

SECTION 4, CHAPTER 2

BLACKSMITHS EQUIPMENT AND FORGING

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Introduction

1. Before dealing with the actual fashioning of iron and steel it is necessary to have a sound working knowledge, not only of the tools and other equipment that a blacksmith uses, but also of the physical effects that occur when the metal is cold or hot worked. Much information will have been gained from Section 1, Chapter 6, on the subject of Metallurgy; the major points in the chapter that affect forging processes are summarized in the next two paragraphs.

Cold Working

2. Cold working of steel means the use of force to change the shape of the metal when it is below the lower critical temperature (pearlitic condition). In effect, it distorts the crystal structure of the metal making the metal harder and more brittle. Providing that the metal has not been worked so much that it cracks, its structure may be brought back to its original condition by normalizing. Cold working is practised when metal is cold rolled, drawn into wire, bent cold, etc., and can mean working a

metal which is "dead cold", at a dull red heat, or any other temperature in between these two extremes.

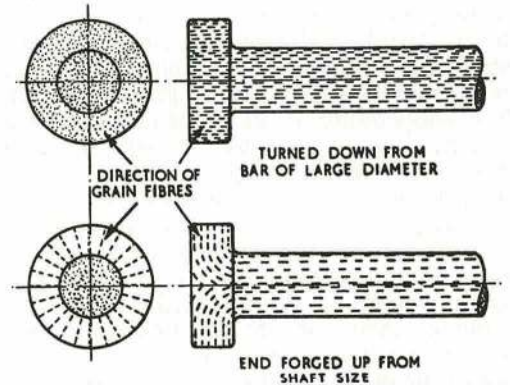


Fig. 1. SHAFT END-UPSETT

Hot Working

3. Hot working refines the structure of steel by breaking up large grain formations and closing up any cavities which may exist. It consists of changing the shape of the metal when its temperature is above the upper

critical point, and may be done by hammering, drop stamping, or by applying the slower but more positive pressure of a hydraulic press. If the directional flow of the grain is suitably controlled by good forging, a much improved product can be manufactured. Fig. 1 shows a gear integral with the shaft, and how the grain would flow if the object was produced by turning, or, alternatively, by forging. Fig. 2 shows the direction of the grain in a forged crankshaft, where again it can be seen that the directional qualities of the grain give added toughness to the webs and corners.

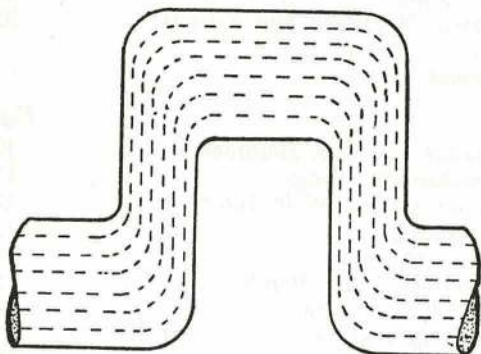


Fig. 2. DIRECTION OF CRANKSHAFT GRAIN

Temperature

4. Steel should not be heated to near melting point, a condition often referred to as "burnt". Overheating steel makes its structure brittle, and nothing short of remelting will bring it back to good condition. The temperature at which hammering of a forging should be discontinued is also important. When steel is heated to a temperature much higher than its upper critical point its grain size increases and, if cooled from this point it may lose its toughness. During hammering operations this grain growth is compensated for by the refining effect of the hammering which kneads it together, but if hammering ceases whilst the metal is still at a high temperature, grain growth will remain as the forging cools. Also, if the metal is hammered until it is below 700°C., it will suffer from the effects of cold working and may finish up with small hairline cracks. The best time to stop hammering is when the steel is just above its upper critical temperature, and if any doubt still exists the forging should be normalized.

BLACKSMITHS EQUIPMENT

General

5. A portable type hearth, an anvil, a swage block and a standard metal-covered bench equipped with a combination vice and shearing machine, make up part of the main equipment of a R.A.F. blacksmiths shop. An oil bath and water trough for heat treatment and slaking purposes should be available, whilst sand and slaked lime should be at hand for use during annealing operations. Coke breeze is stored in a bin which should be kept outside the workshop, and other equipment such as sledge hammers, tongs, setts, fullers and hardies should be at all times available.

The Furnace

6. For heating small work the blacksmiths forge or furnace is generally used. It consists of a hearth on which the coke is burned, a tuyère for directing the air blast into the fire, and a motor driven blower for supplying the forced draught to the tuyère; a smoke hood and chimney direct the smoke and gases away to be discharged into the atmosphere. Usually the tuyère is surrounded by cooling water supplied from a tank at the back of the forge.

7. Portable type hearths (Fig. 3) are usually used in the Service. They burn coke breeze

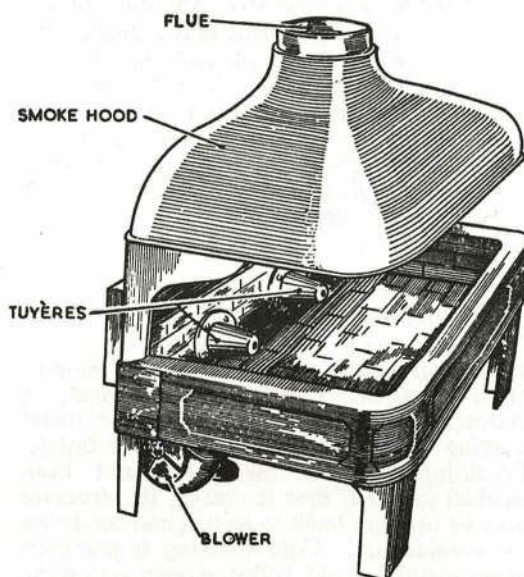


Fig. 3. PORTABLE TYPE HEARTH

fuel, which is gas coke crushed into small pieces; small soft coal may be used, but it should not contain sulphur and, when burnt, should stick together in a mass. The temperature of the fire is governed by blast regulating valves.

Forging Tools

8. **The Anvil.** The anvil (Fig. 4) is used to support the work while it is being hand forged, by means of the blacksmith's or striker's hammer. It usually weighs about 3 cwt., the body being made of mild steel, and having a section of high carbon steel welded in place to provide a hard top face.

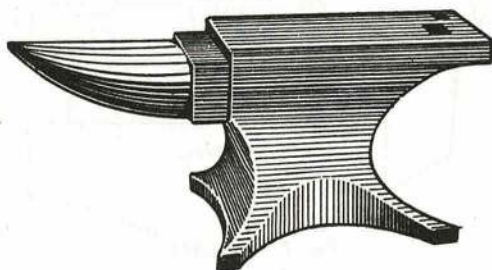


Fig. 4. THE ANVIL

The beak is soft, its shape making it useful for bending operations. The ledge between the beak and the anvil face is used when a chisel is being employed to cut through metal, and in the top tail end of the anvil there is a square hole which receives the shanks of the various tools. The anvil may be placed on a wood base in order to raise it to the correct height of 2 ft. from the floor.

9. **Hammers.** Two kinds of hammers (Fig. 5) are used by blacksmiths when hand forging—the smith's hand hammer, with which he directs the work, and the sledge hammer, which his assistant (or striker) wields. Hammer heads are made of cast steel, the faces being hardened and tempered, and their weight will vary according to the class of work being done.

10. **Chisels.** Chisels (Fig. 6) are used for cutting metal and for nicking the metal before breaking it off. They must not be confused with the fitter's hand chisel which is an entirely different tool. The smith's chisels have a slightly rounded cutting edge, and are referred to as being either "hot" or "cold". The cold chisel is set at an angle of about 60°, whilst the angle of the hot chisel is nearer 30°. Since contact

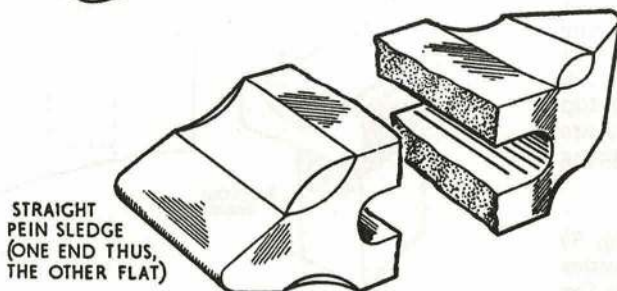
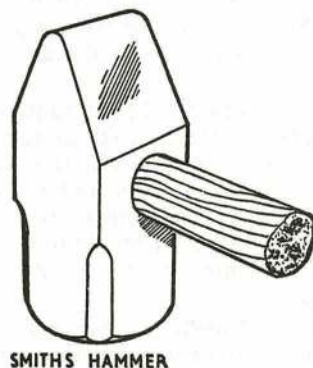
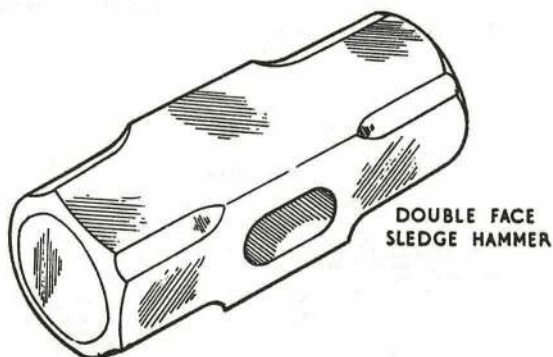


Fig. 5. HAMMERS

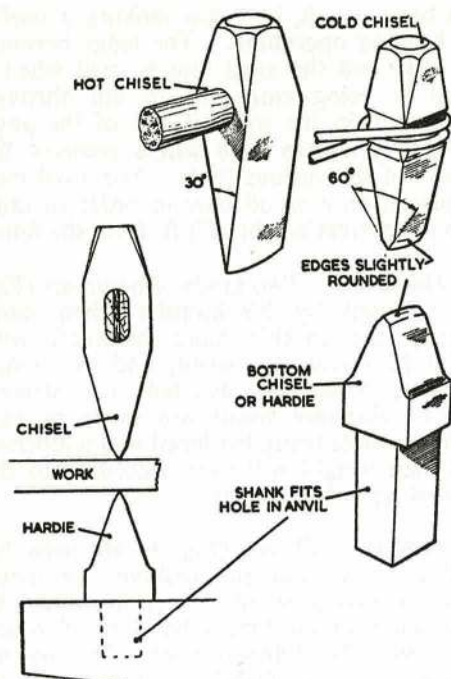


Fig. 6. CHISELS

with hot metal would re-soften it, the edge of the hot chisel need not be hardened and tempered. Chisels are generally used along with a bottom tool (or *hardie*). The hardie (Fig. 6) has a square shank which fits into the square hole in the anvil face.

11. **Fullers.** These tools (Fig. 7) are used when it is required to form a neck in the work. Like chisels, they are made in top and bottom tools and are of various sizes, the size being equal to the width of the fuller edge. For shouldering round work, fullers may have their edges hollowed out.

12. **Swages.** A swage is a kind of die or form used when shaping metal by hammering or pressure. Swages (Fig. 8) are made in various sizes, with grooves to suit the work being reduced; they may have separate top and bottom halves, and the two halves are sometimes connected by a strip of spring steel.

13. **Swage Block.** A swage block (Fig. 9) is usually made of cast iron and, besides having a range of suitably sized grooves for swaging operations around its sides, it is

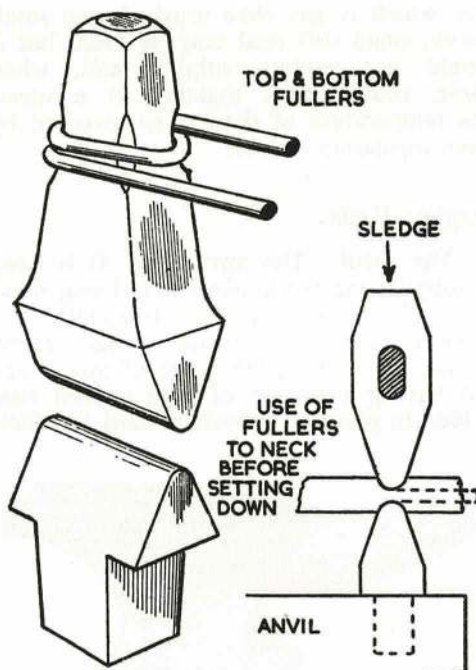


Fig. 7. FULLERS

also provided with holes which are useful when bending and knocking up bars. A stand is usually used to support a swage block at a suitable height.

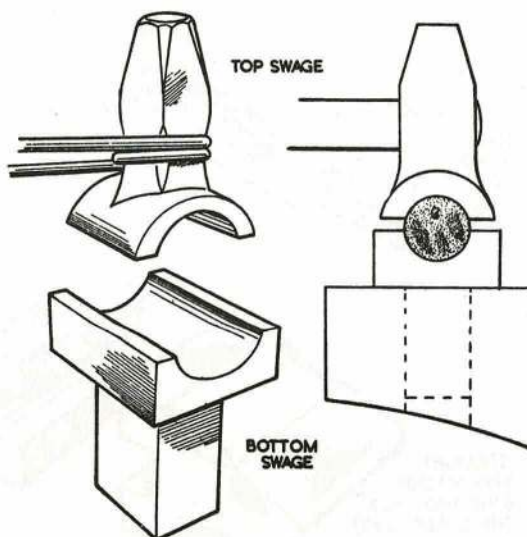


Fig. 8. SWAGES

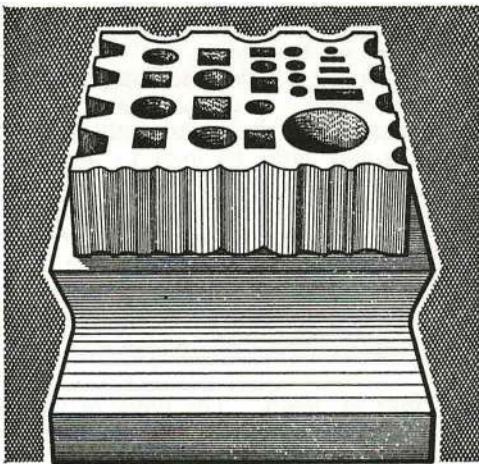


Fig. 9. SWAGE BLOCK

14. **Flatters.** These tools (Fig. 10) are used for finishing off flat work, and are therefore made either square or round but having a flat face. The sett hammer is used for finishing in corners and confined spaces. Only the top, handled tool is needed, for the work is usually supported directly on the anvil when flattening.

15. **Punches and Drifts.** Hot metal is easily pierced by punching, after which, the hole can be opened out and cleaned up to size and section by the use of a suitable drift. To avoid driving a punch on to the anvil face, it should be broached from both sides.

16. **Tongs.** Some of the various types of tongs as used by the smith are shown in Fig. 11. To relieve the smith of the strain of

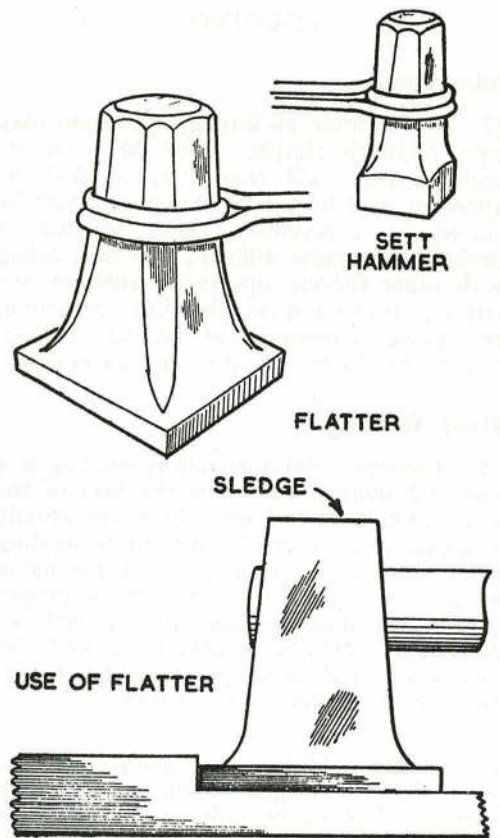


Fig. 10. FLATTER AND SETT HAMMER

holding them tightly for long periods during a forging operation, the handles are often clamped together with the aid of a strong wire ring.

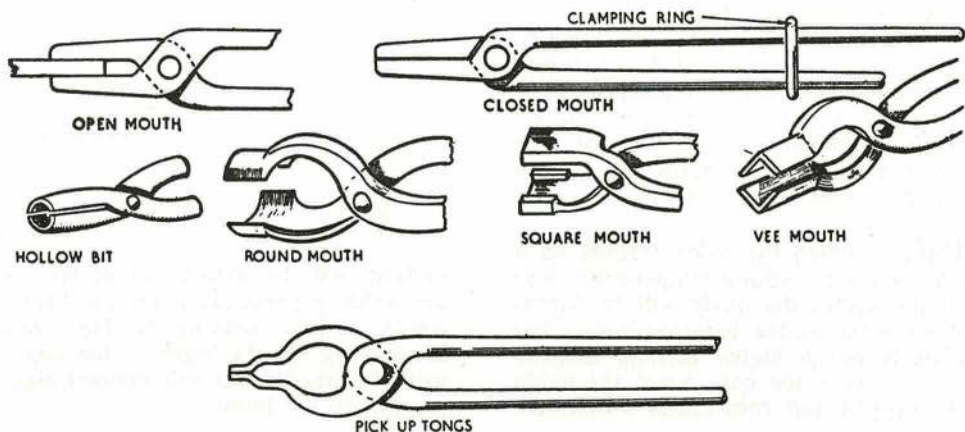


Fig. 11. BLACKSMITHS TONGS

FORGING

Introduction

17. To the fitter, all forging operations may seem relatively simple. They do, however, require more skill than may at first be apparent, and to a large extent can only be gained by experience. Hand welding is probably the most difficult, and this, along with other forging operations such as upsetting, drawing down, bending, punching, and power hammers and presses, are described briefly in the following paragraphs.

Hand Welding

18. **General.** Hand or smithy welding is a very old method in which the heat of the smith's fire is used to bring the metal, usually wrought iron or mild steel, to a welding heat, followed by hammering of the metal around the joint so as to effect a proper union. Its disadvantages are a lack of control of welding temperature, and the difficulty experienced in excluding oxides and foreign matter from the joint.

19. **Welding Heat.** The quality of the weld depends largely upon the welding heat, which must be sufficient to bring the surfaces to be joined to a plastic or semi-molten state. Insufficient heat prevents adhesion—excessive heat causes burning which adversely affects the physical properties of the metal, thus producing a weak and brittle joint. The heat must be applied slowly to ensure a uniform temperature throughout the ends to be joined. Too rapid heating does not permit uniformity, and unless the temperature is uniform, excessive internal stresses will occur during the hammering process, thus resulting in a weak and defective weld. An excessive air blast from the bellows or blower produces an oxidizing fire and increases the risk of burning the metal being heated.

20. **Fluxes.** When the oxide formed on a metal has a lower melting temperature than that of the metal, the oxide will be forced out of the joint by the hammer blows, but if the oxide has a higher melting temperature than that of the base metal, the oxide will be trapped and thus cause a defective

weld. The oxide formed on wrought iron has a lower melting point, but that formed on tool steel has a higher melting point than the parent metal. Thus, to ensure a satisfactory weld when the latter metal is being worked, a flux must be used to lower the melting point of the oxide below that of the tool steel. Sand and borax are two examples of flux, each having a melting temperature below the welding temperature of the work. The flux is sprinkled upon the heated ends of the metal when they have reached about a yellow heat.

21. **Types of Joints.** The types of welded joints are classified by the way the ends are formed prior to making the weld. The illustration (Fig. 12) shows some of the various shapes which are ordinarily made in hand forging practice. Generally, the surfaces are rounded or crowned to ensure that they will unite first in the centre, thus, any slag or dirt adhering to the heated

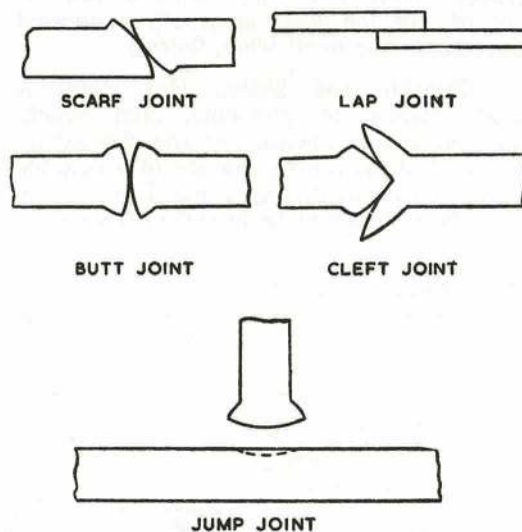


Fig. 12. HAND FORGED WELD JOINTS

surfaces will be forced out of the joint as the welding proceeds from the centre outwards. When making a lap weld the hammering should begin at the centre and work outwards, this will prevent slag being trapped in the joint.

Upsetting

22. The operation termed *upsetting* (Fig. 13) increases the diameter of a bar during forging at the expense of its length, and it is brought about by end pressure. It may be either throughout the whole length or only

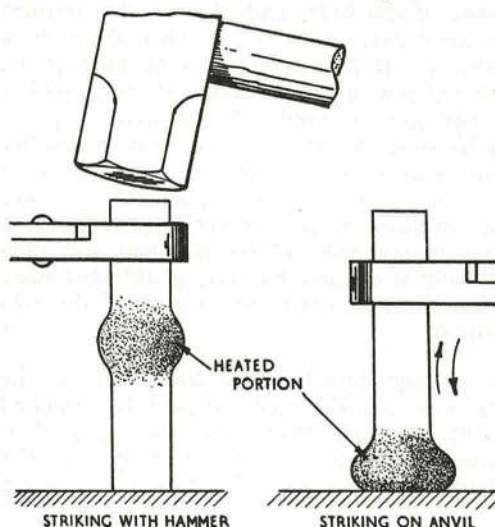


Fig. 13. UPSETTING

applied locally, for the position and nature of the upsetting will depend on the heating and the type of blow delivered. If a short bar is heated at the same temperature throughout, heavy blows will cause a fairly uniform degree of swelling, but light blows will have a more local effect at the ends only.

Drawing Down

23. *Drawing down* (Fig. 14) is the process by which the diameter of a bar is reduced and its length is increased. Usually, the edge or the beak of the anvil is used for this operation, the work being turned between

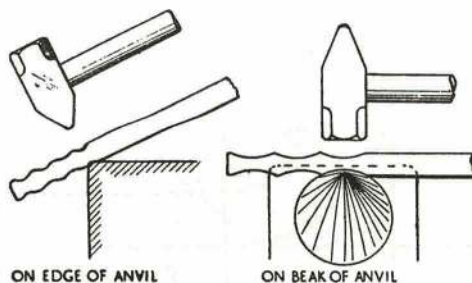


Fig. 14. DRAWING DOWN

each blow when the full thickness has to be brought down. When the assistance of a striker is available, a pair of fullers may be used.

24. When round bars have to be reduced considerably, they should first be shaped to a square and then drawn out in the usual manner before being squared up again. The corners are then hammered out until the work is octagonal in section, before being finally rounded off and finished between swages. Care should be taken not to drive the metal outwards from the centre too hastily, otherwise internal cracks will occur which will weaken the structure of the metal.

Setting Down

25. *Setting down* is the local thinning effected by a sett hammer or sett; quite often the work is fullered out at the place where the setting commences.

Bending

26. When metal is bent, the layers of metal on the inside are shortened and those on the outside are stretched. This causes bulging on the inside and a radius on the outside of the bend. Additional metal must therefore be worked on to the outside, or (if a true square bend is wanted), the metal must be worked up with a light hammer.

27. *Sharp angle bends* (Fig. 15) may be made by hammering the metal over the

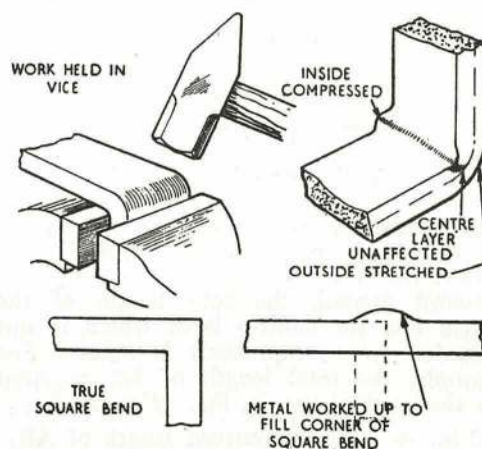


Fig. 15. BENDING (SHARP BENDS)

edge of the anvil, over a block of metal held in the hardie hole or in a vice, or over the vice jaw itself, whilst the metal is being gripped. With double bends a simple bending fixture which grips flat metal is often used.

28. *Gradual bends* may be formed over the beak of the anvil, or the metal may be bent over a bar of the correct radius held in a vice (Fig. 16). When a large amount of bending

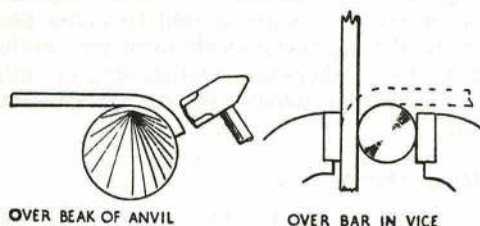


Fig. 16. CIRCULAR BENDING

has to be done, the use of a bending fixture will give better results and also save time. Many different sizes of bends may be effected by fitting different centre pieces and suitable rollers; Fig. 17 shows the bending fixture being used.

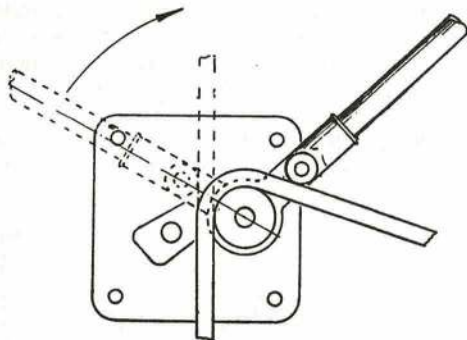


Fig. 17 BENDING FIXTURE

29. Bends may be set in their exact place by bending a bar over a shaped former held in the vice. To work out the length of material needed, the bent length of the centre line (or neutral layer which is not extended nor compressed) is taken. For example, the total length of bar required for the work shown in Fig. 18 would be:—

$$\begin{aligned}
 &2 \text{ in.} + 1 \text{ in.} + (\text{curved length of AB}) \\
 &= 2 + 1 + \left(\frac{1}{4} \text{ of } \frac{5}{8} \text{ in. rad. circle}\right) \\
 &= 2 + 1 + \left(\frac{1}{4} \times 2\pi \times \frac{5}{8}\right) \\
 &2 = + 1 + \frac{5}{8}\pi = 4 \text{ in. approx.}
 \end{aligned}$$

Punching

30. *Punching* is often used as a shaping process as well as for merely piercing holes. When forgings in their hot state require a hole to be punched in them, the method of punching will depend upon the size and shape of the hole, and also on the amount of metal desired around it when the hole is finished. If the metal is to be kept to its original size, a punch that is slightly smaller at the point is used. If the metal requires to be swelled out, a punch with a smaller point still is used, varying according to how much the metal is to be swelled out. Where the swelled-out part is very pronounced, a long narrow hole is first punched and then the hole is opened by driving different sized drifts through until the hole is of the size desired.

31. When punching is done without the aid of a die, the metal should be punched partly through from one side and then turned over and met by punching from the other side. If a die with a hole just clearing

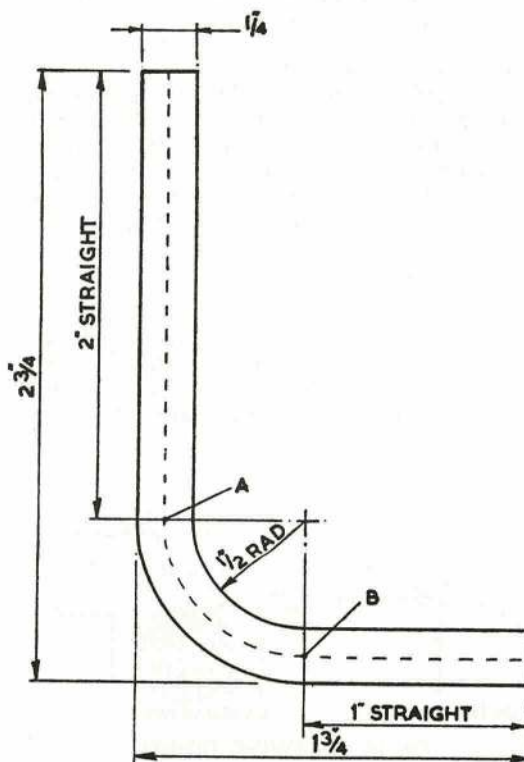


Fig. 18. MEASURING BEND

the punch is used, the hole may be punched out in one operation. The taper in the die hole allows the punching to fall straight through, and a top plate may be used to line up the punch. After a hole has been punched, it may be opened out with a tapered drift.

32. It will be found necessary to cool off the punch in water after three or four blows when punching holes in thick metal, and sometimes it will be found difficult to release the punch for this purpose. To obviate this, crush a piece of coal or coke into powder or pieces small enough to enter the hole being punched. When the punch is withdrawn for cooling off, drop a little of the crushed coal or coke into the hole before replacing the punch; this forms a kind of buffer so that when the blow is struck, the punch will simply spring out of the hole, and it will also be found more blows can be given each time before cooling off.

Power Hammers and Presses

33. Power operated hammers and presses are not standard R.A.F. equipment, and as detailed information is beyond the scope of these notes, only a very brief description is given in the following paragraphs.

34. **Power Hammers.** These are used on big forgings when large amounts of metal have to be worked, the upright type being the most commonly used. These mechanical tools may employ a crank or spring, and either steam or pneumatic pressure to drive a piston to which is connected the tup (or hammer) which strikes the work. The tup and anvil block are faced with carbon steel pallets which may be removed for the fit-

ment of special tools as required. Classification is according to the weight of the tup, piston rod and piston. Drop forging, i.e., squeezing the hot metal into shaped impressions cut in heavy steel blocks called dies, is a very common method of making multiple and similar parts. It derives its name from the fact that one die is allowed to fall from a considerable height on to the other, the hot metal being in between.

35. **Power Presses.** These machines usually derive their motive power from an electric motor. By means of energy stored in flywheels they can shear out metal to a required shape, or press a previously cut-out shape to the requisite form over a "blank". Large machines may be up to 20 ft. high and be able to exert a maximum pressure of 1,000 tons. The "single action" press is supplied with a single ram; the "double action" press embodies two independent rams working one inside the other. Rotary movement of the motor, geared down to a suitable operating speed, is transmitted to the ram, either by a crank motion (impact) or by a toggle action (gradual squeezing). Operations generally carried out by a power press are:—

- (a) *Blanking*, i.e. cutting the required shape from the metal.
- (b) *Piercing*, i.e. the cutting of any shape or hole in the blank.
- (c) *Swaging or upsetting*, i.e. altering the thickness by pressure.
- (d) *Drawing*, i.e. pressing a punch into a blank so as to form it into a cup-shaped vessel.
- (e) *Bending and forming*, i.e. production of bends with either sharp or radiused corners.



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