig. 25

A cross section of the bolster is shown in the centre of Fig. 25. Below this is a sectional view showing the countersunk edges on the round holes and the upraised shoulder on the square hole.

The right hand drawing shows how the shoulders are formed when the tine is driven into the bolster and the drawing on the left shows the assembly of the tine in the two harrow bars.

CHAPTER 3

THE BLACKSMITH'S FIRE

FUEL

Both coal and coke breeze are used for blacksmithing, and the choice seems to depend mostly on local custom. Although first class work can be done with either, a blacksmith familiar with one is usually embarrassed by the other. Good blacksmithing coal should be bituminous and free from sulphur, and as regular supplies are now hard to obtain the beginner may be well advised to use breeze. This must be good smithy breeze free from dust; the most suitable size is known as 'beans'. Crushed or broken-up boiler coke or furnace coke is not suitable for forging.

FIRE TOOLS

Four tools are used to manage the fire: a poker, shovel, rake (Fig. 26) and

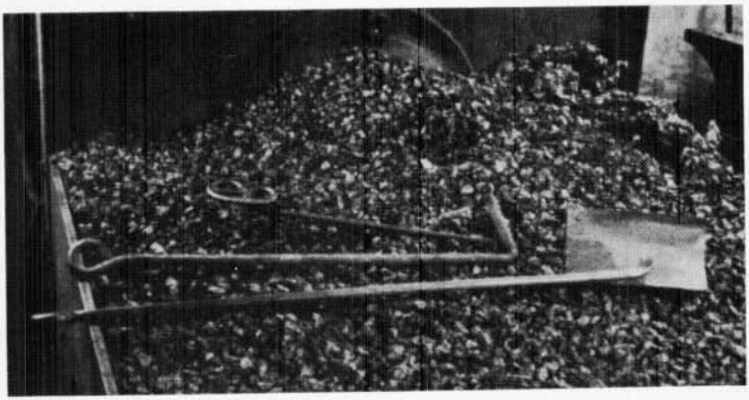


Fig. 26

swab (Fig. 27). These vary in more ways than can be imagined. Some blacksmiths never use a rake, and others scorn the swab altogether, but the tools shown are a fair example of a practical set.

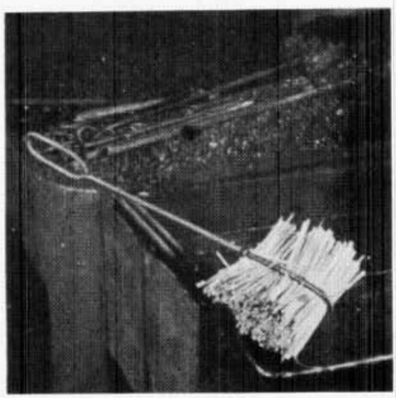


Fig. 27

THE FIRE

Coal and coke require slightly different management both in lighting the fire and in keeping it burning properly. To confine the burning part of a coal fire to the required size, soak the coal with water. This will retard combustion, assist coking and impede the passage of the blast. It is not necessary to wet breeze, because its flame does not spread so readily and in any case wetted breeze does not form a draught-proof barrier. As long as enough fresh breeze is fed on to the fire, which must be kept clean, the fire will remain sufficiently concentrated of itself. This difference should be borne in mind when reading the description of managing the fire later in this chapter.

The blacksmith's fire does not burn steadily indefinitely. It gradually builds up to its best, maintains this condition according to the fuel and the work, then dies down until it becomes useless. With good fuel the fire may last all day on rough work, but with poor fuel on fine work it may be dead in an hour. When using coal, make sure before starting a job that an adequate well-soaked supply is available and banked up ready to replenish the fire as required.

Fig. 28 is a sectional view of the fire showing a piece of metal being heated in the heart of the fire and a lump of clinker forming beneath, in front of the tuyere.

Fig. 28

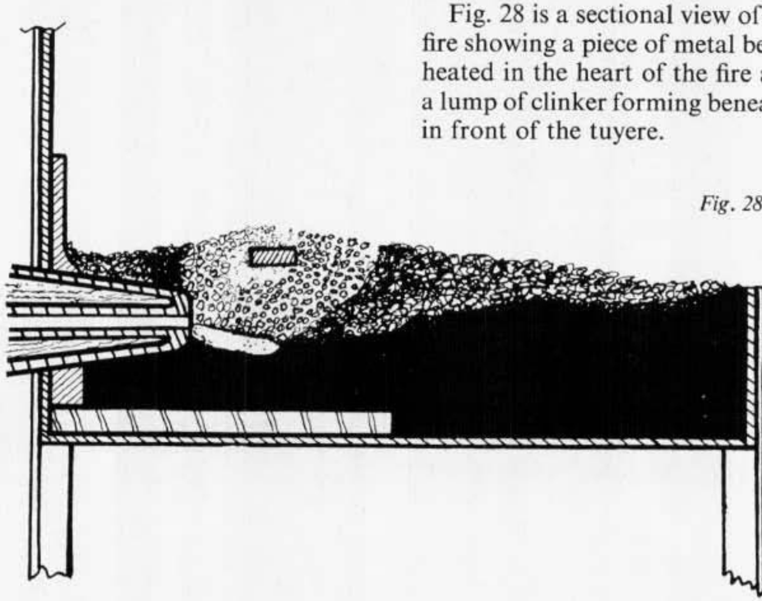


Fig. 29

To light the fire, scoop out a hole in front of the tuyere nose. Remove the clinker (Fig. 29) which is sure to be left over from the last heat and dig out and throw away any excess of dust and fine ash. A coal fire can be lit with nothing but a ball of paper, but a coke fire may need wood shavings or chips. Light the kindling, push the burning part right down by the blast hole, and turn

Fig. 30

Fig. 31

on just a mere breath of blast (Fig. 30). As the kindling lights, draw a little dry coke over it (some coke or half-burned coal will always be found in the remains of a coal fire). Gradually increase the blast and as the fire breaks through (Fig. 31) it can be made up directly with fresh breeze. New coal should never be heaped on top of the fire, but always worked in from the outside as in this way the impurities in the coal are burnt away before it comes in contact with the metal. Wet coal should be packed all round and gradually driven into the heart of the fire with the edge of the shovel.

MANAGEMENT OF THE FIRE

There are three aims in managing the fire.

(i) **To keep the fire as small as possible.** The whole purpose of the fire is to heat metal and anything more is both wasteful and a nuisance. Never use more blast than is necessary to keep the fire at the size and heat required for the job.

(ii) **To prevent the fire from burning hollow.** The heat in the fire must be in the middle, immediately below the piece of metal being heated. A hollow fire has no fuel to produce heat where it is wanted. Also the unburnt blast air will get at the hot metal and oxidize the surface or may even burn it beyond recovery.

(iii) **To defeat clinker.** Clinker is the blacksmith's worst trouble. Cold, clinker is like a crude black glass; hot, it is like black treacle. It is produced by the combination of oxygen in the blast with impurities which are more or less present in all fuels. This is a further reason for not using more blast than necessary.

As the fuel burns, clinker is formed in a molten state and trickles down to the bottom of the fire, just in front of the blast hole. Here the clinker obstructs the blast and bits are blown upwards and stick to the hot metal giving it a molten coating. Metal in this state cannot be welded and when it is struck, the molten clinker spurts out from under the hammer and burns the hands. This not only hurts but interferes with the work.

Unless very good fuel is used, the fire will become dirty almost as soon as it begins to burn freely. At this stage the only thing to do is to persevere for one or two heats in spite of the dirt. The blast is then cut off for a few minutes to allow the liquid clinker to cool and solidify sufficiently to be hooked out in one piece with the tip of the poker, which is flattened and curved for just this purpose (Fig. 32).

Fig. 32

A great deal of judgment is required to know exactly how long the clinker must be allowed to cool, when it is ready to catch, and just where to find it. Even so, it is a feat of considerable skill to remove it all without disturbing the fire. Nothing but practice is any real help in this. Sometimes the clinker does not form into one lump or else the lump breaks up, but in either case, the pieces can be distinguished from the dully glowing fuel of the cooling fire by their brighter red heat, their smooth surface and, as soon as they begin to cool, by the characteristic 'clink, clink' they make when touched by the fire tools. Hell to a blacksmith is not a place of fire and heat, but of clinker.

The metal which is being heated should be kept near the top of the hot part of the fire with a good bed of live fuel underneath it and a sufficient covering of glowing coke on top. Remember that a coal fire always produces some coke as it burns. This covering not only prevents the heat from being radiated from the metal, but burns up the free oxygen from the air above the fire before it can reach the hot metal and oxidize it.

For this reason metal should never be brought to a red heat on top of the fire—always keep it below the surface where it is protected from the air and where the fire is hotter.

CHAPTER 4

THE BLACKSMITH'S WORK

Blacksmithing consists of working or forging iron and steel at the right heat into the required shape by means of hammer blows delivered either directly onto the metal or transmitted through tools. Parts II, III and IV explain and illustrate in detail each forging operation which may be done singly or in combination. The various processes used are summarized as follows:

TAKING A HEAT

It is very important that the smith should know the signs and the effect of burning iron and that he should be able to recognize instantly the correct degree of temperature which he requires for a particular operation. The instruction 'Take a BRIGHT RED heat' or 'Take a FULL WELDING heat' will be found throughout the lessons and a beginner cannot do better than practice with a bar of iron so that he is able to judge by eye the heat required for a specific purpose.

Always look at the iron in ordinary daylight. Take care by the arrangement of the windows, that the sun's rays cannot fall directly on either the hearth or the anvil as this makes it very difficult to judge the heat of the metal.

WARM HEAT is taken by passing the metal slowly through the fire until it is just too hot to be touched safely by the hand. This is the correct heat for 'setting up' springs without removing the temper.

BLACK HEAT. No red colour is visible in daylight, but the metal will glow faintly red in the dark. This temperature is not used in any smithing operation, but may be used for obtaining an oil or matt black finish on ornamental ironwork.

DULL RED OR BLOOD RED HEAT is used for easy bends on mild steel and for forging carbon steel. It is a little above the temperature required before quenching carbon steel to obtain the maximum hardness.

BRIGHT RED HEAT. Simple forging operations on mild steel are carried out at this temperature: for example, bending over the anvil, light punching and hot chiselling.

BRIGHT YELLOW OR NEAR WELDING HEAT. The principal forging operations on mild steel and wrought iron are carried out at this temperature, including drawing down, upsetting, preparing scarfs and punching on heavy work. This is the correct temperature for forging high-speed steel but carbon steel should not be made so hot.

LIGHT WELDING, SWEATING OR SLIPPERY HEAT. While this is not hot enough for welding many grades of mild steel, it is sometimes used successfully if difficulty is experienced at higher temperatures. Considerable skill is needed to weld mild steel with a slippery heat.

Wrought iron can be forged at this heat.

FULL WELDING HEAT. If the blast is correct, and the fire has a good heart, a few white bursting sparks will begin to appear among the red sparks from the fire. This is the correct temperature for welding most types of mild steel. *A hollow fire and insufficient blast will produce white sparks, but in this case the surface of the metal is being burnt without attaining the correct welding heat.*

WHITE OR SNOWBALL HEAT is too high for welding mild steel but is the correct heat for welding good quality wrought iron. Wrought iron has a spongy texture at this temperature but will be restored to normal condition by correct forging.

DRAWING DOWN

Drawing down needs a NEAR WELDING heat and is the process of increasing the length of a piece of metal and at the same time reducing its cross section. The simplest example is the formation of a point on a round or square bar by hammering which is described in Lesson 1. On heavy work the drawing down can be done quicker by fullering between top and bottom tools or by using the bick of the anvil as shown in Lesson 9 C.

BENDING

This can sometimes be carried out cold, but it is preferably done at a BRIGHT RED heat. Bends can be made over the anvil or bick, as shown in Lessons 2, 3 and 4, or sometimes on the swage block. The metal on the outside of a bend is subjected to a stretching action while the inside is upset. This is why the square outside corner bend described in Lesson 29 must always be formed by first upsetting the metal to provide the extra material required on the outside.

UPSETTING OR JUMPING UP

This operation, carried out at a NEAR WELDING heat, is for swelling or increasing the cross section of a bar of metal in one particular place, its overall length being reduced at the same time. Considerable practice is required to upset metal exactly in the place where the swelling is needed and the beginner is advised to do the job in easy stages by cooling off the bar with water, leaving just sufficient at the right heat for the first swelling. The bar should be re-heated and upsetting continued to the required amount.

HOT CUTTING

Hot cutting is done with hot chisels and sets; portions of the metal are either cut away completely or, in some cases, a split is made and opened out to receive another piece for welding, as shown in Lessons 5, 20, 31 and 32. A BRIGHT RED heat is best for hot cutting. Cold cutting is described on page 28.

PUNCHING AND DRIFTING

These operations are best carried out with the work at a NEAR WELDING heat. If the hole is deep, the metal tends to contract round the punch which should be withdrawn after every three or four blows and quenched in water. Drifts are used to finish holes that have been punched smaller than the required size and it may be necessary to take two or more heats to complete the job satisfactorily; this is described in Lesson 16. When punching deep holes sprinkle a few grains of fuel into the hole before replacing the punch. The gas formed when the punch is next driven in will blow it out again quickly, saving both time and trouble.

FIRE WELDING

Fire welding is the operation whereby two pieces of metal are joined together while in a plastic state by hammering. Different types of welds are explained in the lessons and considerable practice is required before the simplest fire weld is mastered and even then, some grades of mild steel present difficulties which call for ingenuity in using the right technique. The essential conditions for fire welding are as follows:

(*a*) Metal properly prepared to suit the type of weld required.

(*b*) A clinker-free clean fire with a good heart.

(*c*) Accurate judgment by eye of the correct welding heat which varies from a LIGHT WELDING heat to a WHITE heat with different types of steel and iron.

(*d*) Speed in withdrawing the metal from the fire and placing the pieces in the correct position on the anvil, followed immediately by rapid and accurate hammer blows delivered on the heated metal at the proper place and in the right order.

Much practice is needed to develop and co-ordinate all these essential factors, the most difficult being the judging of the correct welding heat, which ranges from a bright sparkling white heat for good quality wrought iron down to a bright red just changing to white heat for mild steel.

INSTRUCTIONS FOR FIRE WELDING

The following instructions on fire welding should be read and the procedure thoroughly understood before attempting any of the lessons which include this operation.

A certain amount of metal is always lost during fire welding, so it is essential to upset or thicken the ends first. The upset ends are then forged to form scarfs which must 'pair' when laid together. The important factor when shaping a scarf is to make certain that the point of contact between the two pieces is in the middle so that when the metal is hammered, any scale or oxide is squeezed to the outside and not trapped in the centre.

The scarfs should not be so short that they slide apart before they 'take', neither should they be too long or the lips will burn off before the thickened parts reach welding heat.

Although welds can be made without using a flux, it is often an advantage to use either silver sand or one of the preparatory fire welding compounds, such as 'Laffite' Welding Plate.

When using silver sand, the pieces to be welded are placed in the fire side by side with the faces of the scarfs *downwards* and brought to a NEAR WELDING heat. Each piece in turn is then removed from the fire for a moment and the face of the scarf sprinkled with a little silver sand which immediately melts and flows over the iron, fluxing any scale or oxide that may have begun to form. Both pieces are then returned to the fire still face down and are jockeyed about a little to get a heat on each evenly.

The following actions have to be done much more quickly than they can be described. Immediately welding heat is reached the first piece is removed from the fire still with the scarf face downward. It is tapped over the edge of the anvil to shake off the melted sand and dirt clinging to it and immediately turned over and laid face upward on the anvil.

The second piece is also taken from the fire face downward, similarly tapped over the edge of the anvil to shake off the dirt, and, without turning it over, placed in position on top of the first piece. The first blow is then struck in the centre of the weld.

Some experienced smiths can tell from the sound of the first few hammer blows if the weld has taken or not. A dense or hard ringing note indicates that the weld has not taken. It is quite permissible to take a second welding heat to close the ends of the scarfs as these cool off much more quickly than the thicker section of the metal, particularly the bottom one which is in contact with the cold anvil face.

If Laffite is used, the procedure is a little different—when the prepared parts are heated to a DULL RED heat they are removed from the fire and a piece of Laffite plate, a little bigger than the area of the weld, is placed between the scarfs and squeezed with light hammer blows until it melts and spreads over the scarf faces which will stick together. The adhering pieces are then carefully returned to the fire and brought to a LIGHT WELDING heat when they are lifted out and given a few gentle blows with the hammer to unite them. They are then returned to the fire for another LIGHT WELDING heat and the job finished off with ease and certainty.

HEAT TREATMENT

Heat treatment is applied to steel to make it harder, tougher or softer as required. These qualities depend on the composition of the steel combined with the heat treatment it receives (see Chapter 5 on Blacksmith's Materials). Although an open fire is not an ideal method of carrying out all these processes, there are five types of heat treatment that the blacksmith frequently undertakes on small articles, and the following brief descriptions are only intended to explain the meaning of the terms used. More detailed information should be obtained by studying the relevant chapters in the books listed at the end of this publication (page 104).

Hardening is carried out by heating medium and high carbon steels slowly and uniformly to the correct temperature between BLACK and DULL RED heat and then quenching them suddenly in some suitable cooling medium, such as water, oil or brine, according to the composition of the steel and the degree of hardness required.

Tempering. Carbon steel that has been hardened by quenching as described, is very brittle and in this state is useless for cutting tools, particularly those which are subjected to blows. Some of this hardness must be sacrificed to obtain the requisite toughness and this is done by re-heating the metal to a lower temperature than that required for hardening and cooling rather more gently in the cooling medium. The degree of temper required is obtained by controlling the temperature to which the metal is re-heated and varies from a high or hard temper for small edge tools to a low or soft temper for certain kinds of springs.

Annealing is a softening process carried out by heating steel to the correct temperature and then allowing it to cool slowly in a dying fire or by burying the metal under hot ashes or in dry lime.

Normalizing differs from annealing in that although the metal is raised to the same temperature, it is allowed to cool off naturally in the air. It should not be laid on a cold floor or other cold surface or exposed to draughts when cooling. It is an advantage to normalize any steel which has been forged or welded, before the article is put into service.

Case Hardening is a process by which a hard skin is obtained on steel which does not contain enough carbon to make it harden by heating and quenching. It is carried out by packing the article to be case-hardened in a suitable metal container with a special case hardening compound, such as 'Kasenit', and then heating the whole container to a RED heat (900° Cent.) and letting it soak at this temperature for a given period before allowing it to cool slowly. The carbon in the compound penetrates the skin of the metal and unites with the steel to produce a dead hard surface when the article is subsequently hardened by re-heating and rapid quenching.

CHAPTER 5

THE BLACKSMITH'S MATERIALS

WROUGHT IRON

Wrought iron has long been regarded as the traditional material worked by the blacksmith, and its replacement by mild steel for most forging is still a matter of regret amongst older craftsmen whose early experience did not include the forging and welding of mild steel, which requires modified techniques.

Wrought iron, which is produced by puddling pig iron in a special hearth, is more expensive than mild steel. Commercial wrought iron contains approximately 0·04 per cent carbon and 0·2 per cent slag which, during the process of manufacture, is hammered or squeezed throughout the mass of the metal, producing the well-known fibrous structure which makes wrought iron so easily recognizable when broken across the grain. Two of the vital qualities possessed by wrought iron are its ability to be drawn out—'ductility', and its ability to be hammered into shapes—'malleability'.

Iron which is malleable is not necessarily ductile and iron which possesses either of these qualities when cold does not necessarily possess them when hot, and vice versa.

Iron which is apt to break when cold is called 'cold short' and iron which is apt to break when hot is called 'red short'. These most undesirable qualities are caused by impurities in the metal, excess of phosphorus and sulphur making it cold short and excess of silicon making it red short.

Due to its low carbon content, wrought iron is highly malleable and ductile and is easily forged and welded by the blacksmith. It was once used