HANDBOOK OF PRACTICAL SMITHING AND FORGING

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PRACTICAL SMITHING AND FORGING

ENGINEERS, & GENERAL SMITHS' WORK

BY

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FOREMAN AND PRACTICAL SMITH

401 *ILLUSTRATIONS*

NEW IMPRESSION

London:

E. & F. N. SPON, LTD., 57 HAYMARKET

New York:

SPON & CHAMBERLAIN, 123 LIBERTY STREET

1914

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PREFACE.

THE absence of a useful and practical treatise on the art of Smithing and Forging was a source of great disappointment to the Author in his early days, and often since then, he has wondered why no one ventures to devote himself to the subject through the great medium of the press, with a view to helping and interesting their fellow smiths. The Author, after a life experience in the trade as a Smith, Forger, Stamper and Foreman, seeks in the following pages to submit some sound and practical suggestions on the subject, which he hopes will be interesting and instructive to those in the "trade." The tables at the end have been compiled with a view to usefulness, and no doubt they will often prove a convenience to the reader.

This work does not pretend to be a learned and classical treatise, such as would be expected from some great professor, but simply a plain straightforward statement of the experience of a practical smith, and the Author trusts that this will prove a recommendation, and assist the work in its mission to supply a long felt want.

ENGINEERS' AND GENERAL SMITHS' WORK.

CHAPTER I.

INTRODUCTORY.

ONE of the first duties usually given to a boy in a smithy is to drive one of the steam hammers, and this is a task which requires great care and attention, not only to avoid accidents, but to become really proficient; and when a good driver is at hand, much more work can, with safety, be done at the hammer than otherwise. When a boy is employed in this capacity, he should be always on the alert and ready to stop at a word or signal from the smith, and while engaged in this way he should never let his attention be taken from the work in hand. A hammer driver often has a few minutes to spare between the heats, and this is an opportunity for him to do little bits of cleaning and siding away; a clean and tidy hammer will always reflect creditably on the person in charge.

The men occasionally require little services of the boys, and this is an opportunity for them to lend a hand, and they should do so cheerfully and willingly, and they will find that it will bear its own reward; the men will usually remember any lad who tries to do his best, alike to his master and to them: they will always take an interest in such a boy and help him on whenever they can, but this will not be the case when a boy is surly, sulky and objectionable, and will not do a stroke beyond what he is compelled.

sensible boys will not waste their golden opportunities, and these moments of leisure will prove the most useful and profitable portions of their lives, if they turn them to proper account, and not dawdle them away. When at work, the Author would advise all boys to let their interest be centred in the task before them: they should put all the energy into it that they can, and when they take a duty in hand they should make up their minds at the start to do it well, and not to be satisfied with any slip-shod business, nor with any work that will merely pass inspection. He would say further, do not aim at killing time, but aim at making yourself useful, and at being eventually the best "smith" in the shop. Another matter that a boy must begin to busy himself with as early as possible, is the question of Drawings, Sketches, Patterns, etc., and he should work out in his own mind what form the article shown on the Drawings or Sketches will take when finished. He can suppose that he has the job to do, and ask himself the question, how, in that case, he would set about it, and then, having done this, he can watch how the smith in charge sets about the job, and compare his own ideas with what actually takes place, and he will find this is real good practice; it will enable him to train and educate his inventive faculties, and qualify him for the future; it will also serve to impress the right way of doing the work on his mind. The right way is intended to mean the best way with the tools at hand. Another bit of excellent practice for a boy in his spare time is to try to make a round taper pin with true taper, say out of round iron $\frac{3}{8}$-inch diameter, 4 inches long, drawn down to $\frac{3}{16}$-inch at the point, with the hand hammer alone. This would, at first sight, appear to be a very simple task; but let any boy try, and he will find it not so simple or easy as it looks.

Take a piece of bar iron as above, raise the same to a light welding heat, then draw out a square taper about 3 inches long, on the edge of the anvil, as shown in Fig. 1, then when you think it about the right size, work on the corners until the piece assumes something of the octagonal or eight-sided shape; now draw back on to the anvil face and round up; and if you burst or split a few while doing this, as will most probably be the case before you make a good one, do not be discouraged or dismayed, but persevere. A boy should also try to accustom himself to using the sledge hammers; he should not, however, struggle with these tools beyond his strength, or he may injure himself, by being too anxious and too energetic in this respect, before he has learned to handle them properly.

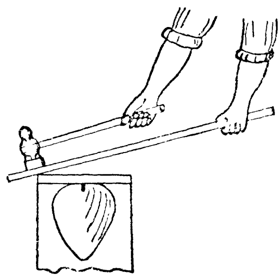


FIG. 1.

The next task expected of a boy in the smithy, usually, is to strike for another apprentice or learner in advance of himself, who has become accustomed to working at the fire; or he may be required to do some small work himself, such as bending collars, small brackets, eyebolts, S hooks, repairing light chains, and other small work, which we shall deal with later.

CHAPTER II.

FORGES OR HEARTHS.

THERE are a variety of forges in use, some of which are built chiefly of bricks, while others are built almost entirely of iron, as clearly shown in Figs. 2 to 5.

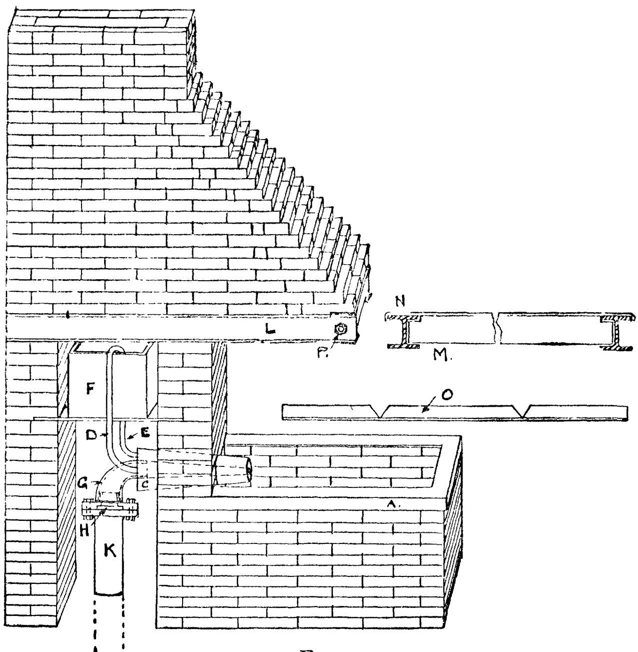


FIG. 2.

In Fig. 2, A is an angle frame to hold the bricks together round about the top of the forge; it is easily made by cutting out the corners as at O and bending to shape, or if preferred the corners may be welded. C is the tue iron or tuyere; in this case a wrought iron one is shown, with pipe E to supply or feed it with water from the tank F; another pipe marked D conveys the water, as it gets hot in the tuyere, back to the tank, thus keeping the tuyere cool; the blast nozzle or elbow marked G fits on the stand pipe, and conducts the blast from the stand pipe to the tuyere; the valve H is made of sheet iron, and works between two flanges; the stand pipe K connects the forge to the main; the hood is built on two very stout girders, secured at

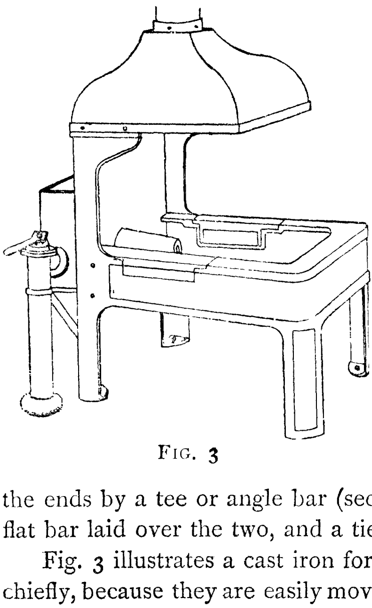


FIG. 3

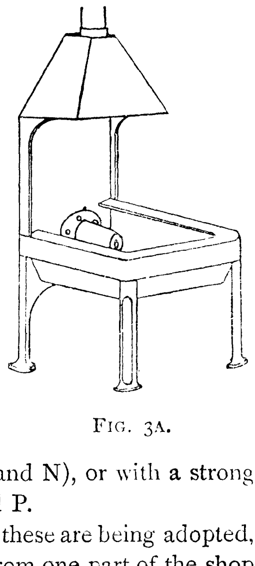


FIG. 3A.

the ends by a tee or angle bar (see M and N), or with a strong flat bar laid over the two, and a tie rod P.

Fig. 3 illustrates a cast iron forge; these are being adopted, chiefly, because they are easily moved from one part of the shop to another, which is a great consideration in up-to-date shops where they are frequently making room for something new. The blast stand in this case is fitted with plug valve and handle.

Fig. 3A is another design of cast iron forge with sheet iron hood.

The chimneyless or down-draught hearth is illustrated in

Fig. 4; this forge is also made in cast iron, and has a fire brick lining with a flue at the back of the hearth as shown to carry the smoke and heat from the hood, down into a main underground leading to a tall chimney elsewhere. These down-draught hearths are now being adopted in many of the modern works, because with them it is much easier to comply with the law relating to smoke nuisance; another great advantage is the clear overhead space for the adoption of cranes, which would not be possible with chimneys passing from each forge through the roof.

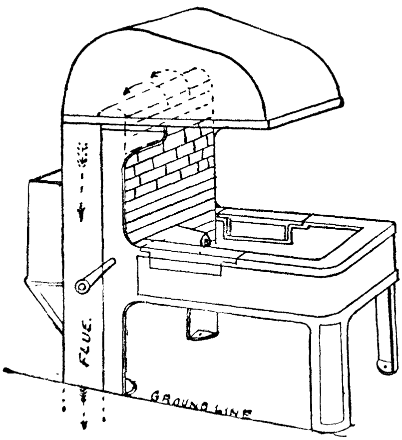


FIG. 4.

Fig. 5 represents a forge with a movable hood, arranged by carrying the back wall high enough to build a flue in the same; A is the flue, B a movable sheet iron or steel hood, hung with two hooks on to a flanged plate set in the brickwork, on which the hood may be pushed backwards and forwards, or taken down as occasion requires; C shows a series of flat bars or a plate for carrying the brickwork of the chimney; it would be a convenience, and that not an expensive one, to have two hoods, one large and one small, particularly for working on tyres; this is a very useful style of forge for coach-builders' work.

Portable Forges.—There are, of course, many of these in use, but as we are going to confine our attention to the indoor work of the smith, we need not stay to consider the several varieties of portable forges on the market. We will only state that there are the cast iron forges with bellows, made with and without water tuyeres, used for rivet heating, etc.; some of

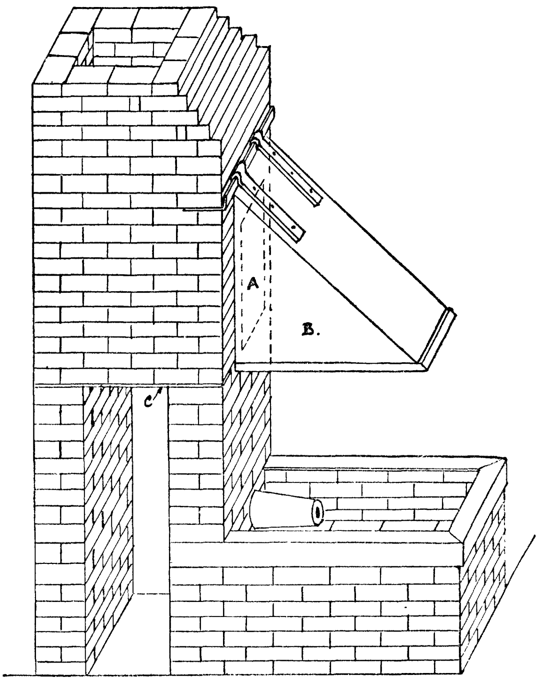


FIG. 5.

those without tuyeres have a grate in the bottom of the forge, through which the blast is forced into the fire.

There are also wrought iron forges fitted up in the same way, and many portable forges have small fans or blowers of various styles fixed to them, each and all claiming to have special advantages.

Fuel.—Gas coke is generally accepted by engineers as the best and most economical fuel for use in the smithy. Some smiths, however, mostly those in the country and small towns, still use coal.

Blast is the draught or air forced through the fire for generating heat quickly and thoroughly. The blast is produced in several ways, i.e., by means of bellows, blowers, and fans.

The bellows are of course the oldest method extant, and they have varied in shape from the old fashioned long single shape, like the household utensil of the same name, to the more modern circular and double bellows. The latter, if about 2 feet 9 inches or 3 feet diameter, make a good fire.

The Circular Fan is another means of producing blast, see Fig. 6, the casing of which is made of cast iron, held together at the flanges by means of bolts and nuts; the fan itself is a cast iron spider arrangement, with sheet iron blades

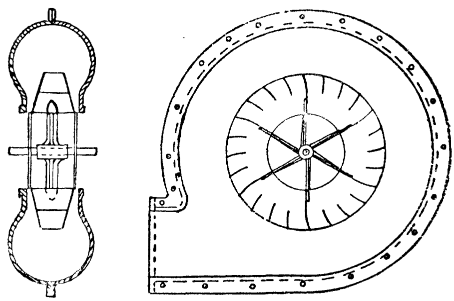


FIG. 6.

fixed to a hard steel spindle, and arranged to revolve at a high speed, in bronze, gun or white metal bearings, on either side of the case. The fan practically produces no pressure, but a constant draught which can be varied considerably in volume.

Roots Blowers, see Fig. 7.—These blowers are the most recent of all modern blast producers; they are simple in design, effective in purpose, and economical in practice, and extend their sphere of usefulness to the foundry cupola, as well as to the smiths' shop forges.

The blower consists of two revolvers fitted in a suitable cast iron casing; the spindles in the revolvers are geared at both ends, except in the smaller sizes, and driven by a belt and pulley; in the larger sizes they are fitted with driving pulleys at

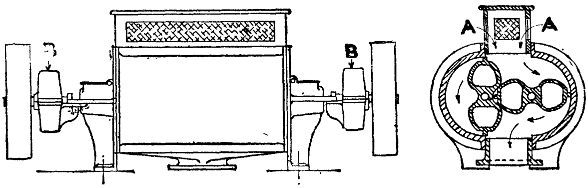


FIG. 7.

both ends. The air is taken in through the inlet marked A and passed through the blower into the main pipe. B are the gear boxes, inside which are the gear wheels.

Some smiths still prefer the fan to the blower, but that is surely because they have not had an opportunity of testing the latest patterns; some of the older ones were admittedly unsatisfactory, but whatever shortcomings they may have had in the past, there is no denying the fact now, that the latest Roots Blower stands unequalled as a blast producer for smiths' shop purposes.

Tools.—Now we come to the working tools, and we will deal with the anvil first. It is made of wrought iron, with a steel face welded on to the wrought iron body in strips about 3 inches wide, as shown by dotted lines in Fig. 8.

Anvils can be procured any weight up to about 4 cwt., and the class of work they are intended to be used for must decide the weight of anvil most suitable in any particular case; as a rule, engineers' shops are provided with these tools weighing about 3 cwt.

The Block, or Stand, for the anvil is the next item for consideration. Almost anything can be made to answer the purpose, if only large enough, i.e. ash, oak, elm, or any hard wood, iron, or stone, all of which are used. The objection to wood is that when it begins to decay or crack, the hot scale from the work often falls into the cracks or crevices, and as it lies there smouldering, gives off an offensive smoke and smell; but with this exception it makes the best stand. The block selected should be a large and sound piece, let into the floor the right distance, with the grain downwards, to make the anvil a suitable height, viz. about level with the smith's knees. A hoop or band of iron should be fixed round the top of the block. The anvil is fastened on to the wood block, with two staples made of $\frac{5}{8}$-inch or $\frac{3}{4}$-inch square iron, about 12 inches or 13 inches long, drawn down at the ends to a point, and bent as in Fig. 9. These staples are driven into the wood block, one on each side of the anvil, holding the same securely, while the

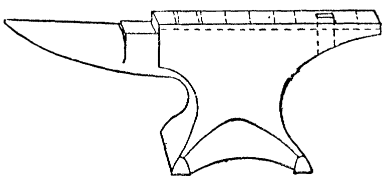


FIG. 8.

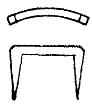


FIG. 9.

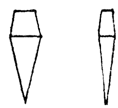


FIG. 10.

anvil can always be lifted off if necessary. When a stone is used to bed the anvil on, staples similar to the above are used to secure the anvil to the stone, only, instead of being pointed, they are left blunt and the ends jagged. Holes are then cut into the stone to receive these staples, and when the anvil is placed in position, they are put into the holes made for them, and run or filled in with molten lead.

A dowel, Fig. 10, is used in many cases, set into the anvil stand as a supplemental fastening; it is made the right size for the hole in the bottom of the anvil, and set in the wood or stone block in the same way as the staples. In the case of cast iron stands, a wrought iron dowel pin is usually cast in the stand itself for this purpose.

Swage-Block.—A cast iron swage-block is another useful tool in a smithy. The illustration, Fig. 11, will best explain what it is like. It will be seen that the holes in the block vary in size as well as shape, being round, square, and oblong. The indentations round the sides, like the holes in the block, vary in size and shape, being half-round, half-hexagon, and V-shape. The stand is generally made, but not always, with a sort of pocket at the sides, to take the swage-block, when it is necessary to use the block side upwards, to utilise the indentations.

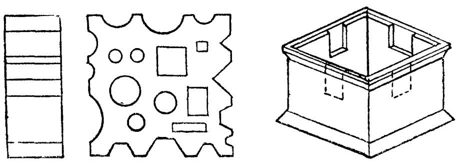


FIG. 11.

Hammers.—Hand hammers can be bought so cheaply that it does not pay to make them singly or in small quantities. There are firms that make these tools a speciality, and fit themselves up with special appliances for manufacturing them quickly, and of course cheaply. When hand hammers are manufactured as a speciality, they are made in large numbers at a time. The process of manufacture is as follows. The bar is heated and then forged under a steam or belt driven hammer, as in Fig. 12, with special tools or dies fitted to same. The top tool is fitted to the tup, and the bottom one to the hammer block, and only a very few strokes from the hammer are required to complete the process.

When these small hand hammers can only be made in very moderate quantities at a time, the best way to manufacture them is to make the above tools in the form of spring swages, illustrated in Fig. 13, for use under the hammer with the plain blocks or pallets.

It will be seen from Fig. 12 that with these tools in use, the shoulders are formed, and the hammer is made to length, less the expansion, which takes place in the punching and finishing processes; the hammer is also practically cut off the bar, and after this the eye is slightly flattened one way, as indicated by dotted lines in Fig. 12.

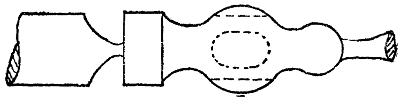


FIG. 12.

The punching of the hole takes place under a drop hammer, or another steam hammer, fitted with blocks sunk to the shape of the forging; in some instances both blocks have a punch fitted in them, so arranged that they almost meet at the centre; in others the top one only is made with a punch, and this is driven part of the way through the forging at one side, after which it is turned over, and the punch applied to that side; now, except for a small burr in the centre, the eye is made, and if the drift be applied to the burr, it will quickly be removed. The hammer can then soon be finished off, the ends requiring very little hand work indeed.

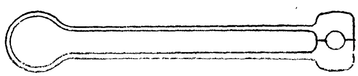


FIG. 13.

When making the dies or tools, provision must always be made for the flow of superfluous metal, by cutting spaces in the ends of same for the purpose, see Figs. 12 and 13A. Of course, if a smith was asked to make a hammer head or two, he would never think of making special tools in that case; he would have to treat them as an ordinary forging, and proceed as follows (say he is making an ordinary blacksmith's hand hammer as used in the smithy): He would take a round bar of cast steel, about 1½ inches diameter, and heat the same carefully and steadily in the fire to a suitable heat, taking care not to burn it; the bar will then be shouldered down with fullers as in Fig. 14, the small end marked A being reduced in diameter, either with swages or on the anvil; he would now flatten the centre part marked B to the same as A, making it as wide as possible the other way, trim up the corners, punch the hole for the shaft with an oval punch half way through, then turn over, and meet it with the punch from the other side. This should be done over a tool made the same shape as the sides of the eye, with a hole in the centre for the burr and the drift to pass through. After four or five blows have been struck on the punch, take it out and cool the point. Now put a little coal dust in the hole, replace the punch, and proceed with the punching; the coal dust will generate gas,

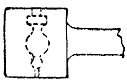


FIG. 13A.

FIG. 14.

and help to force out the punch. Note, a good punch will not fasten or wedge itself, if a little coal dust is used in conjunction with fair play, but remember it is not fair play to continue punching cast steel after the heat has so far abated that it practically has little or no effect on the steel.

Now insert the drift and flatten on the sides. This must be done very smartly as the drift will soon cool the steel; when the hammer is nearly finished, drive the drift well home from each side, to make the outsides of the eye larger than the centre part; the hole will then assume the best shape for receiving the shaft, and allowing the same to be wedged tight and fast.

To Harden hand hammers, heat the forging to a dark red, and cool the ends alternately in water, without immersing the eye at all; by this treatment the ends are hardened while the eye is not, also the heat from the eye tempers one end while the other is in the water; and here we should notice with regard to hardening that the chill, in cold weather, should be taken off the water before it is used for this purpose. It is a great mistake to harden cast steel tools in perfectly cold water: this is the cause, or at least one cause, of tools cracking during the hardening process; another cause of cracking is unequal heating, which produces more contraction round the edges, and causes the hammer to snip or fly. Bear in mind there is a great difference in temperature of water standing in the troughs and tanks of a smithy at various times of the year.

Eye Drifts for Hammers, Tools, etc.—In Fig. 15 we have two drifts, somewhat different in shape, one marked A, the other B. It will be seen that the one marked A has four sharp corners, which condemn it at once; if this tool was used for drifting the eye of the hammer forgings we have just been considering, the sharp corners on the drift would nick or cut the steel forming the eye, and weaken it at that part considerably; in fact it would make the hammer dangerous to use, as it might any time give out at one of these weak places when in use, whereas, if a drift be used that is nicely rounded off, as in the case of B, it would make a good clean eye in the hammer, without weakening any part of the forging.

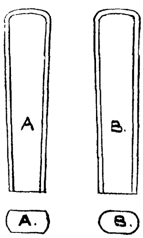


FIG. 15.

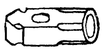


FIG. 16.

Sledge Hammer, Fig. 16.—To make a sledge hammer, take a piece of steel, preferably cast steel, shear temper, $2\frac{1}{2}$ inch square, about 7 inches long, punch and drift the eye, which should be about 1 inch by $1\frac{1}{2}$ inch oval; now make the short end of the hammer by drawing out the steel, if you have power enough; or, if not, and you have to depend solely on hand-work, have the piece long enough at the start to allow the hammer to be cut to shape at the small end; this done, proceed to make the other a true octagon, i.e. having eight equa.

sides, cut the end slightly round or ball-shaped, also cut off the sharp edges round the striking surface or face, work up with a large swage, and hammer the face slightly round. Note, hammer faces should never be hollow, but rather a little convex.

If a rather mild cast steel is used for the forging, it must be hardened by heating the face to a cherry-red, and then lowering the hammer head into the water, small end first, holding the face where the stream of running water will strike it while immersed in the tank, say 2 inches or 3 inches below the surface; if, after this treatment, the hammer face snips or flies off in pieces, it proves either that the steel is higher in carbon than it should be for the purpose, or that it has not been properly treated during the forging process. If the steel is at fault by being too hard, it may be remedied by drawing the temper; to do which, clean well with a piece of sandstone and water, then heat steadily from the small end on the front of the fire, watching it carefully all the while; when the face of the hammer is turning from a straw to a purple colour, take it off and plunge into water or oil; should it then be too hard, clean again and draw the temper to a blue colour, and treat in the same way as before. If it is known that the steel used for the hammer is harder than shear temper, it would be better to harden it in boiled oil, and, if necessary, the temper may be drawn as before.

If the hammer still cracks or snips, or flies in pieces, then clearly the steel has been overheated during forging, in which case there is no remedy, and it had better be thrown to the scrap at once; it is really dangerous for anyone to work such a defective hammer.

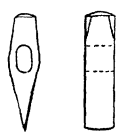


FIG. 17.

The Cold Sate, Fig. 17, is a very simple tool in itself, and easy to make; it, however, requires careful attention while hardening and grinding.

To make a sate, draw the end of a bar of sate steel down to a wedge-shaped point, taking care that it does not overlap as illustrated in Fig. 18, while it is being forged; however, the overlapping may occur, and if it cannot be avoided, cut off as at A B, for if it is left on, it will break the first time it is used; now punch and drift the eye, cut off the bar, and shape the head as shown, by tapering off the corners from the top side of the eye.

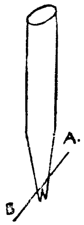


FIG. 18.

To harden cold sates, heat the point steadily to a dark red colour, then cool the same by holding the cutting edge in water about $\frac{3}{4}$-inch deep; when cool, take it out of the water, clean the hardened part by rubbing same with a piece of sandstone; do this quickly, and the heat that is left in the body of the tool will re-heat the hardened part, and gradually tone down the hard and brittle temper just set up at the edge, and so make the tool useful and serviceable. We may note for the benefit of the learner that if the sate, when being hardened at the edge, had been plunged overhead in water, and cooled straight away, the temper would be so hard that the tool would be simply no use at all; it would break the first time it was struck with a hammer. The reader will see, therefore, why only a portion, i.e. the cutting edge, is hardened, and the other part of the tool held up away from the influence of the water; it is so that the heat may remain in the top part of the sate and afterwards gradually extend itself back again through the portion that has been cooled in water, and so gradually temper or toughen the same.

If the sate is examined after being hardened and cleaned, the colours showing the degrees of temper can easily be followed; first a light straw will be seen, deepening to a dark straw, then changing to a purple, followed by a light blue, which, if allowed to go on, will turn to a deep blue. The sate, if made of steel of a proper temper, will be the best, when the extreme point is turning from a purple to a light blue; it should then be plunged in water to cool, thereby arresting the temper at this point.

Grinding.—The edge of the sate should be ground slightly round, except when the work it is intended for requires the edge made straight. It is found in practice that when cold sates are ground with a straight edge, and are required to cut, say plates or flat bars, they almost invariably snip at the corners; but by making the cutting edge slightly round, it prevents the corners snipping or chipping off, the strain and jar being directed to the centre and strongest part of the tool, and when properly hardened this shape, they will stand a large amount of work; if, however, the edge should snip slightly, it will be well to grind up again without re-forging, as the tool will be slightly softer further back, and perhaps be the right temper; it is surprising how rarely this suggestion is put into practice. If the edge turns or knocks up, as they term it in the trade, the sate must be re-forged and left a little higher or harder temper than before.

Cold Sates are extensively used in other trades, such, for instance, as boiler making, bridge and girder work, stripping and cutting up scrap, etc., and for these purposes they are made without the eye; the ordinary shaft as used in the smithy would not be strong enough to endure the rough usage they receive in these departments—they would always be getting broken. Boiler makers therefore use a sate with a rod bent round the body of the tool; this shape of handle permits of the sate being used in many positions that would be impossible with the ordinary shaft, and another advantage in using is that it does not transmit so much of the jar to the operator's hand, as does the shaft.

To make a cold sate suitable to use with a rod, set in the corners where the sate rod is to be bent round, instead of punching the eye, and proceed otherwise as before.

The Hot Sate, see Fig. 19, is made in much the same way as the cold sate. The blade, having to cut the metal while hot, should be thinner and wider; this is the only difference in the forging; it is also ground a little further back.

The Top Fuller, Fig. 20, is a tool for everyday use, and there should always be four or five sizes at hand, according to the class and size of work to be done. To make a small one, taper down the end of the bar, spreading it out as much as possible, upset in a bottom swage until the fuller is a suitable length, and the bottom of the tool made round, then work round the top of the feet or projections with another fuller, while standing in the swage, and punch and finish as in the case of sates.

FIG. 19.

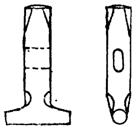


FIG. 20.

The larger sizes of fullers are made rather differently; take a piece of steel say 2 inches square and commence by forging the shank part, then cut a piece off the bar beyond the shoulder and let it be sufficient to work up to the required size; this done, place the shank in the hole of the anvil, while the rounded part, as shown in Fig. 21, is made, or, place the shank in a square bolster under the steam hammer, see Fig. 22, and work up with a top hammer swage in a similar way.

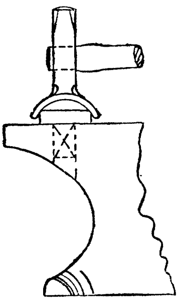


FIG. 21.

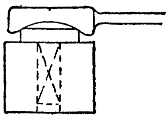


FIG. 22.

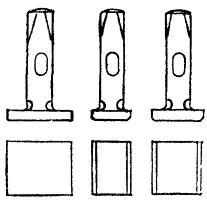


FIG. 23.

The Flattener or Set Hammer, Fig. 23, should be made in the same way as the large fuller, but with a perfectly flat face. The face is easily made by putting the shank under the steam hammer in a block, or bolster, and spreading with a piece of half round iron or steel, then levelling the face and paring the sides to size.

Set hammers of various widths, with round as well as square edges, are very useful tools. The round edged set hammer should be more frequently used than the one with the square edges, for this reason, that iron and steel, when cut or shouldered down with a square edged set hammer, will often develop into a fracture; this should be borne in mind by all smiths, and the practice avoided as much as possible.

Large Top Swages, Fig. 24, are made in the same way as the previous tools, with the exception that, when the forging is put in the block or bolster, a piece of round iron is sunk into the same, after which the ends, marked A, Fig. 25, can be drawn out under the edge of the steam hammer, as illustrated, and then finished on a piece of round bar, which should be a size larger than the swage is intended to be used on.

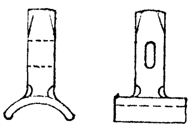


FIG. 24.

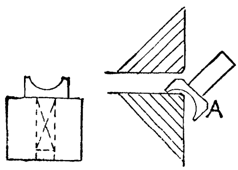


FIG. 25.

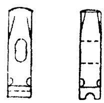


FIG. 26.

Small Swages, like Fig. 26, are sometimes made by taking a piece of square steel, long enough to make two of these tools, and punching a hole in the centre to form the concave surfaces, the bar afterwards being cut in two at the dotted lines, see Fig. 27; but this method does not appear to be so simple as cutting a piece for each swage, and then sinking a fuller into the end of each piece separately to form the concave surface, neither is there any saving of time.

Punches need really no explanation after what has been said about the previous tools; but they should have a good taper when intended for hot punching. For illustration, see Fig. 28.

Shouldering Fullers, Fig. 29, are very useful for setting down, previous to drawing out; they are similar to ordinary fullers with a piece hollowed out and rounded off in the same way; the bottom one is made to fit in the anvil. When using these tools it is advisable always to mark round the bar while it is lying in a swage or on the anvil, with the top fuller, before starting with the pair, as it is difficult to always get the top fuller square with the bottom one unless this advice is followed.

The Side Fullers, as illustrated in Fig. 30, are used for making one shoulder square and the other taper; they are hollowed out in the same way as the previous tools, and then,

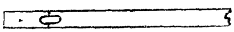


FIG. 27.

FIG. 28.

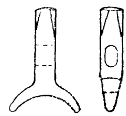


FIG. 29.

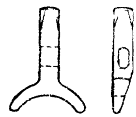


FIG. 30.

instead of rounding off, they are made straight on one side and taper on the other. There are two advantages to be gained by using these special tools, when a square shoulder is required; namely, in the first place, the square shoulder is made without any extra work as shown, and the other side, being taper, does not overlap when being forged out. The edge of these fullers should not be too sharp; they should be made about equal to $\frac{1}{4}$-inch round or $\frac{1}{8}$-inch radius for 2-inch fullers, but for the larger sizes, say up to 4 inches, let the radius be $\frac{1}{4}$-inch, and so on in proportion.

ANVIL TOOLS.

Bottom Swages and Fullers should be made to pair with the top tools. Steel of the lowest quality, with a fair percentage of carbon, is quite good enough for this purpose. The thick part of a piece of old rail will make good bottom swages and fullers, but this quality of steel is not good enough for top tools, being brittle. It would certainly not do to strike at: it would fly to pieces with repeated hammering, and be a source of danger during the short time it lasted.

Bottom Swages should be made out of a piece of steel that is large enough to leave the body, when finished, a fair thickness, so that they will not bend upwards when at work. The small sizes are often made in pairs, occasionally in trios, such as $\frac{1}{4}$-inch, $\frac{5}{16}$-inch and $\frac{3}{8}$-inch, or $\frac{1}{4}$-inch, $\frac{3}{8}$-inch and $\frac{1}{2}$-inch, see Fig. 31; but for sizes above 1 inch this method is not advisable, because the swage would need to be uncommonly wide, and it would be awkward and clumsy, and in time the bottom would work round, with the result that the forging in hand would be jumping out of the swage at every blow it received.

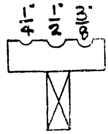


FIG. 31.

To make a 1-inch or larger bottom swage, proceed as follows: take a piece of steel, say about 4 inches by 2 inches, or a piece of billet $2\frac{1}{2}$ inches or 3 inches square, and fuller down one end of same under the steam hammer. To do this, place a piece of $\frac{5}{8}$-inch round iron across the steel and hammer it in, as shown in Fig. 32, on the four sides; then place a piece of $\frac{5}{8}$-inch round on the hammer block, and resting the forging on

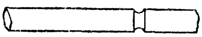


FIG. 32.

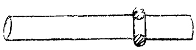


FIG. 33.

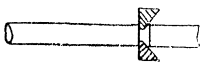


FIG. 34.

it, hammer the round in the top, as in Fig. 33. Now introduce the side fullers, and work the steel between them under the hammer, as in Fig. 34, until the required size is reached; and while referring to the side fullers for the steam hammer, we may say they are very simple tools indeed, forged with three corners, and two of the sides at right angles to one another, in section as shown in Fig. 34; both tools have the working corners rounded, so as not to cut the steel. The idea of these tools is to squeeze and push the steel as it were away from them at one side, and make a square shoulder at the other side, and while doing this not to nick or cut the steel they are working on; the top fuller has a handle forged on to hold it with. And now reverting to the making of the 1-inch swage, we may say that when the shank has been forged with the fullers, as described above, and then drawn out, cut the piece off the bar and put the same in a bolster under the hammer, and work to size and shape; then sink the groove by using two or three different sizes of round bars, commencing with the smallest diameter of bar first, and increasing the diameter until the required size is obtained. When finishing swages, always open out the top of the same with a larger sized bar, to give clearance; for instance, if making a 1-inch swage, use a piece of round bar 1 1/8-inch diameter to open out the top edges. The most suitable depth for this class of tool is about 3/8 of the diameter in the top and the bottom swage.

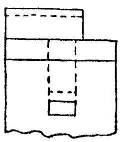


FIG. 35.

Bottom swages are most convenient when they are forged so that at least one end will come flush with the side of the anvil, as shown in Fig. 35.

To make these swages, when there is no power at hand, i.e. no steam or other power hammer, take a piece of iron the right size, or the nearest size obtainable, for the body of the tool, and a piece of square for the shank; upset, and forge one end of the latter piece as much like a mushroom in shape as possible, then punch a round indentation, not a hole, in the former or larger piece of iron, that has to serve as the swage; now raise the prepared part of both pieces to a good welding heat, brush off the dirt or cinder with a small besom, and place the mushroom end in the hollow place prepared for it, in the piece for the top part of the swage, and give three or four sharp blows with a sledge hammer, then turn it over into the hole in the anvil, and work on the top to complete the welding process, or keep it on the anvil with the shank upwards and work round the edges of the weld with a fuller or round edged set hammer.

If the swage is intended for any special work, it may require to have a face of double shear steel welded on, but as a rule it is quite sufficient if the face is case-hardened, which process is usually done as follows. Take some prussiate of potash, and crush to a powder; heat the swage or tool to a white heat, clean off the scale with a file, and then sprinkle the powdered potash over the surface to be hardened; the potash will melt, and, while in its liquid state, can be run all over the surface to be hardened, until it has been absorbed by the hot iron, the degree of hardness and the depth of the case being determined by the quantity of potash absorbed; if, therefore, a deep hard case is required, use the potash freely, and when it has all been absorbed by the iron, heat the tool again to a dark red, and plunge into cold water, the colder the better for this purpose. The above process may be repeated if a still deeper case hardness is required.

Bottom Fullers.—When making these for general use, always forge a lip or stop on, as shown in Fig. 36, to keep the forging on the fuller, whilst turning it over; this will greatly

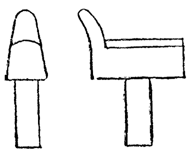


FIG. 36.

FIG. 36A.

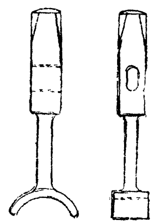


FIG. 36B.

assist a smith while manipulating some of his work. The square shank of all these tools should be made a loose fit in the hole in the anvil.

Tongs are most necessary tools for a smithy, and it is surprising how many more bad pairs there are in the tool racks than really good ones, and another surprising feature is the number of smiths there are who do not get anything like the full life out of their tongs, through sheer thoughtlessness and neglect on their own part: the habit of leaving them gripping the work in hand, while the same is in the fire, and so allowing the tongs to be continually getting hot, and as often being cooled in water, bent, straightened, closed in, and the like; when much of this sort of thing could be obviated by a little thoughtfulness on the part of the smith, and the life of the tongs extended in consequence considerably.

When making tongs, remember the eye is very important, if not all-important, since it is in the making of this particular feature of the tool that so many tongs are spoiled; for instance, some smiths, when making the eye, will forge them out on the square edge or corner of the anvil, thereby making a weak place at the start, whereas a good smith will do this part of the work on the beak of the anvil, or some tool with a round edge, and finish off with a fuller and round edged set hammer; while other smiths make the eye much too thin and weak in proportion to the other parts.

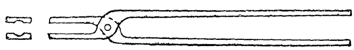


FIG. 37.

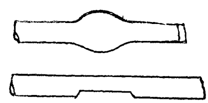


FIG. 38.

The tongs known in the trade by the name of "flat bits," are used most frequently, not only for flats, but for rounds and squares also, by grooving down the centre, as shown in Fig. 37.

To make an ordinary pair of these tongs, take a piece of good $\frac{7}{8}$-inch round iron, or mild steel, raise the iron to a light welding heat, or the steel to a white heat, and commence by flattening the eye, see Fig. 38, on the beak of the anvil, taking care not to make the same too thin; then draw back, and give it a quarter turn to the right and forge the end to $\frac{5}{8}$-inch by $\frac{1}{2}$-inch, see Fig. 39; now turn half over, and pass or push the forging forward beyond the eye, so that the part A in Fig. 39 will rest on the beak of the anvil, and form the other side of the eye.

Another way to proceed with the making of tongs, that is, as far as we had gone in the other case, is to set the forging in at the parts indicated by dotted lines with a fuller, and undoubtedly this will be the more satisfactory of the two; this done, cut off the bar and shut or weld on the rein or handle, which should be a piece of $\frac{3}{8}$-inch or $\frac{7}{16}$-inch round iron or

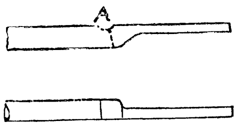


FIG. 39.

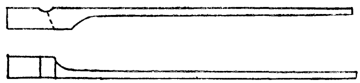


FIG. 40.

steel, well jumped up or swelled at the end to form a long taper for strength; the side of the tongs will now appear as at Fig. 40.

Now forge out the ends, make the groove down the centre with a small fuller, punch the eye for a rivet say $\frac{1}{2}$-inch diameter, and rivet a pair together, then re-heat and bed on to whatever

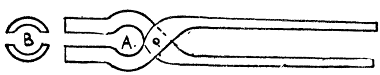


FIG. 41.

they are required to hold, cutting both ends to a suitable length.

Next we have what are termed the **Hollow Bits**, for holding rounds; they are generally made to hold the same size at A as at B, see Fig. 41.

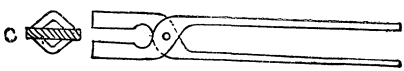


FIG. 42.

Then we have the **Square Bits**, Fig. 42, and these tongs, as well as those just referred to, should be made to hold a piece of flat iron of suitable dimensions between the jaws, as shown at C in Fig. 42, which will make them doubly useful.

The **Anvil Tongs** or **Pliers**, Fig. 43, are made to open very wide, and pick up almost anything that is required; they are called anvil tongs, because they are invariably kept somewhere close to the anvil for regular use, generally resting on a hook driven into the anvil block.

Now we come to what are termed the **Hoop Tongs,** Fig.

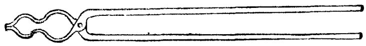


FIG. 43.

44, so termed because the ends are turned in to enable them to grip a hoop securely as shown, or a bar crosswise.

Then we have what are called the **Clip Tongs,** intended for holding flat bars; they are made by welding a piece across the end of one of the bits, or forging one of the same with a

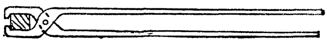


FIG. 44.

long end, and splitting and opening back, and bending the ends over the edges of the bar, as at Fig. 45; the latter is the better method, as the weld is troublesome in some cases; these tongs are also often made for holding squares, but are not so good for that purpose as the square bit, see Fig. 42.

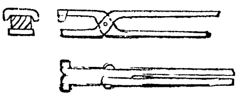


FIG. 45.

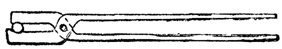


FIG. 46.

Link Tongs, illustrated in Fig. 46, are intended for holding links, eyebolts, etc.

Bow Tongs.—These are used when forging nuts, collars, and the like. It will be noticed that the bow is a long distance from the eye, see Fig. 47; this enables the ends to open very wide, but we must remember that the greater the length the less grip there will be; however, a little experience will soon decide the best length to adopt to secure the best results, when it is known what weight and size of work has to be handled. Of course, for nuts only, the tongs would be made to fit the nut, see Fig. 48.

Hammer Tongs, see Fig. 49.—These tongs are used for

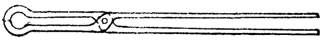


FIG. 47.

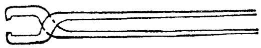


FIG. 48.

holding sledge hammers while forging or repairing the face of same.

Angle Tongs, illustrated in Fig, 50, are made with one bit, or side, in the form of an angle, while the other is a round. The angular bit fits on the outside of the bar, and the round

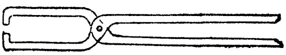


FIG. 49.

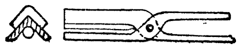


FIG. 50.

one goes inside, thus securing a firm grip of the bar; one pair of these tongs will serve for any width of angle of the same thickness.

Bill Tongs, as in Fig. 51, are made for gripping the sides of a piece of angle iron, and are also used for bent work. In

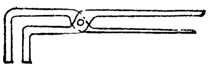


FIG. 51.

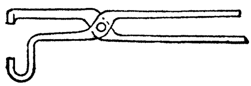


FIG. 52.

Fig. 52 we have another pair of tongs used for holding angle iron the reverse way. Tongs for holding hot sates, shaped as illustrated in Fig. 53, are very useful, and so are those with a good clearance at the back for holding a bruised chisel, Fig. 54. These same tongs are very convenient for holding bolts and the like. Tongs for holding flatteners or set hammers are illustrated in Fig. 55.

Tongs for Holding Picks.—These are made with an eyebolt serving as a rivet, see Fig. 56. The pick passes through and is steadied by the eyebolt, while it is gripped by the tongs as shown.

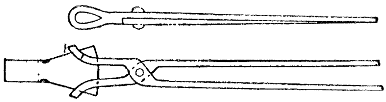


FIG. 53.

The best way to make the larger size tongs, used specially at the steam hammer, is to forge them in mild steel out of the solid, that is without any shuts at all. They should be made of a quality of steel that is not too hard, so that if they should be broken by accident, they can be mended again. Take a

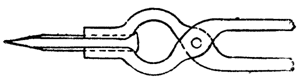


FIG. 54.

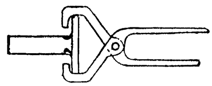


FIG. 55.

piece of steel the right size for the bit required, place a flat tool with rounded edges on the hammer block, and forge out the bit on the same; first flatten for the eye, holding the piece across the block diagonally, from left to right, then draw

FIG. 56.

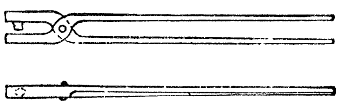
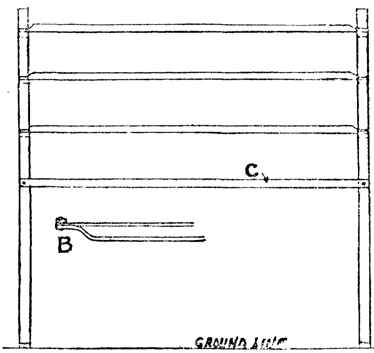


FIG. 56A.

back, and, standing square with the hammer block, give a quarter turn to the right; this will set down for the rein; now pass forward to the edge of the part first flattened, turn right over and set down the other side of the eye; now draw out the piece at the end for the rein, cogging it down with the edge of the hammer, until very near to the required size, when it may be almost finished under the hammer, with a very little practice; the above work may be done with one heat. A good smith will draw out the tongs from the solid, in less time than another man would take to make a shut; and the tongs when forged from the solid will be decidedly stronger in consequence. Now finish off in the same way as illustrated in the smaller sizes.

Before leaving the question of tools, it will be well to remind the reader, that the foregoing only deals with the general tools, and does not profess to touch upon the question of special tools; these will be described and fully dealt with



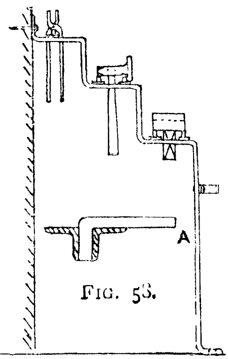


FIG. 58.

FIG. 57.

later on, as we proceed to consider the work for which they are intended to be specially used; this will simplify matters considerably, as it is impossible to describe them now, and demonstrate their usefulness fully, without introducing into the question the work they are to be used for, and so hopelessly mixing up the two together; and before passing on, we shall see that, in a shop like a smithy, where there are such a multitude of tools required at one time or another, it is impossible to keep them handy, without there is some sort of an arrangement for holding or storing them in a systematic and orderly way, so that they may always be in sight and always be accessible when wanted. What is needed therefore, is a rack for the purpose.

A favourite rack for ordinary tools, and one that will recommend itself to every smith, is made as illustrated in Fig. 57; it has steps or tiers arranged one above another. The principals are made of flat iron, bent as at A, Fig. 57, with holes drilled or punched for riveting the cross-bars thereto and also for fastening to the wall; the length of the rack must decide how many of these principals are to be used; a fair distance to allow between each of the uprights is from 4 feet to 4 feet 6 inches, if this distance is exceeded, the cross-bars will spring open with the weight and strain, and let the smaller tools fall through.

The two bottom bars in Fig. 57, marked C, it will be noticed, are not on a step, but are bolted or riveted to the perpendicular part of the principals, below the last step; being set out as in B, so that the tools will go between.

For storing heavy tools, such as swages, cutters, etc., for the steam and other hammers, a convenient rack can, if there are any roof columns in the shop that can be utilised for the purpose, be made as follows. Take two lengths of angle or other strong bar, and fasten the same at the ends from one column to another, leaving a space about $1\frac{1}{8}$ inches wide, between the two bars.

Then take some pieces of 1 inch square iron, and bend the same into hooks, see Fig. 58, these only need to be placed as required between the bars, that have been fixed to the columns, one of the hooks projecting to one side, and the next one to the other, and so on alternately, making use of both sides of the rack. The hooks can be moved from one part to another as most convenient.

If there are no columns at hand, two strong standards can be substituted,

CHAPTER III.

HAMMERS, FORGING MACHINES, AND PRESSES.

THERE are many hammers in use to-day, some of which are adapted to general, and others to special work.

When steam power is available, the steam hammer is best for general and miscellaneous work, especially when a good assortment of tools is at hand.

The sizes of steam hammers are denoted by their weight, which is approximately the weight of the piston rod and tup, and not the weight of the fall, which would, of course be much heavier, taking into account the velocity and steam pressure combined.

Next in order of usefulness, is the power hammer which is an excellent substitute for the steam hammer, when steam is absent, or insufficient, or when electricity or gas are substituted for steam. But be it understood, that for heavy general work, no hammer yet devised can surpass or eclipse the steam hammer for effectiveness. If this were not so, or not generally accepted as being a fact, we should not have the power hammer manufacturers claiming that their hammers, i.e. those worked by belt, gave the nearest possible results to the steam hammer. This is an argument, if such were necessary, that speaks volumes for the steam hammer.

Drop Hammers in their way are very useful; there are many types in use, from the one with the old grooved pulley and rope, to the steam stamp and the patent lifting apparatus of various kinds.

The Oliver, as it is called, is an old-fashioned type of hammer now almost obsolete. It is being superseded by the various forging machines and light power hammers; olivers, however, are still in use in some of the old-fashioned shops, chiefly for making odd sizes and small quantities of special work.

For small steam hammers, not exceeding 7 cwt. or at the most 10 cwt. for general use, the one with the single bracket or standard, known as the Rigby type, see Fig. 59, is the most effective, and suitable, there being plenty of room round the anvil block; but for heavier work, a hammer with double

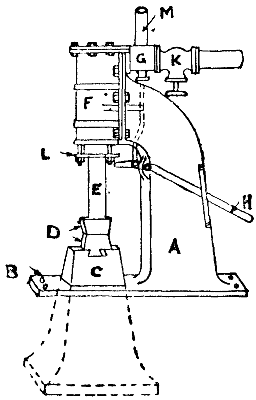


FIG. 59.

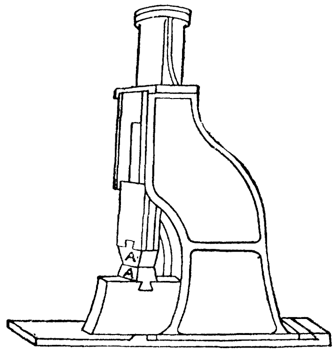


FIG. 60.

standards, and the tup working between slides, will be most satisfactory, see Fig. 60.

A in Fig. 59 is the standard and bedplate cast in one piece, resting on a bed of concrete and hard wood specially prepared to receive it; B are the holes through same for the foundation bolts; C is the anvil block or tool bed; D represents the pallets or working faces; E the piston rod; F the cylinder, inside which the piston is actuated by steam-pressure, delivered through the valve G alternately to the top and the under side of the piston; the driving lever, marked H, is connected to the valve G; K is the stop valve for shutting off the steam when not in use; the gland marked L, when properly packed, keeps the rod and pallets free from the condensed water; the pipe, marked M, carries away the exhaust steam.

Fig. 60 is a double standard hammer working on much the same lines as the one with the single standard.

The piston, in the case of the double standard hammer, is not so deep nor so strong as in the previous one, because the tup in this instance works between the slides, and is greatly supported thereby. The pallets marked A are separate pieces arranged so that they can be easily and readily changed for special blocks.

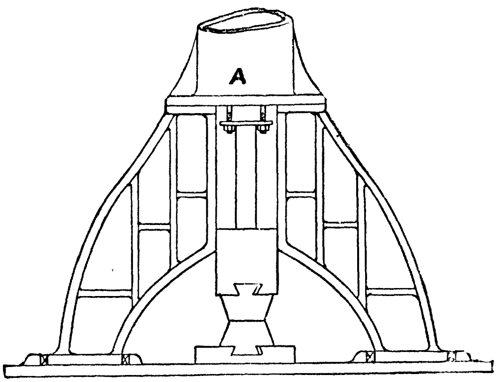


FIG. 61.

Fig. 61 represents a heavy forge hammer, the standards forming an arch or bridge. The cylinder A is placed in the centre of the arch, and the hammer is similar in action to the others. These hammers vary considerably in size, and are anything from 4 to 100 tons.

Drop Hammers or Stamps.—In the case of repetition work, when large quantities of any particular article are required, and when it is essential that the same should be uniform in size and shape, then the drop-hammer has no equal, either for turning out satisfactory work, or doing the same economically.

Of course, tools and dies are required to work with in the case of the drop hammer, and oftentimes it is an expensive matter; in fact, occasionally, it is an appalling item to the parties concerned, especially when the selling price of the article to be manufactured is considered. Inquiries frequently come to hand for quantities of repetition work, which cannot possibly pay for the expenditure in tools; in that case the offer is declined, or if accepted, it is in the hope, if not with the

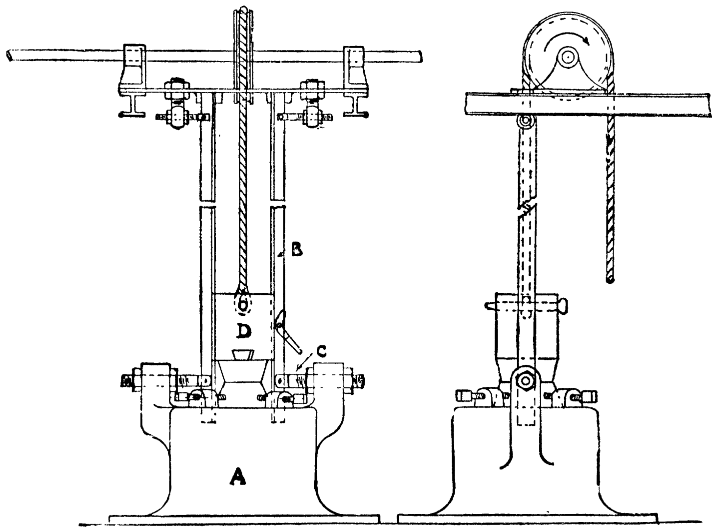


FIG. 62.

assurance, that further orders will follow to recoup the expenditure on tools. In many cases the manufacturer makes a clean sweep of the cost of the special tools, charging the same to the customer along with the articles made, and reserving the tools for that customer's work alone. Fig. 62 represents an old style of drop hammer still in general use.

The block, marked A on Fig. 62, is a very massive casting, and it is on this block that the bottom tool or die rests; it is held in position by four adjusting screws or pins, working through four large wrought iron or mild steel boxes, set in the block.

The slides, indicated by the letter B, are planed to fit the tup on the working side, and the bottom ends are arranged to rest in grooves formed in the block A; the slides are held in position by two forks, marked C, which are screwed and run through the ears of the block with a nut at each side of the same; the tops of these vertical slides are held in position in a similar manner.

The tup, D, is shaped or planed to suit the slides, and has a dovetail for holding the top tool, which, by-the-by, is fastened into the tup by driving a key along the side of the tool, in the dovetail of the tup.

Above, and over the hammer a line of shafting is fixed in suitable bearings on which a fast pulley is placed, actuated by a belt and kept running. On this shaft a grooved pulley is fixed, one side of the pulley being in line with the centre of the tup. A rope is securely fastened at one end to the tup, and is loose at the other; the loose end is passed over the grooved pulley, and hangs low enough at the other side to be easily reached by the assistant whose duty it is to pull the rope tight on the pulley, which, as I said before, is kept revolving, and the friction of the pulley on the rope raises the tup to the required height, when the assistant suddenly lets the rope go loose, which releases the friction, and the tup falls on to the work with great force.

A good Manila rope is best for the purpose, and the part that comes in contact with the grooved pulley, is usually protected by wrapping or binding the same with cord, which is replaced as it wears; by this means the rope itself is preserved.

In some works a stamper often has the use of two, and even three of these hammers to enable him to get through his work, and when this is so the blocks are arranged for the stamper to finish his work ready for the machine shops, or the assembling rooms, but when he can only be spared the use of one hammer, then he has to build his work up to, as nearly as possible, the size and shape required, allowing for reheating and stamping, and when the articles are stamped as near as possible, the fray is cut off, either by pressing the forgings through a die, or dressing off with hammer and chisel, and finishing with a file or grindstone.

The Dies used under the drop hammer are made in two ways: either they are cast as nearly as possible the size and shape in steel, or they are cut out of the solid.

When they are cast, a pattern is necessary, and in preparing this, allowance should be made for double contraction; the block or die, when cast, will shrink or contract considerably in cooling, and this must be taken into account; likewise the forging, when it leaves the blocks or dies, will also shrink or contract as it decreases in temperature, and this also must be borne in mind, so that the work when finished may be in every way satisfactory. When the dies have been cast, the mould or working part is cleaned out, and made ready for use.

When dies are cut out of the solid, pieces of forged steel are used, the temper being much the same as in the case of sates and other edged tools, but a cheaper quality of steel.

Die sinking requires a lot of experience and knowledge; this part of the work is very important, and must needs be very carefully and accurately performed. Provision must be made for getting the work out of the dies easily, and for cleaning purposes, and also for the flow of metal where more than one pair of blocks are used for the same forging; allowance must also be made in this case for contraction, as when the die sinker has done his work the blocks have to be hardened, and during this process they will contract, as also will the article to be manufactured when it comes to the cooling stage; so whoever makes the dies must bear all these points in mind while preparing these working tools, or when finished they will not be satisfactory.

The most reliable way for sinking dies is to find out how much contraction will take place in the several instances mentioned above, and make an iron, brass, or other metal pattern of the stamping or forging to be made, with the allowance added on to it, using the same as the master gauge for fitting the dies to.

In order that a stamper may clean his heat, while he is working at it, and not be obliged to forge or work a lot of scale and dirt into the forging, he has by him a supply of water, and a miniature mop, which he usually rigs up himself, and uses for the purpose of throwing a splash of water into the die, and on to the forging that he is making; and this has the effect of cleaning his work. The next time the tup descends, a sharp report is heard, as though a rifle had been fired, and immediately the scale and dirt that a moment before was adhering to the forging, flies off in all directions; and it may be stated here, that throwing water on just as the blow is struck is the most effective way of cleaning a heat; either at the stamp, the steam hammer, or on the anvil.

In the case of other drop hammers, much the same routine, as stated above, is observed with regard to working them, except that the means for lifting the tup varies in every case; as for instance, sometimes an ordinary double-flanged belt pulley is used for this purpose, in conjunction with a flat rope or strap. Friction clutches are also used. There are also steam and other stamps in use.

We now come to the forging machines and presses, of which there are lots on the market, that can be used to great advantage by intelligent smiths, for upsetting, shutting, bending, and the like; but we shall have a better opportunity of explaining and demonstrating the use of these machines later on, when we come to consider the various examples of smiths' work.

CHAPTER IV.

IRON AND STEEL.

Until quite recently, comparatively speaking, malleable wrought iron was the material principally specified for forgings of all descriptions; but to-day, owing to the progress of science, and its application to the steel industry, and to industrial advances, and the consequent requirements thereof in recent years, we find ourselves in a new era in the forging world. And what once was required by engineers and others to be made in wrought iron, is now specified to be of mild steel, either Bessemer or Siemens Martin, as the case may be; and experience and the various tests go to prove conclusively that mild steel is much superior to ordinary wrought iron, for making forgings of any description; it is also, comparing equal sections in each case, stronger, and easier in many cases to manipulate. The reader will possibly have noticed that, since mild steel has been introduced and become better understood, and more generally used in making forgings, a marked increase has taken place in the number of large steam hammers at work. The writer has no doubt in his own mind that the impetus given to the hammer trade was partly owing to the peculiarities of mild steel, and partly through heavy forgings made of this material being in demand.

Some qualities of mild steel are bad to weld or shut; the difficulty being to get sufficient heat to weld, and, at the same time, to obviate the fire cracks; now this was not the case with wrought iron, which material would always weld splendidly, and this admirable feature in wrought iron enabled large forgings to be made in parts or pieces, and welded or shut together, after which the whole job would be sound, and equally as satisfactory as if it had been made out of one piece.

Of course, when speaking of mild steel, we must understand the ordinary qualities are referred to: there are higher priced qualities that will weld and shut equal to wrought iron, but the slight increase in price prohibits its use for general work.

The difficulty in welding mild steel and obviating fire cracks, together with the demand for forgings made of this material, has proved that "necessity" is indeed the "mother of invention." The smith, finding that he had no alternative but to make certain forgings in mild steel, and knowing full well that he could not always rely on a weld, in this material, had to set his wits to work, and devise some means of obviating either the weld or the fire cracks; and he found that, while he could not escape the risk of fire cracks in the weld, he could shun the same, by forging the article in one piece, which is now the rule, with regard to making mild steel forgings; and these remarks apply to large forgings as well as small ones; and engineers have had to meet the circumstances of the case with heavier hammers.

It must not be inferred from the foregoing remarks regarding shutting or welding, that mild steel cannot be welded, for, with a little care, most mild steel will weld, some of it equal to iron.

In order that a smith may obtain the best results, both in forging and hardening, it is essential that he should possess some knowledge of the material he is working; and to help him in this respect, if he does not already possess such knowledge, the few following remarks on the manufacture and testing of iron and steel, may probably be found useful and interesting, for the more he knows, the more likely he is to be able to deal correctly with the same.

Iron is obtained in the first place in the form of ore, or ironstone as it is called, which is melted in a blast furnace, by charging the same with ore along with fuel, limestone, and other purifying substances; a very powerful hot air blast is then forced through the whole mass by means of tuyeres set at certain distances round the furnace, the blast being first passed through large iron pipes, arranged in ovens for heating the air, which is obtained by powerful cylindrical pumps coupled direct to the engines.

When the iron is melted sufficiently, which is ascertained by practice, experience and timing, and by looking through the small mica sight-holes for the purpose, the furnace is tapped first at the side above the level of the molten iron, so that the slag may be run into inverted conical shape holes, having a stout bar reared up in the centre, around which the slag sets, when it can be readily removed by hooking a crane chain round the bar and lifting into an iron truck or tip wagon provided specially for the purpose, or it is run direct into cast iron trucks on wheels.

When the slag has been all run off, the furnace is tapped at the front near to the sand or pig beds, which have been prepared beforehand, and the molten metal as it runs from the furnace is directed along gulleys or channels in the sand to this pig bed, forming itself into the pigs of iron common to the foundry and forge.

As soon as the iron has become solidified, and partly cooled, the pigs are broken into convenient lengths, which is readily done while the iron is at a red heat, and as soon as it is cool enough to handle with a leather guard on the hand, it is loaded up, and a stream of water from a hose pipe turned on to the bed to cool it in order to prepare the moulds for another cast. There are other pig beds near by, prepared ready to receive the molten iron, and the next one or two heats are directed to these other pig beds, so that those just used may, in the meantime, be re-prepared for further use.

The pig iron at this stage is now taken to what is called the puddling furnace for a further boiling and purifying process, and while in the puddling furnace it is converted into balls of pasty or malleable iron. These balls are taken to one of the forge hammers, and subjected to a thorough good hammering to rid it of any slag it may yet contain and make and shape the ball ready to pass through the rolls, through which it is passed several times, being rolled into various widths and thicknesses to suit the bar or plate mills.

The puddled bar is then cut into lengths, and placed one on the other, as in Fig. 63, into what are termed piles, each of which contains a certain required weight, and these piles, after being raised to a welding heat, are passed through a number of gaps in the mill rolls, for bars, each succeeding gap being smaller than the preceding one, the result being that each time the bar is passed through the rolls, it is so much less in width, depth, or diameter, so much nearer to the finished size and

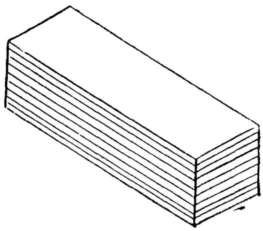


FIG. 63.

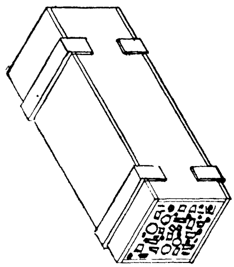


FIG. 64.

shape of bar required, be it round, square, or flat, as the case may be.

If the piles are intended for plates or sheets, then they are passed through the plain rolls, being reduced in thickness, and extended in length or width by passing through lengthways or sideways until the required size is reached.

When bar iron is made in the way described above, the material produced is what is termed in the trade "common bars."

In the production of better class iron, the common or first piles are rolled into flat bars, as just explained, then cut into lengths as before, and re-piled one on the other, re-heated and rolled out again in the same way as described before, each successive piling, heating, and rolling producing a superior class of iron.

Best bars or plates made from scrap iron are produced as follows: four flat bars, of good quality, are placed together as in Fig. 64, forming a box, and are held together by pieces of scrap hoop iron being bent round them; the inside of these wrought iron boxes are made up with the wrought scrap iron, and the whole put into a furnace and raised to a welding heat. The box can then be turned over and moved about without any fear of it falling to pieces. When it has reached a suitable heat for welding, it is taken to a steam hammer and pounded thoroughly to force out the dross and dirt, after which and at the same heat it is rolled into flat bars; these bars are again cut up, piled, heated and rolled into bars or plates as required, and they are then undoubtedly a very superior quality iron. This special quality is branded and sold by some of the makers as the "best scrap." It follows, then, that the more iron is worked in a proper way, the better does the quality become.

Steel for making general forging is made in two ways, known as the Siemens and Bessemer processes. In making Siemens mild steel a charge of pig and scrap iron is placed in a gas furnace where it is melted and converted ready for running into ingot moulds. The moulds are arranged in a pit running between a line of rails, and on these rails a large ladle fixed on a carriage is moved to and fro over the whole line of moulds.

The ladle, which is capable of containing the whole of the charge from the furnace at one time, which will vary according to circumstances from 25 to 50 tons, is lined with gannister, and has a tapping arrangement at the bottom, through which the steel is run into the ingot moulds. The whole of the steel in the furnace is run off into this large ladle at one time, to allow the furnace being fettled and recharged, and to enable the men to cast or run the molten steel into one mould or another, until the whole has been cast.

The ingot moulds vary in size to form ingots from 5 cwt. to 7 tons, to suit orders on hand in the rolling mills and forges and are made square, oblong, hexagonal, etc., whichever is most convenient for the subsequent processes. Fig. 65A illustrates the oblong mould, which shape is mostly used, and the reader will see from the illustration, that they have a very decided taper in them to facilitate stripping the mould from the ingot. Of course, ingot moulds used for producing ship's armour plates, are very much larger indeed than those we have just referred to. They are made to contain anything up to 80 or 100 tons of steel,

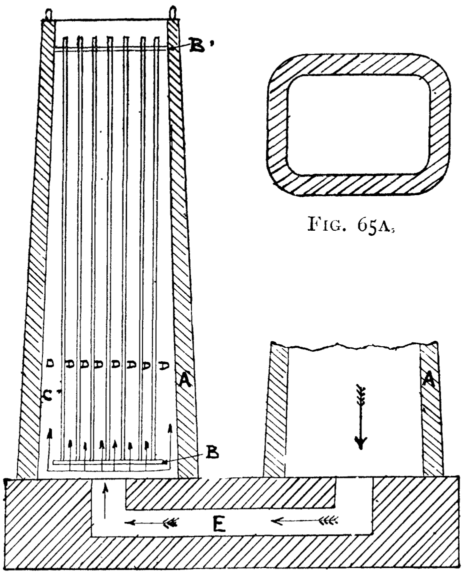


FIG. 65A.

FIG. 65.

and are shaped more like a slab. In the Bessemer process the charge is first melted in a cupola, and then transferred to the converter; but in some of the larger works, it is run direct from the blast furnaces into the converter, and while it is there a strong blast is forced through the molten metal, which in the case of an 8-ton charge, occupies from eighteen to twenty minutes. This being done, it is run into a ladle, as described in the case of the Siemens process, and from the ladle it is tapped into the moulds, or, as is the case in some works, it is run direct from the converter into the moulds.

When the ingots have cooled somewhat, and the steel is set, they are taken to the soaking pits or furnaces, and then passed on to the heavy rolls, where they are made into blooms, slabs,

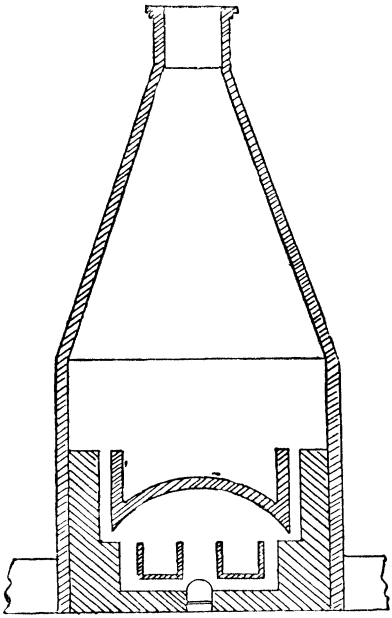


FIG. 66.

and billets, and are afterwards cut up into suitable lengths and weights for the smaller mills, and for the smith's and forger's use.

Blister Steel is so called because of the blisters on the surface, produced in the manufacture. It is made by what is called the cementation or carbonising process, which method was the earliest way of making steel.

The furnace used for this purpose, is a large brick structure with an oblong base, and conical top, as in Fig. 66. Two fire-brick pots are arranged inside about 3 feet deep and 3 feet wide, and from 10 to 15 feet long. The fire grate is in the middle, and extends from end to end. The flues are arranged to keep the temperature around the pots as even as possible. The iron bars are laid in the pots sandwiched between layers of charcoal; that is to say, a layer of charcoal is placed in the pots, then a layer of bars, then another layer of charcoal, then bars again, and so on until the pots are full, when the top is covered over with a layer of mud, or wheelswarf out of the grindstone pits, which when heated forms an air-tight covering, and keeps the flame off the bars and the charcoal.

When the charging has been completed, the fires are made up, and the charge is raised to a white heat, which occupies about forty-eight hours; the iron then begins to absorb the carbon out of the charcoal, and continues doing so, until converted into steel, taking from seven to nine days.

There are various tempers of steel made in this way, some of which are as follows.

Spring Temper.—This is the mildest form of all, with a core of unconverted iron in the centre.

Shear and Double Shear are the medium tempers, and what is termed the **melting temper,** is the hardest of all. Those bars that are converted into the melting temper, are steel right through the bar from one side to the other; this temper is very much used in making cast steel. The bars that are intended for making springs, are broken into suitable lengths, and heated to a light welding heat in a hollow coke fire, or furnace, and rolled to the section required.

For making high class springs, such as are used for watches and clocks, the blister steel is passed through the crucible cast steel process, to make the temper uniform throughout the whole spring. This uniformity of temper is not always secured by the cementation and forging processes, but it will be easily understood how necessary, and how essential this evenness of temper is in the case of springs for clocks and watches, if they are to be reliable.

Spring steel is also manufactured by both the Siemens and the Bessemer processes, and for all ordinary and general purposes, this quality is most used, it being the cheapest; but when there has to be any welding attending the manufacture of the spring, then the blister steel or converted bars are the easiest to work and most reliable; the cost of production, unfortunately, makes the price of this quality of steel rather high, which, no doubt, is the reason why it is so seldom used.

Some of the Siemens and Bessemer spring steel can be welded, but it should be specified as "welding spring steel" when ordering, as the proportion of welding spring steel produced by these processes is rather low; and the bulk of it cannot be welded so satisfactorily as to be of any service, and even the welding quality must be treated with great care, as once it is overheated it is of no more use as a spring.

Shear steel temper, when it leaves the converting furnace, is also broken into lengths, and heated again as in the case of spring steel; but in most instances this quality is hammered instead of being rolled, as the majority of users of shear steel contend that hammering improves the quality much more than does the rolling. Double shear steel is the latter quality, bent or doubled on to itself again, then reheated to a welding heat, and hammered. Sometimes this is done by piling several pieces, as in the manufacture of iron.

Cast Steel is a term which used to be understood to mean steel made by the crucible process, but the term has become very misleading and very indefinite, since all steel, except the converted bar, was cast; and manufacturers of cast steel proper, when quoting, contracting, or advertising, have been obliged to add the word "crucible" when describing the quality of their steel. They have had to do this to protect their interests, therefore what was formerly known as "cast steel" is now termed "crucible cast steel"; so called, because it is made by melting the ingredients in fireclay, or plumbago, pots or crucibles, in coke or gas furnaces.

These pots, or crucibles as they are called, are shaped as in

Fig. 67. They are made from mixtures of clays or plumbago most suitable for resisting the great heat to which they are subjected. The clay is mixed with a small percentage of fine coke-dust, and old crucibles or pots ground up very fine; the whole is well mixed together and moistened with water, and then thoroughly worked up. The pot-maker does the working up by treading it for several hours with his bare feet, after which he takes the clay and weighs it up very carefully, so much to a pot; and after working it again by hand on a bench he shapes it by placing the lump in a mould. A plug is then forced into the mould.

The plug and the flask are shaped as in Fig. 68, and are

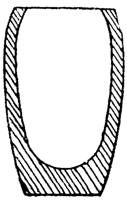


FIG. 67.

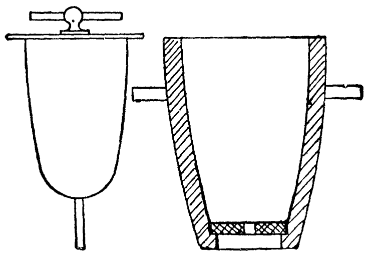


FIG. 68.

made of cast iron. The inside of the flask is scoured out and made quite smooth, and the plug is turned to shape usually to template supplied by the pot-maker. After the plug has been well forced home, and the clay pushed into the space forming the crucible, that is, between the sides of the plug and the inside of the flask, it is withdrawn by an upward and twisting movement; the flask with the clay crucible inside, is then lifted over a stake fixed in the ground; the loose bottom is placed carefully on the stake, and the mould or flash is steadily lowered on to the ground, when it will be quite clear of the new pot or crucible just formed, and left standing on the loose bottom on the stake.

The top of the pot is now closed in by pressing on a tin shape; it is then placed on a shelf in the pot-house, and left there with others to dry for two or three days, after which they are moved to the shelves against the flue in the melting-house, where they undergo still further drying for from twelve to fourteen days. In some of the large works they have special drying chambers for this purpose, heated with a hot draught, and these firms are able to get their pots ready for use in much less time.

The night previous to the pots being used, they are taken with the stands and cover, and placed in a slow-burning coke fire in the annealing grate, and next morning, after the fires have been made ready in the furnaces, or melting holes as they are called, the stands are placed on the fire bars, and the pots placed on the stands. A handful of dry sand and fireclay is thrown into each pot, which, when heated, acts as a flux and fastens the pot and stand together. The cover is put on, and the fires are now made up with coke to the top of the pot, and allowed to burn slowly for about half an hour; then a charge of Blister steel broken into small pieces, or best Swedish bar iron cut into small bits, are put into the pots through a sheet iron funnel held over the pots to convey or guide the pieces into the same.

When the man in charge is sure that the steel is ready to pour, the fires are poked down and the pots are lifted out of the furnaces by one of the men, with a pair of tongs, made specially for the purpose, with long bits shaped to fit the crucible. The teamer takes hold of the pot with another pair of tongs, and, the cover being removed, he pours or teams the molten steel into a cast iron mould, made in halves, and fastened together with rings and wedges, taking care not to splash the steel about in the mould, and when teaming to keep a continuous stream of metal running in until the mould is full.

The next process is to re-heat the ingot, and have it hammered or rolled into the size and section required.

For large ingots, the contents of a number of pots are poured into the one mould.

In some cases, mechanical appliances, "hoists and cranes," are used for drawing the pots from the furnaces.

Crucible cast steel is mostly used in making the best springs, and various kinds of tools; the different tempers necessary for these several purposes being made in the following order, from the mildest to the hardest: springs, chisels, sates, snaps, shear blades, drills, turning and slotting tools, and the special high speed and self hard steels.

Some steel users have tried having a different temper for each kind of tool, but experience has proved that a large amount of confusion and waste is caused by this; the best rule for engineers to follow is to stock only three, or at the most, four tempers, viz. the high speed or self hard, ordinary turning tool, drill, and the sate tempers, and with these four different degrees in temper, an intelligent smith can make one or other of the different classes of steel, do all that is required of them, that is, of course, by hardening and tempering to suit, in which case certain tools would be made of a standard temper, and the smith would always know how to treat the same. For example, the self hard would be plainly marked to distinguish it from the turning tool temper, so that all turning, planing, and slotting tools not so marked, would be treated accordingly; drills, boring bits, rose bits, taps, etc., might all be made out of the drill temper; chisels, sates, smiths' top tools, punches, shear blades, dies, etc., may very well be made out of sate temper. By some such system as the above many firms would effect a great saving in time and material.

Swedish Bessemer Steel is often substituted for crucible cast steel; some of it is really very good, but taken all round, it is inferior to the crucible steel. It is, however, quite good enough for making articles like road wedges, crowbars, miners' drills, bushes, smiths' swages and set hammers, drifts, stamp blocks, and a large number of similar articles; but in the case of cutting tools, such as drills, turning tools, sates, chisels, dies and punches, and the best shear blades, crucible cast steel is undoubtedly the better. In such articles as these, the extra cost incurred by making them of crucible cast steel is more than repaid by the increased length of service of the tool.

Iron Fibred Steel, or **Compound Iron and Steel,** known among engineers as "compo," is made by placing bars of iron in the ingot moulds. These bars are fixed in perforated plates, one of which is placed at the top, and the other at the bottom of the mould, and are in this way held in correct positions, while the molten steel is being run in at the bottom end by arranging it to fill from another open mould through a hollow fire brick, as shown in Fig. 65; by way of explanation, it should be said, that the bottom perforated plate has as much of the corners sheared off as can be spared, also some pieces taken out of the sides, and as many $\frac{3}{4}$-inch round holes as possible punched in the plate between the square holes to make way for the steel to rise, in the mould, about and around the bars.

A are ingot moulds placed side by side; B B the perforated plates; C the iron bars fixed in the plates; D the spaces between the iron bars, which are filled with molten metal; E the hollow fire-brick; the small arrows represent the molten steel, and indicate how it passes from one mould to the other.

The iron bars are placed in the mould cold, and the molten steel, as it flows around them in the ingot mould, heats them up, and they are soon merged into one solid homogeneous mass. It has been worked out to such a nicety that from forty to fifty wrought iron bars, $1\frac{1}{8}$-inch square, can be embodied in an ingot about 16 inches square, and this again can be rolled into wire. Rods rolled out of this material, $\frac{3}{8}$-inch diameter, have been cut through, and the ends faced and made smooth, and by the application of a little acid to cause corrosion, and enable the eye to determine which part is iron and which is steel, the bars of iron have been counted, and the number of strands prove that the compo has been well cast, and that the subsequent working has not disturbed the relation of one metal to the other.

This compo is a good substitute for the highest qualities of iron, and is an excellent material for making articles that require to resist great strains, such as crane hooks, shackles, etc.

Another kind of compo is hard and soft steel, combined in the same way; hard steel bars are placed in the mould, and soft steel is run in among the hard steel bars, as in the case of the other compo; these ingots are re-heated, and chiefly rolled into plates for making safes, and when rolled into bars will make good crowbars and reins for tongs when proper care is taken with the shutting.

The reason for using the above class of plates in the manufacture of safes is, that when the plates are hardened, no drill can penetrate through the hard steel, and the bars are so placed in the ingot that they overlap one another, and the soft steel toughens and binds them together, so that they cannot be broken with hammers, and this method gives a material which is most awkward for the burglar to deal with.

Then we have the **self hard** and the **high speed tool steels**, made by the crucible process, with the addition of tungsten, chrome, molybdenum and vanadium, all expensive materials.

In manufacturing this special steel, the makers are competing one with another, and each firm is trying to make a better steel than its neighbour, some in one way, some in another, for the matter even yet is only in the experimental stage; but all that skill and science can do or devise, or that the human mind can conceive, is being brought to bear on this very interesting subject; and every effort is being made to reduce to a minimum the question of risks and uncertainties in manufacture, as is evident from the fact that we find such delicate registering instruments as the pyrometer being used for indicating the heat during the manufacture, instead of trusting or leaving anything to chance as in the old system; and blacksmiths will be well advised if they will strictly adhere to the instructions supplied to them by the makers of any special steel they may be working on, and that too, as faithfully as it is possible to do, knowing that the manufacturers have been to great trouble and expense to find out the best treatment for each of their different qualities; and his own employer, having shared in the expense of the manufacture, by the high price he has paid for the material, will be at a loss, if the tool is spoiled by not being treated in a proper manner, to enable it to do all that is expected of it.

There is one great advantage from the smith's point of view with most of these special steels (not all): they are easier to work than the old self hard and ordinary turning tool steels

CHAPTER V.

TESTING.

THE necessity for testing samples of each cast of steel is admitted by all makers. The tests applied by them are usually very severe and searching; and though they know exactly what each charge put into the furnace consists of, yet they cannot feel satisfied, until they have tested the output thereof by analysing samples of the steel, with a view to satisfying themselves that the conditions of the melting process are what they should be, and to make sure that all injurious ingredients have been eliminated, during the same, and also with a view to deciding the nature of, and the best purpose for which each particular cast can be used.

It is the duty of the chemist to see to the analysing, and his report as to the various percentages of different ingredients found in each sample of manufactured material, is taken as a guide in deciding the best purpose that the steel can be used for; but besides searching into and examining the contents of the material itself, its very nature is also inquired into, examined, and tested most minutely, and this part of the business is divided between the testing house and the practical smith.

Samples of mild steel are prepared and shaped something like the sketch marked A in Fig. 69, the centre part of which is reduced in area to come within the scope of the testing machine, and is usually made to a standard size to facilitate and simplify calculations.

The usual test applied by manufacturers, is that called the "tensile test," i.e. the act of trying the amount of tension, or, the amount of stretching, which is the same thing, that the piece will stand before breaking, and the weight it will carry before commencing to stretch. This is done by fixing the ends of the test pieces in the machine, and allowing the same to drag or pull the bar, until it parts or breaks under the strain. Very careful measurements are taken at different stages of the testing, with regard to the length, só that the amount of weight the material will carry without stretching, may be ascertained, and when the substance comes apart, the breaking strain or weight is known, being registered by the machine, and the elongation or elasticity is also known; the appearance of the fracture is also carefully examined, and all particulars noted, for reference whenever required. After the bar has been tested in this way, and taken out of the machine, it is in shape similar to illustration B in Fig. 70.

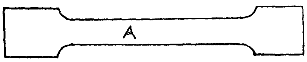


FIG. 69.

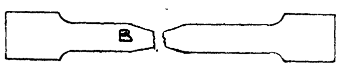


FIG. 70.

Test pieces are cut from plates, and machined on the centre part, for the same reason that bars are reduced in the centre, as already pointed out, viz. to bring them within the scope of the machine. The machining serves another purpose also, namely the removing of any rough places that may exist and be likely to start a fracture. The testing is then performed in the same way as in the case of bars.

Bend Tests are made in the testing house in the interest of the manufacturer; but these tests are also made by the smith in the interests of his master, and as they will come up again for consideration later on, we can deal with them then.

Now the object of all this testing and proving is obvious to the practical and experienced mind; but to the uninitiated the case is different. It will probably appear to them very much in the light of a fad, and if they had seen sufficient of the business to know what large sums of money are spent on laboratory appliances, testing house machinery, and in wages to testing house officials and chemists, no doubt they would say it was a very expensive fad also; but there is another side to the question: the manufacturers, when they come to dispose of their steel, have to say what sort of steel it is, and what it will do. They have virtually to make certain guarantees that it is suitable for this, that, and the other purpose; that it will be capable of resisting certain pressures, tests, strains, and so forth, and the purchaser expects to have ample satisfaction that such is the case. And before he expends any money in making the steel up into forgings, boilers, or whatever he is about to use it for, he instructs his responsible smith to make a certain number of tests selected at random from the steel supplied, and test the same in the way described hereafter, and on the result of these tests, depends the question of returning or retaining the material in question. If it stands the tests, he will keep it: if not he will return it as unsuitable, and the manufacturer will have it on his hands, and may have to bear the expenses attending loading, unloading, and carriage. If the would-be purchaser happens to have a penalty clause in the contract for the work for which the material was intended, and he is prevented from finishing in time owing to the delay in the delivery of suitable material, the steelmaker may then also find himself saddled with at least a portion of the penalty, if not all. Of course, the wording of the contract with the manufacturer would have a lot to do with deciding the question for the liability of penalty; but whether or not, very much unpleasantness and annoyance would arise in any case, which is always much to be regretted, and the material would have to be replaced after all. It will, therefore, be seen from this how important it is that steel makers should know every possible peculiarity about their steel—what it will be most suitable for doing, what it will stand, and all about it, so that they will not only be able to answer all questions regarding it, but also that they may know when they can best place it with a customer without any likelihood of its being returned on their hands, and being a burden to them in the way of carriage and other risks

On the other hand steel users, who make the same into forgings, to stand Admiralty and other tests, for high pressure engines and boilers for ships of war, and ships for the passenger and merchant service, and who use it in the construction of bridges and a host of other things, require to satisfy themselves, and make doubly sure that the material they are buying is really A1 quality and suitable in every way and every particular for the special part it has to play, so that they can feel and know from the start that they are secured against any risk of the work they have in hand being declined when delivery is tendered, because of inferior material being used.

In the case of contracts for steel for use in His Majesty's workshops, the Government always send inspectors from the particular departments to see the steel tested at the makers' works, and the same course is now followed by other large users of both iron and steel.

The inspector has full power to reject the whole or part of any consignment, if it does not come up to the standard laid down in the specifications, and on the other hand, if he accepts or passes any consignment as being satisfactory, he takes the whole responsibility upon himself, and the firm or department that he represents have then no claim on the manufacturer.

We will now consider the various tests as performed by the smith.

Bending Tests.—There are many rules relating to the radius of the bend for this particular test, some of which are much more trying than others, but if the steel will close in to three times the thickness of the bar itself, as in Fig. 71, without any sign of fracture, it may be considered good enough for any ordinary purpose, but much of the true mild steel will go even closer than that, and in the thin sections will close right up without fracturing.

It must be understood that all these bend tests are made cold.

In order to carry out the above test in a shop where there is no hydraulic or other special press or machine available, the best way to proceed is to lay the piece across a large swage, as in Fig. 72, under the steam hammer, and bend as far as possible with a large fuller or knobbler, as the hammer fullers are generally termed; after this, take hold of the test piece with a pair of pliers or bow tongs, and complete by holding up on end under the hammer. This is a trying operation to a new beginner, but if he is not nervous, he will find it easily enough performed, with the aid of a reliable hammer driver; if he is nervous, and fails to hold the piece still, and the top end directly over the bottom one in the centre of the pallet, then, instead of the test piece taking the full fôrce of the blow, it will be driven from under the tup, and it is here where the danger lies; but let the beginner bear the following instructions in

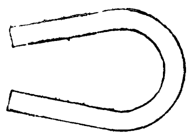


FIG. 71.

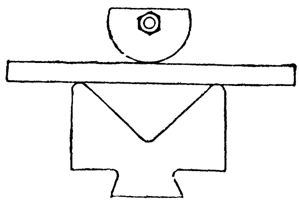


FIG. 72.

mind, when he is engaged on this class of work, and he will take no hurt. Keep your fingers from between the reins of the tongs or pliers, always grasp them with your hands right round both of the reins, then if the tongs are twisted round by the blow, they will slip or turn round in your hands, without injuring you; never use tongs for this particular purpose, unless you can hold them in the way just described.

Tempered Bend Tests.—Sometimes when steel is ordered for special work, the specification requires that it shall stand the preceding test, i.e. "the bend test," after it has been heated and cooled in water, to show that there is nothing in the composition of the steel objectionable for the particular work it is for, and to prove that it is perfectly mild and will not harden. This is called the "tempered bend test."

The Rivet Test.—This test is resorted to in order to prove that certain steel will rivet easily and perfectly without splitting. This test is performed by simply placing a trial piece in a bore on a hard steel stop and hammering or riveting it down while cold to the shape of a rivet; the head is made to overlap a lot more than is expected, or would be necessary, in an ordinary rivet, for the reason that this is simply and purely a testing operation.

Compression Test.—This is another test serving a similar purpose to the previous one, and is made to show that the steel is not seamy. It is done by simply crushing a piece of steel down under the steam hammer to one-half its original length while cold, see Fig. 73.

Testing Steel Angles and Tees.—There are several ways of testing steel angles, etc., one of which is to crush the

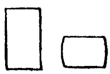


FIG. 73.

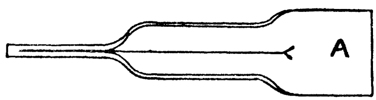


FIG. 74.

two flanges together at one end of the test bar and open them out at the other end of the bar, see Fig. 74. Another way is to flatten the flanges outwards as at A or close them both together as at B, but flattened or closed, as the case may be, for the whole length of the piece; it is then doubled over as in the bend test, see Figs. 75 and 76. *Note.*—This is all done cold, and good steel angles will not break.

Tees are treated in exactly the same way.

Plate Bending Tests.—The Book Test. The plates for the tests up to ½ inch thick are usually supplied to the smith in square pieces, and he is expected to fold them over one way, and afterwards to fold the doubled portion over again in the opposite direction, see Fig. 77, and by doing so, testing both ways in the one piece. This is known as the book test.

In the case of thicker plates, it is usual to cut one test piece from the end, and one from the side of the same plate, and subject them to the ordinary or tempered bend tests.

Sometimes rough edges on the test pieces will give a start to a fracture before the testing is finished, and once a fracture is started, in the case of steel, it is a difficult job to check it, and for this reason some firms machine the edges of their plate test pieces before they are proved.


FIG. 75.


FIG. 76.

Drifting tests are applied to plates and flat bars in the following way. Certain holes are punched or drilled in the same, and then the holes are increased by drifting, while cold, to twice and even three times the size of the hole as at first punched or drilled.

This test is common in the case of boiler plates, to demonstrate the tenacity of the steel, and prove that it is not likely to give way in the seams when made into boilers and subjected to heavy pressure.

Welding Tests.—This particular test is usually entrusted to one of the most experienced and competent smiths in the shop, for the reason that if the welding when tested should turn out to be indifferent, the master can feel assured that the steel will be of no use to him; since, if the best smith in his shop cannot weld it satisfactorily, none of the others can reasonably expect to succeed; whereas, if the test had been given to a smith with less experience, and the result was not satisfactory, he could not then naturally feel so sure that the indifferent welding was through some fault in the steel.

Now, suppose we want to make an ordinary weld with two pieces of say 2 inches by $\frac{1}{2}$ inch. In the old way, in the case of iron, we should upset the two pieces, scarf out the ends to a thin wedge shape, then raise the ends to a welding heat, place the scarfed portions one on the other as in Fig. 78, and hammer the two together until they were thoroughly merged into one and the same piece. In the case of iron this makes a perfect weld, the best that can be made, and sometimes in the case of steel; it will also make a good weld, but the best and safest way to weld steel is to upset the ends just where the end of the other piece will come, and, omitting the scarfing, raise both ends to a welding heat as before, then place them one on the other, as in Fig. 79, and hammer them well together, then take another turn at the fire and raise to a welding heat a second time, and finish by hammering smartly, until the two pieces are thoroughly welded together.

By upsetting the ends and placing them one on the other as shown in Fig. 79, the reader will see that the smith has more material to work on than he would have had if the two ends had been scarfed as shown in Fig. 78, thus affording a better chance of making a good weld; and, besides, when put together in this way, they do not slip one off the other when the first two or three blows are struck, as is so often the case with

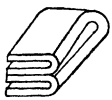


FIG. 77.

FIG. 78.

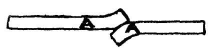


FIG. 79.

steel that has been scarfed; when this sort of thing does happen the result invariably is an imperfect weld.

It is the contention of most smiths that are experienced in working steel, and who have been in the steel trade, that the second heat on a steel shut does far more good than the first, and in the opinion of the writer, who has had a large experience in this particular line, all steel shuts should have a second welding heat on them. There is very little time taken up if the weld is returned to the fire quickly—in fact, it will often prove a gain rather than otherwise, because the part will in many instances be made to size and shape quicker and easier with the extra heat.

When the weld has been made, the test piece is bent over as in the bend tests already described, Fig. 71. In some cases these test pieces are bent hot, and in others they are tried after the piece has cooled down, and it is a curious fact that those that are bent when cold often give the best results. Welded test bars are often bent when cold, without showing any sign of fracture or fire cracks, and this should always be the case with the best quality of welding steel when tested by a competent smith.

Link Test.—To make a link test, assuming that the steel is supplied to the smith in a large bar, that is referring to the thickness or diameter: Hammer or forge a piece of the bar down to about $1\frac{1}{4}$ inch by $\frac{1}{4}$ inch, by about 9 inches long, cut off and bend the same, U-shape, heat the ends and scarf out with a fuller and close the link together, see Fig. 80; "scarfing in a case like this is recommended, because, when closed together for welding, it is much the same as two pieces rough welded together, no dirt can get between the surfaces to be welded, and the link is one of the easiest forms of weld to make without overheating, seeing that the part to be welded goes furthest into the fire." Now reheat and weld on the beak of the anvil, and when cool, place it on end on the anvil, or under the steam hammer, and gently crush the welded end down close to the other end, see Fig. 81, or, if a more severe test is desired, cool in warm or chilled water as soon as welded, and crush as before.

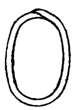


FIG. 80.

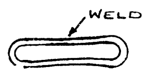


FIG. 81.

Tube Tests.—These tests are made from a plate, say 10 inches square, with the thickness varying from $\frac{1}{8}$ inch to $\frac{3}{8}$ inch or $\frac{1}{2}$ inch. In the case of $\frac{1}{8}$-inch and $\frac{1}{4}$-inch plates, it is the best to scarf both ends; but when using the stouter plates, it will be best only to scarf the inside end, for this reason, the thinner plates are more easily heated through to the inside scarf, and being so light, must be welded as quickly as possible before the welding heat has gone back; whereas the thick ones require to be longer on the fire before the inside scarf is hot enough to weld, and by leaving the outside end unscarfed it takes longer to heat, and tends to equalise the temperature, and at the same time gives more material to work on, which is an advantage when the heat can be kept up.

Tube tests when made with both ends scarfed should be welded with a swage on the outside on a suitable tool or block; but when welding the thicker plates, with only the inside end scarfed, then the sledge hammer is used instead of the swage, as it makes the best weld by thinning out the end and working the scarf well in at the same time, the swaging being done afterwards.

A tool for welding the tubes on is easily made by taking a piece of iron or mild steel about $2\frac{1}{2}$ inches diameter, and flattening out the end in a 3-inch swage; this is recommended.

FIG. 83.

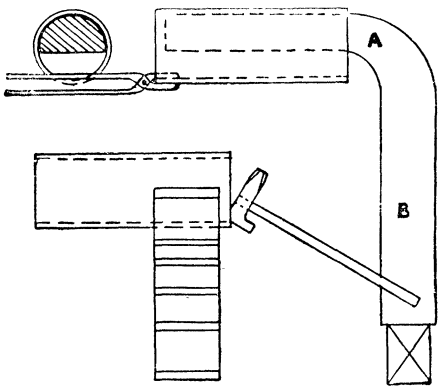


FIG. 82.

because it leaves plenty of room for the tongs at the under side, see Fig. 82; then bend over as at A and make the bottom to fit some suitable block, which may be used on the stand; but for this purpose it is better set on the floor, the length of the tool stem B being made to suit.

The best way to obtain the welding heat is to lay the tube on a clear fire, and place a piece of fire-brick inside the tube to cover up the part to be welded, thus keeping away the cold air and drawing the heat through; put about a good shovelful of coke up to the sides of the tube and apply the blast with a medium pressure, and as the fire burns away feed it by raking or poking down some of the coke lying up the sides of the tube; do not let the fire burn hollow. The progress of the heat can be easily ascertained by lifting up or pushing to one side the fire-brick inside the tube, and as soon as it is turning from a white heat to a greasy appearance, sprinkle a little clean sand inside; this forms a slag, which is fusible, and will assist the welding; experience only can satisfactorily instruct the reader as to the proper moment to bring the heat off the fire; but as a rule the heat is ready directly after the sand runs freely.

The tube is generally heated and flanged at one end by holding in a swage, and working out with a ball-faced hammer or large fuller, see Fig. 83.

The tubes are sometimes crushed, instead of being flanged, after the welding has been done; and at others they are crushed as well as flanged, to see if there are any fire cracks still un-

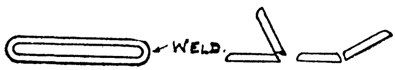


FIG. 84. FIG. 85. FIG. 86.

detected. The tube should be crushed for testing with the weld at one side, see Fig. 84.

Of course it does not follow in every instance that, because fire cracks appear in steel that has been welded, therefore it is the fault of the steel; it may be that the steel has been too hot, or as the smith would term it, burnt, and until the smith has had a fair experience with steel welding, it is just as well for his principal not to be too hasty in condemning the material.

The author, in the course of his experience, has known steel to be returned to his employer as not good for welding purposes; and in the course of his duties, he has put the materials thus returned to the most severe of all the tests just referred to, and proved that the steel was as good as it was possible to have it; and this has happened not once, twice, or thrice, but many times; and the only conclusion to be arrived at under the circumstances, is that the steel has been worked either by careless or incompetent smiths.

A coating of clean sand thrown on to the steel, or taken up by dipping or rolling the pieces in the sand, when it is turning from a white to a welding heat is a great help to a smith; the sand forms a slag which is fusible, and prevents cinder and dirt from adhering to the forging. The sand, when hot, is in a fluid state, and when the two pieces to be welded are placed together and struck with a hammer, the fluid sand is excluded immediately, leaving the faces clean, and so giving the best possible chance to make a good weld. Some smiths seem to hold the idea that the sand should not be allowed on the part to be welded; they try to work the sand round the sides and the back of the weld, as though they were using it solely to protect these parts from the action of the fire. This is a great mistake; the weld is assisted by being coated with sand, provided always that it is clean before the sand is applied.

Some smiths use a mixture of sand and borax, others borax and sal-ammoniac; there are also some patent compounds for the same purpose, some of which certainly make the steel weld better and easier; but it is rather amusing to read in the pamphlets issued by the proprietors of these patent compounds how, after extolling very loudly the virtues of their compounds, they wind up, after all, with some remark to the effect that much depends on the ingenuity of the smith.

The fact is that if the steel is what it should be, and the smith understands his task in all its bearings, he ought not to need anything more than the sand to make a good weld.

There are many other ways of testing steel, but those we have just described are most generally used, and are ample to prove satisfactorily the quality of mild steel.

Testing Wrought Iron.—This is another matter altogether to testing steel, owing to the different formation and composition of the material.

The common tests for iron are the bend and the fracture. There is no necessity to test iron for welding, because all iron is perfect in that respect. The bend tests are made in the same way as in the case of steel, except for the angles and plates. Angle iron should not be expected to close in or open out to the same extent as mild steel angles without splitting. It will give way at the root, as shown in Figs. 85 and 86, unless it is of very high quality indeed, and too high in price to be of any practical use; but the flanges, when separated, should double into a bend similar to an ordinary flat bar.

Iron plate should bend over one way almost equal to mild steel, but should not be expected to stand the same both ways, because there is the grain one way or the other; a piece off the side of the plate with the grain running lengthwise will bend over quite well, if the iron is good; but a piece off the same plate with the grain running across it will break sooner when put to the test. Manufacturers have endeavoured to get over this difficulty by having the plates crossed in the piling, or doubling, and when treated in this way they certainly make a good plate, but even then they will rarely stand the same test as mild steel.

The rivet test is sometimes used on iron, but no iron is expected to stand so much riveting as mild steel; it will split sooner.

The Fracture.—In testing iron the fracture test is mostly relied on, and this is a test that requires some experience, not so much to perform the breaking, as to judge the quality when done.

To make a fracture in a round bar, nick with a cold sate 2½ inches or 3 inches from the end, say for about one quarter of the circumference, and in the case of squares and flats, nick one side, then hold over the beak of the anvil, and let the striker give the end of the bar two or three light blows with his sledge hammer, increasing the force of the blow as required. If the iron is of a soft nature and low quality, it will break irregularly with a dark bluish appearance, intermixed with crystal particles, and but little fibre; if the iron is hard as well as low in quality, it will generally break off with a fracture of chiefly coarse crystals. The medium qualities when broken, give a fracture, fibrous or stringy, with a fine grey silky appearance, and rarely break right off the bar. The highest qualities generally break off short as mild steel, with a fracture very similar, close grained if there is any to be seen at all, and small fine crystals.

Fracturing iron can be made very misleading, because the appearance of the fracture depends somewhat on how it has been made. For instance, the fracture made by repeated and increasing force, will show much more fibrous results than the same bar fractured with a heavy and sudden concussion; then again, a bar that has not been well welded together in the making, will tear and open at the seams and cause the untrained operator to think that it is better than the same quality of iron which had been well welded.

The reader should bear these points in mind, and weigh them one against the other when testing iron.

CHAPTER VI.

GENERAL FORGING AND SMITHING.

In most shops there will be a number of jobs to be done in small lots that could be done to better advantage in other ways, if larger quantities could be put in hand at one time, to cover the cost of special tool and preparation; but as this cannot always be done, firms, like individuals, have to make a virtue of necessity, and do the best they can under the circumstances with the facilities at hand. A smith that understands his trade will often make use of his special tools for doing work, other than that for which they were specially made, as there are many forgings in which one part of the same may be identical with a part of some other article that he has been making in large quantities, and yet when each piece is viewed separately as a whole, they are quite different in shape.

We will now consider the general smith's work, by selecting certain articles, and describing some of the various ways by which they may be most profitably made; and we must each and all determine for ourselves as we proceed, which method, herein described, will be the best according to the tools we have at hand, and the licence we have for making others, and bearing in mind all the special circumstances with which we find ourselves surrounded; for, evidently, the process which would be the best in one shop, will not always be the best in another. The reader must use his own judgment in this matter, and he should easily be able to decide.

Bolts.—The reader will see that in the case of bolts, the first article selected for consideration, that it would not pay to set a smith to make ordinary bolts for stock. These articles can be made so quickly in the bolt-making machines, in large or small lots of stock sizes, that bolts in any quantity can be purchased much cheaper than they can be made by the smith. Yet it sometimes happens that a few are wanted in a hurry; the stock being run out, and the job being urgent, they cannot wait for delivery, the bolts being wanted there and then, or the sizes wanted are a special shape; then the smith may be asked to make them, and we shall assume that we are working under these conditions; and in order that a smith may make them, he will require what is called a "bore" to hold the shank of the bolt while he is working on the head, and the best shaped tool of this description is what is called an "Oliver Bore," fitted into a cast iron block, as shown in Fig. 87. The arrangement is a very simple and very effective one.

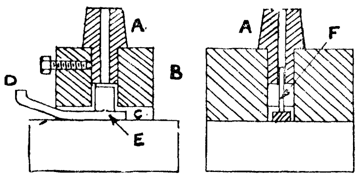


FIG. 87.

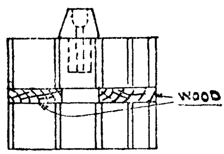


FIG. 88.

The "bore" A is packed tightly into the block B, or fastened with a strong set-screw as shown; a groove is cut into the block, as shown at C, or it may be packed up at each side, as at Fig. 88; a piece of iron or steel is laid underneath for the distance piece E to rest on, and this piece of iron bent as shown in sketch serves to drive out the bolt by striking the end D. If the bolt being made is required shorter in the shank than the bore, a steel peg F is dropped into the bore on to the lever D. or the piece E.

If the block B is not to hand, two ordinary swage-blocks can be made to answer the same purpose by placing one on the top of the other with two hard wood strips between them, as shown in Fig 88, and if the head is to be hexagonal, we shall want a nut swage, Fig. 89, to forge the heads, and a snap,

Fig. 90, to round or chamfer off the top edges or corners of the head.

We will say the instructions are to make six bolts, as shown n Fig. 91. The smith will most probably receive his instructions as follows: Make six bolts $\frac{3}{4}$ inch by 4 inches, hexagonal heads.

To begin with, take a bar of $\frac{3}{4}$-inch round iron, and cut off a piece $5\frac{1}{4}$ inches long, then cut a piece $\frac{1}{2}$ inch by $\frac{3}{8}$ inch off another bar of that section, long enough to bend and make a collar on the piece previously cut off the $\frac{3}{4}$-inch round bar, and place it $4\frac{1}{4}$ inches from the end of the bolt; this will cause the shank to thicken up under the head, while being worked in the bore, but it will make the most perfect weld. If the collar is put on at the exact distance from the end of the shank, it will have no material in it to compensate for the loss caused

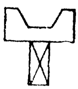


FIG. 89.

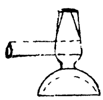


FIG. 90.

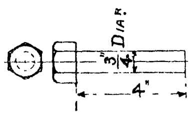


FIG. 91.

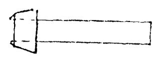


FIG. 92.

by scaling or oxidation set up by heating; the head must be welded on, consequently there is bound to be some loss of substance, which will vary according to the dexterity of the workman, the quality of the coke and the material, and if the collar is put on the shank in the way last described, then in that case, the weld under the head, if examined closely, will in all probability be found to be defective.

When the collar has been closed on the shank, it should be raised to a welding heat, and then worked in a nut swage, tapering the head, as shown in Fig. 92. Now put the shank in the bore and work on the top, being careful to bring the hammer straight down on to the head, or the portion of the shank projecting above the head; this must be done very carefully until the collar rests on the bore, or the head will be driven to one side, instead of being central with the shank as desired.

The piece of the shank that was projecting through the collar will now be spread over the top, making as it were a welded rivet, and by using a snap to round off the edges, and working the head in the nut swage and bore alternately, the bolt will soon be finished, and will be the best sample of welded bolt head that can be made by hand. Another way, and a very good one too, of making this same bolt, is to forge out the shank from a piece of $1\frac{1}{4}$-inch or $1\frac{3}{8}$-inch round iron or steel, and cut sufficient of the $1\frac{1}{4}$-inch or $1\frac{3}{8}$-inch off the bar to form and make the head; this done reheat and work up in nut swage and bore alternately as in the previous case. When the shank of the bolt is forged and cut to length, the peg in the bore may still be used, although it is not absolutely necessary, to control the length of the bolt and keep it right, as well as being a convenience for driving the bolt out of the bore each time.

When steel is used for making the bolt, the latter method of making it by hand is undoubtedly the best that can be given, and in some shops, and by some smiths, even when using iron, it would be preferred no doubt to the way described in the other cases, and it is far the best for short bolts and set-screws. Another way to proceed with the making of this bolt, when only a hand bore is to be used, would be to cut a piece of iron about $5\frac{1}{4}$ inches long off a $\frac{3}{4}$-inch bar, then make a collar out of $\frac{5}{8}$-inch by $\frac{3}{8}$-inch, or if that section is not to hand, take a piece of $\frac{1}{2}$-inch diameter and flatten same and make the collar, then heat the end of the $\frac{3}{4}$-inch iron, and upset the same into the collar, while cold. This will make the shank a little thicker just under the head, then it will fit tightly into the bore, and minimise the tendency to tear away again under the head while working in the bore; but if the shank is upset too much, and made too thick, then it will fasten in the bore too soon, and will drag or cut up a piece of the shank, as in Fig. 93, making an ugly looking scarf edge under the head, besides making the head too large, and perhaps the shank too short, so care should be taken to obviate swelling the shank too much. Now reheat and weld the collar on to the shank as before, but without tapering the head as in the first case.

Suppose now, that we have to make a few bolts $\frac{3}{4}$ inch diameter by 9 inches long or anything over that length, the best way to proceed is to weld a collar on the shank as in the case of the $\frac{3}{4}$ inch by 4 inch bolt that we have just dealt with, but this time without upsetting or swelling the shank, and instead of using a bore for working up the head, use a forked tool, as in Fig. 94, turning the bolt round in the fork of the tool while the top of the head is being hammered. The forked tool should be made so that the shank of the bolt will turn round in the fork quite easily; and when this tool is being used, it must be packed firmly and securely in the anvil or swage-block, as it will make all the difference to the quality of the workmanship put on the bolt, if this tool is not firmly and rigidly fixed while in use. We may repeat that the shank need not be upset previous to welding on the collar as in the case of the bolt we considered previously, because, since the head is being hammered on the top, whilst lying in the fork tool, it is thickening up the shank under the head. We must note here that a light hammer is the best for working against the top of the head, say one about $3\frac{1}{2}$ lb. weight. It is not generally known what a good bolt this will make, and there is no doubt that it is the quickest, the easiest, and the best way of making small lots of long bolts. It is much better than making short bolts and shutting to length.

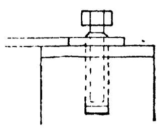


FIG. 93.

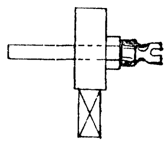


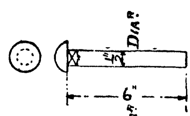
FIG. 94.

Fig. 95 represents a bolt $\frac{3}{4}$ inch by 4 inches, and would be described as having a square head and square neck. The method for this sort of bolt depends on the tools at hand. If, say, the smith has a bore that will take $\frac{3}{4}$ inch diameter with the top cut out for the square neck, then the best way will be to forge out of a piece of $1\frac{1}{8}$ inch or $1\frac{1}{4}$ inch square, or a piece of $\frac{3}{4}$ inch square may be rounded down, and a collar welded on to make the head; if the bore is square right through, the best way will be to weld the collar on first, and draw down the shank afterwards.

Fig. 96 represents a bolt $\frac{1}{2}$ inch by 6 inches with a square neck and a snap or cup head. This bolt is made by upsetting a piece of $\frac{1}{2}$-inch diameter iron, long enough for the purpose, in a bore with a recess at the top (see bore in Fig. 88); the recess being made large enough to hold sufficient iron to make the square and the head, in which the bar is first upset. It is then taken out, and placed in a finishing bore and snapped, the square neck being formed as it is driven into the finishing bore.

FIG 95.

FIG. 96.



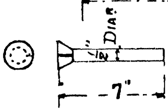


FIG. 97.

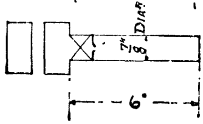


FIG. 98.

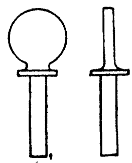


FIG. 99.

Fig. 97 represents a bolt $\frac{1}{2}$ inch by 7 inches, with countersunk head. The length in countersunk bolts is generally taken from the top of the head. This particular bolt has a "nib" up the side of the head to stop it from turning round while the nut is being screwed up. It is made by hammering a piece of $\frac{1}{2}$ inch diameter iron into a bore made to suit.

Fig. 98 illustrates a $\frac{7}{8}$ inch by 6 inches T-headed bolt, and is forged out of a bar about the right size for the head, worked up in a square-necked bore.

Fig. 99 illustrates a small wing or thumb-screw. To make these a pair of special dies or tools are required, to shape the iron, as in Fig. 100, the ball part being afterwards flattened out. When forging in the die a difficulty sometimes arises in this way: a bar the right size for the collar will hardly be large enough for the ball part, and a piece right for the ball would give too much for the collar. In this case an easy way out of the difficulty would be to use the smaller bar and turn the end of the bar up a little, as in Fig. 100, and work the bent end into the ball with a light welding heat.

Cotter holes in round bolts and bars, Fig. 101, should be punched first from one side in an ordinary swage, then turned over and punched in a swage or die with corresponding hole in the bottom for the burr to fall through, Fig. 102. Then a piece of steel the same size as the hole should be inserted and the

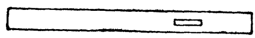


FIG. 101.

FIG. 102.

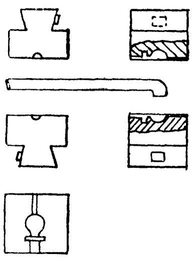


FIG. 100.

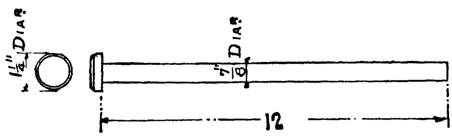


FIG. 103.

bolt or bar swaged round; then drive out the piece of steel with a drift, and let the drift be driven through to clear out the hole.

Sometimes bolts or pins have to be made with long shanks and small heads, the latter being scarcely large enough to weld on in the form of a collar. The best way to make these, when a quantity is required, is to raise the end to a good heat, and swell the same by dropping it on the anvil or hammering against the end; then round up in a pair of tools properly recessed to form the head, Fig. 103. The tools should be fitted to some bolt machine or light hammer while in use.

Strap or Palm Bolts. illustrated in Fig. 104.—These bolts are nearly always made by welding the round part on to the flat portion, in a tool shaped out for the purpose, see Fig. 105. There are, however, two ways of doing this, viz.: either to lay the flat portion in the above special tool, and while there to punch the same with what is called a bob-punch, see Fig. 36A, after which the end of the flat will be shaped as shown in Fig. 106, and then weld the round part into the hollow

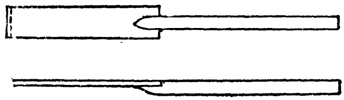


FIG. 104.

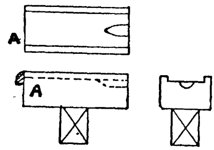


FIG. 105.

thus formed; or the round part can be welded on to the flat without any other preparation, except a little upsetting, which should be done in any case to allow for wastage in working, when a good finish is required.

For turning down the flat ends, the best and quickest way is to cut the ends to length, and bend the flat one in a tool slotted or milled to the right depth, as illustrated in Fig. 107, or the bending can be done in a horizontal forked tool, see Fig. 108;

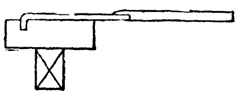


FIG. 106. FIG. 107.

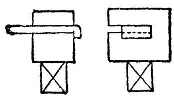


FIG. 108.

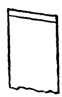


FIG. 109.

but if only small lots are required, bend over the edge of the anvil or the plain end of the welding tool A in Fig. 105 the upstanding sides of which will ensure the flat end of the bolt being square when bent, and not askew, as in Fig. 109.

Fig. 110 represents a strap bolt without the knuckle, one part being tapered into the other; when the round part is only required to be a moderate length, say 5 inches or 6 inches, it is generally forged out of the flat, but if there is to be a longer length of round, then it should be done by shutting the round and the flat together; to do this, first taper and narrow the flat part to about the size of the round, then scarf both pieces and shut together; make the bent ends as before.

Rag or Lewis Bolts, Fig. 111.—These bolts are used for setting in stone or concrete; they are forged out of a

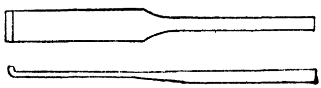


FIG. 110.

piece large enough for the head, which is left as rough as possible, and ragged down the corners, as shown in the illustration referred to, in order that the bolt may take a good hold of the lead or other fastening material.

Another and cheaper form of rag bolt is shown in Fig. 112; it is used for the same purpose as the one just referred

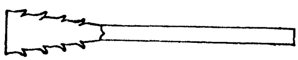


FIG. 111.

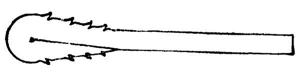


FIG. 112.

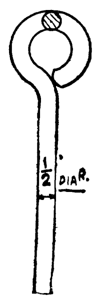


FIG. 113.

to; it is made by slightly tapering the end, bending over, and ragging as before.

Eye-Bolts.—Eye-bolts vary in shape considerably as will be seen from the illustrations shown.

Fig. 113 is the simplest form of all; it consists only of a piece of round iron bent to shape, in fact, it looks so simple as to be hardly worth noticing, but there it is, and while we would gladly pass on to more important and more interesting matters, we must not forget that we are catering for the learner as well as for others, and must, therefore, stoop to explain these minor matters as well as the more important ones.

To make an eye-bolt, as illustrated in Fig. 113, take a piece of ½-inch round iron or steel, and heat the same for about 4 inches up from one end, then place the piece of rod in a fork tool with rounded ends, as illustrated in Fig. 114; the dotted lines represent the first position of the bar; pull to the left with the hand, then bend the other end round the peg with the hand hammer or lever; the small round projection at the top of the

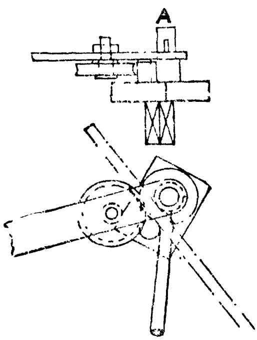


FIG. 114.

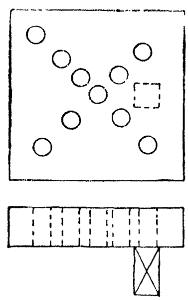


FIG. 115.

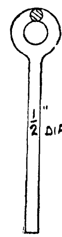
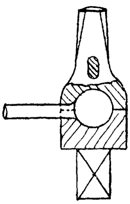


FIG. 116.

peg marked A, is intended to serve as a pivot for the lever to work on, when one is used. Fig. 114 shows the lever and roller in plan and elevation; it is, of course, not absolutely necessary to recess the roller or pulley for the head of the pin for this fork tool arrangement, but it would be the best to do this, then, when a block and pegs are used, as illustrated in Fig. 115, instead of a forked tool, which block can be made to bend any size by having a number of holes and changeable pegs; the same lever with holes to correspond for the pin and roller may be used. If only a few of these articles, say half a dozen or so, are to be made at a time, then, of course, it would not pay to make these special tools, and the bending in that case would have to be done on the beak of the anvil with the hand hammer.

To make an eye-bolt same as that illustrated in Fig. 116, the best way to begin would be to weld a collar on the stem, in the form of a ball, see Fig. 117. The material to be used for the collar, should be of a very good quality of convex beading, Fig. 119, or a section, as in Fig. 118. Common iron, when used for this purpose, will split during the punching and drifting, no matter how expert, or how careful the smith may be; and with the best of iron the flattening and punching must be done at as near a welding heat as possible to avoid splitting.



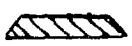
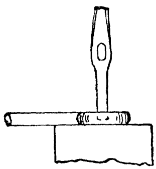


FIG. 118.

FIG. 119.



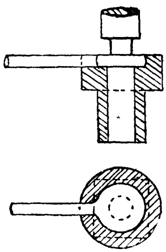


FIG. 117.

FIG. 120.

FIG. 121.

To obtain the best results in punching tnese eye-bolts, and similar articles, do not punch from one side with eye resting on the anvil as shown in Fig. 120, simply turning over to complete the punching; the eye is almost sure to split if you do it in this way. You must punch the piece straight out by using a die, see Fig. 121, and a punch, with the end slightly tapered and a shoulder on it as shown, as a guide to enable the smith to know when the punch is almost through. When this is done, take out of the die and knock out the punch. The best way to do this is to hold the eye-bolt against the edge of the anvil, as shown in Fig. 122, and strike a sharp blow on the shoulder of the punch, which will soon release it. To hit the punch itself on the end would tend to burr it up and make it hold faster each time it was used, so this must always be avoided. Then, if the eye-bolt is to be rounded off inside the hole, do this in the punching die with a punch, as in Fig. 121, turning over to do both sides alike. Another way to make the same eye-bolt, on a larger scale, say out of a 1-inch bar with a 3-inch eye, would be to make a ring, and rough weld the ends together after scarfing them, as illustrated in Figs. 123 and 124; the shank to be

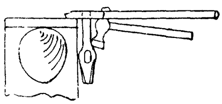


FIG. 122.

FIG. 123.

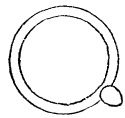


FIG. 124.

scarfed and welded to the scarfed joint of the ring afterwards. The ring may be easily bent without any special tools, but if there are many of these eye-bolts to be made, it would pay to have some bending tools, such, for instance, as a pair of strong tongs, with specially shaped bits, made to grip the iron across the centre and hollowed out to receive the round bar, as shown

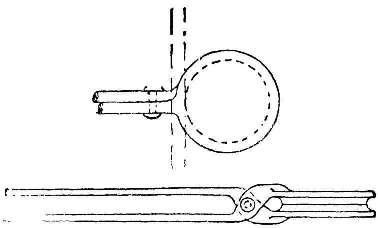


FIG. 125.

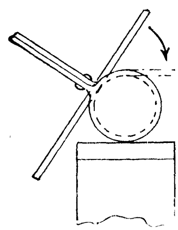


FIG. 126.

in Fig. 125. When using these special tongs, the bars should be heated the whole length, and gripped across the centre with them. Then, by holding the tongs, as shown in Fig. 126, on the anvil, the ends can be easily bent downwards with one or two blows from the hammer, to the position indicated at A in Fig. 127. At this point turn the tongs over and treat the other end of the bar in the same way; then fuller out the ends for the scarf, and complete the bending by holding the reins of the tongs as much below the level of the anvil as they were held above it in the first instance, see Fig. 128. Now strike the ends of the bar down on to the groove of the tongs, and we shall find that this is a quick and easy way of doing this sort of work, and, at the same time, one that will give excellent results. Now weld the ends together and scarf out at the same heat, as illustrated in Fig. 124, with a round-ended punch, commonly called a bob-punch, see Fig. 36A; upset the bar and scarf the same, then weld the bar and the eye together, and work up round the weld with a large fuller, or a link swage, which is a much better tool, all the edges of which should be well rounded off and the light part made as shown, Fig. 36B. This tool

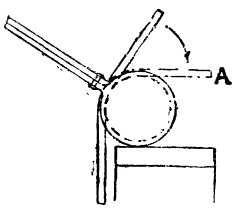


FIG. 127.

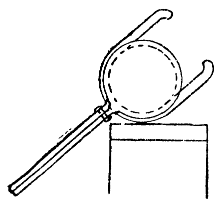


FIG. 128.

can be used in many a position that would be inaccessible to an ordinary swage.

Fig. 129 represents an eye-bolt that is bent and welded. This is considered to be the strongest form of eye-bolt, because the natural grain of the iron is undisturbed, and runs up the shank, round the eye, and back again down the shank, obviating the risk of splitting at the end of the eye.

To make an eye-bolt of this kind, first taper the end of the bar, and bend the same slightly backwards; now bend the bar with a fork tool as explained in the case of the eye-bolt, Fig. 113, and weld round the root of the eye, and where the tapered part butts on the shank with a pair of swages with the ends nicely rounded off, round up the eye on a drift, The eye-bolt shown in Fig. 130 is similar in shape to the one we have just been considering, except that the iron round the eye is smaller in diameter than in the shank part. Some engineers prefer eye-bolts made in this way.

To make this style of eyebolt and also the larger sizes of Fig. 129, bend the eye with the two ends together, as shown in Fig. 131A, which may be done with the tongs already mentioned, with a slight deviation in the manner of working, viz. do not scarf the ends, but bring them close together at the root with a pair of swages or fullers, and drive into the root by jumping back the ends after bringing together; then weld the ends

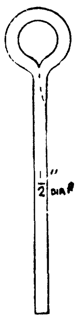


FIG. 129.

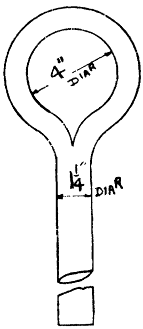


FIG. 130.

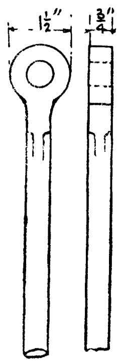


FIG. 131.

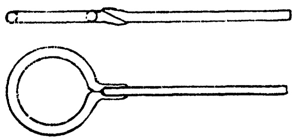


FIG. 131A.

together, and weld on the shank. These two welds may be done at one and the same heat, if the ends of the eye are not left too long. It will be found that this is the most straightforward way to proceed, and therefore, the best way for a beginner to adopt, and no doubt it will make a very strong eye-bolt also.

Another style of eye-bolt is shown in Fig. 131. In this case the edges of the eye itself are square, and also the neck portion. The shank is rounded off a little below the junction of the eye, see illustration.

To make this particular sort of eye-bolt, begin by forging out the shank from a bar $\frac{3}{4}$ inch by $1\frac{1}{2}$ inches, after which cut sufficient off the bar to form the eye; then cut the corners off with a hot sate; now raise the eye portion to a welding heat, and round the forging up with a pair of side swages, see Fig. 132, which process will also serve to close the grain, then punch the eye over a die with a flat bottom, using the punch as in Fig. 121.

Fig. 133 illustrates one of these bolts, such as is used on cranes, etc. A smith is rarely expected to forge the hole in one of these, unless it is for his own convenience. If there is

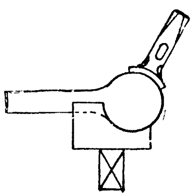


FIG 132.

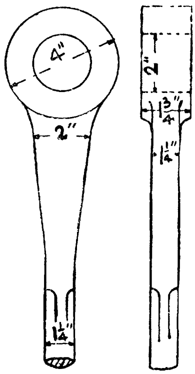


FIG. 133.

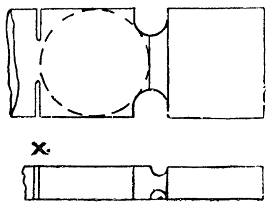


FIG. 134

sufficient power at hand, it is best to forge a piece large enough for the eye; and at this point we may say that there is only one *right way* to forge in iron; in the first place, the piece itself should be large enough to allow a welding heat to be taken at the start, when it should be hammered to the size of the largest part; as none but the very highest quality of iron is sufficiently close-grained to stand much hammering without further welding, and nothing looks worse than a forging showing the seams all its length. To make the tie rod end without special tools, after welding down the iron, set down the shoulders with pieces of round bars, or the hammer fullers, as illustrated in Fig. 134.

The reader will notice that the shoulders are not in line with one another, at all four sides of the forging, but the dotted lines which represent the ultimate shape of the forging, will make it clear why this is so, as by this means the iron is brought the nearest shape to what it is intended and required to be. Now cut partly through off the bar, then reheat the end and forge out to the size and shape that the shank has to be; and when forging out anything of this kind, do not begin by laying the whole piece on the hammer-block at once. This is a slow process and a very unsatisfactory one, and will very probably split the iron before it is drawn to size, as the tendency when working in this way is to keep bulging the iron sideways, and gaining very little indeed in length. Commence with the end of the piece and cog it down, turning it and passing it forward each blow, so that the stroke of the hammer falls on a fresh piece of the forging each time it descends. After working so from the end till the whole part to be drawn has been under the hammer, draw back to the end and repeat the process till the forging is near to the finished size, then let the whole face of the hammer come in contact with the work to finish off. This is much the quickest and decidedly the best way of doing this sort of work, and has the advantage of doing the iron that is being worked some good. When steel is being used it should always be worked in this way, and much time and steam will be saved in consequence. Now cut off the bar, and pare the eye to the required shape with a hot sate, finishing off with side swages, flattener and fullers.

To make the same rod end without power is a task requiring more skill. First procure a mandrel, say $1\frac{3}{4}$ inches diameter, and make a collar on the same (see collars, page 90) but only rough weld the collar, then split it almost down to the mandrel on the welded part; now take a piece of $1\frac{1}{2}$ inches by $1\frac{1}{4}$ inches or its equivalent for the shank, upset the end in a V-swage, enough to spread to about 2 inches wide, now try it in the slit just made in the collar, if it does not go down to the bottom, reheat the collar and open out the slit until the V-shaped end of the shank will go down to the bottom, or instead of this, thin down the end of the bar so that there is no doubt about it reaching the bottom of the slit in the collar.

It is very important that this matter should be attended to, as if the slit in the collar is not wide enough to receive the V-shaped end of the shank, then the sides of the V on the shank will bind on the sides of the slit in the collar, and allow any dirt that may have collected at the bottom of the slit to remain there. Whereas if the V-point on the shank touches the bottom of the slit in the collar properly, any dirt that may be lodging there, will be driven out the moment the hammer is brought down on to the shank, and the weld will be much more satisfactory when this matter has been seen to. Raise the collar and

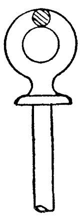


FIG. 135.

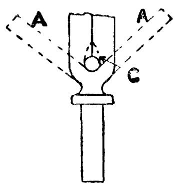


FIG. 136.

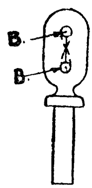


FIG. 137.

the prepared end of the shank to a welding heat, place the collar in a bottom swage, and drive in the shank portion; there is no need to lose time by inserting the mandrel, as the hole can be cut out or drifted to shape when the welding is completed. Now place the flat sides on the anvil and work on them to complete the weld. It should now be about the size and shape required, but if it should be a little too large, close in the material to outside dimensions, and leave the thickness of the eye to be reduced when machining, it can easily be bored and faced, now turn round and forge out the shank with swages, etc. Eye-bolts, such as illustrated in Fig. 135, are now very rarely made on the anvil, but the following is, briefly, a description of how they may be made. Take a piece of iron or mild steel, about $\frac{1}{8}$ inch larger than the collar has to be when forged. Set down both sides of the collar with fullers, taking care not to make it too long at the top side, forge out the shank and cut off the bar; then flatten the eye end and punch the hole, and afterwards work up on the beak of the anvil. If the eye is to be a large one, compared with the other part, it will be advisable to punch a hole and split it, and after forging out the ends as at A Fig. 136, bend them back again and reweld, or punch two holes as at B B, Fig. 137, and split from one to the other, and afterwards open out with a drift and forge the eye on the beak of the anvil; care should be taken when splitting such things that no rough edges are left which would work into the forging and cause lamination, thereby weakening the article being made; for this reason the portions marked C on Fig. 136, should always be carefully pared off or cut away.

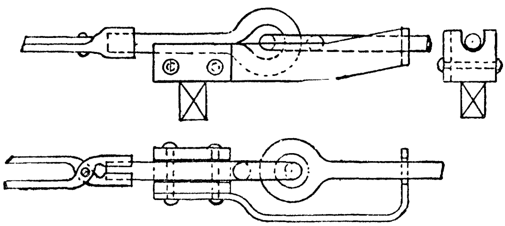


FIG. 138.

Double Eye-Bolts, i.e. when one eye-bolt has the eye of another bolt forged into it, or when a ring, a link, or anything of the kind has to be forged into same, the eye of one bolt, such as Fig. 129, should be opened before placing same into the fire to receive the welding heat, so that when this is done the other eye-bolt, or the ring, link, or whatever has to be welded in, may be easily and quickly slipped in immediately the heated bolt is brought out of the fire to be welded up. It will facilitate matters very much, when this sort of a job is in hand, besides adding very considerably to the finish put on the job, if the loose bolt is supported and held up in line, as illustrated in Fig. 138. The arrangement for doing this is very simple; it is merely a piece of flat iron, bent, and turned upwards, a slot being made in the end to hold the shank of the loose eye-bolt, and the other end is bolted or riveted to the side of the tool as shown.

Split Cotters, see Fig. 139.—These are used in connection with one of the foregoing bolts, Fig. 101, hence the name of the bolts. Split cotters are made in several ways, one of which is to point and flatten a piece of steel or iron, and cut a slit down the centre, as in Fig. 140; then double one side on to the other, as illustrated, and flatten the iron further back to form the head; now draw out to size and cut to length. The cotter must be hammered equally at each side, or one side will be stronger than the other.

Another way of making a split cotter is to take a piece of flat and bend a piece at the end over for the head of the cotter,

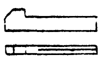


FIG. 139.

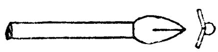


FIG. 140.

FIG. 141.

Fig. 141; this will give three thicknesses for the head, which must now be welded together, or, if a larger head still is required, the other end may be bent also and the two ends brought together to form the head by a bend in the middle; forge the point and cut to length.

Large split cotters are forged solid, and then split at the end as far as required with a hot sate; when they have to be fitted they are lightly welded together again at the point while the fitting is done, and when this is finished and in position, a cold sate is used to separate and open the ends.

Nuts.—Small-sized nuts are very rarely requisitioned from the smith, but he is often asked to make some of the larger ones.

Small nuts ranging up to $\frac{3}{4}$ inch are made by cutting a piece off the bar, with thick cutters which partly form the hexagonal shape, and punching the hole over a die, as illustrated in

Fig. 121; they are then worked up on a mandrel in a nut swage.

When large nuts are being made of iron, the best way to proceed is to bend and weld round a mandrel, the size of which can always be found by referring to table of bolts and nuts; then calculate from the size of tapping hole and width over flats what thickness of iron will be required allowing sufficient thickness to work up the corners; the width should be slightly less than the finished depth of the nut; then cut off a suitable piece and bend U-shape and lay in a nut tool, and close one side well down on to a mandrel with a fuller or thick sate, as in Fig. 142; then close the other end down on to it and hold in the nut swage so that the weld will always come at a corner, as shown in Fig. 143. If the weld is brought round on to one of the flats the tendency, while being worked, will be to push the metal away from the weld, and when this is the case the nut will most likely be a waster, whereas, when the weld is placed in the right position, i.e. at a corner, the natural flow of the metal will be to work itself up towards the corner being welded, thereby obtaining the most perfect result; now heat the nut all over, just short of a welding heat, then take hold of the back of the nut with a pair of tongs and raise the joint to a welding heat, place the nut on the mandrel, and weld in the nut swage; now lay the nut as it is on the mandrel, on the anvil, or hammer block, and give two or three light blows, which will loosen the nut on the mandrel quickly; knock off the nut and work in the edges of the weld smartly while hot; now put on the mandrel again and work up until the size is correct.

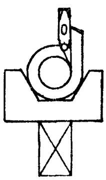


FIG. 142.

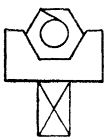


FIG. 143.

In most cases nuts are chamfered off by machine, but when this is to be done in the smithy, a tool called a snap is used on the top of the nut, as illustrated in Fig. 90, that is when the nuts are being made at the anvil; when they are made at a power or steam hammer, they are snapped at the bottom, as in Fig. 144.

In making nuts, it not unfrequently happens that a smith finds his forging has, unknowingly, got askew, as in Fig. 145, and to many smiths it is a puzzle to work it up square again, but it is really a very simple matter; take hold of the nut firmly with the tongs, with one of the long corners to the front, hold the nut on the anvil or hammer block and start by working the long side down, as in Fig. 145, keeping the back part of the nut well down, and work forward at every blow till half way across, then turn the forging over, and round and work this half of the nut as before. Steel nuts should always be made out of a solid piece, having the hole punched, and the nut worked up otherwise in the same way and with the same tools as before.

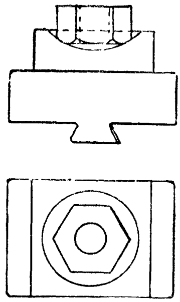


FIG. 144.

Now say we require a nut a certain size, and unfortunately we have not got a nut swage the right size to make it with, but we have a tool by us intended for making nuts a size smaller than the one we want, and we also have a tool for making nut a size

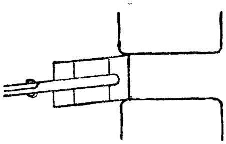


FIG. 145.

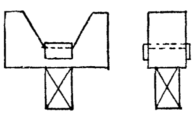


FIG. 146.

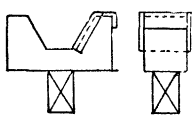


FIG. 147.

larger than is wanted: well, happily, either the one or the other of these tools can be made to answer our requirements; for instance, say we select the smaller tool, then in that case we should require to fit a plate in the bottom of the tool, as indicated in Fig. 146, with the ends of the plate bent, as shown, down each side of the tool to hold it in position.

Now suppose we had selected the other tool, the larger one —then in that case it would be necessary to fit a plate down one side, as in Fig. 147.

Of course, we do not mean to say that this is as good as a tool the right size would be, but it is worth putting into practice for odd sizes.

Where weldless nuts are made with proper plant, the punching is usually performed by hydraulic power. The piece of steel to be punched is placed in a bolster, and the punch is then pressed right through the same. A smith has rarely the means to do this, so he has to depend on the punch to make the hole in the steel nuts he is forging. The punch should be well tapered, and the head should be made smaller than the body part, so that when the nut has been punched from one side and then turned over and punched from the other, the punch may be driven this time, right through the forging, which, by the by, must be placed on a bolster for this purpose, so that the punch may have clearance below and be able to fall, when it is through and free to do so; when this has been done, a drift or series of drifts up to the same size as the mandrel should be inserted, and the nut after this worked up exactly as in the case of a welded iron nut.

Some smiths prefer to use a punch and die under the hammer, and force a piece right out of the blank to make the hole in a nut; but this cannot be satisfactorily performed if the power is not very good and the hammer in thorough good working order, and some expensive tools are needed when this method of making the hole is adopted; for instance, besides the punch itself he would require a guide for same and also a steel bolster or die. The piece of steel used to make a nut forging is generally cut off a round bar and levelled on the ends before proceeding with the punching.

For the benefit of those who wish to punch the holes in the nuts they are making from one side only, the following short description of the tools necessary for the purpose may be useful.

The first item required is the die or bolster, which can be made in several ways; for instance, it can be made out of a solid piece of hard steel, recessed for the nut to lie in the same quite flat, and be level with the top of the tool, see Fig. 148, showing a section of a die made in this way, or it could be made of iron with a stout steel washer in the bottom to form the cutting edge also illustrated in Fig. 148; or another way of making this same tool, would be to make a die the same diameter as the collar or nut, and shrink a wrought iron band deep enough to take the nut on to the die; this would form the recess for the nut to lie in. Sometimes a handle is also forged to the wrought iron band to facilitate lifting up and

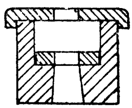


FIG. 148.

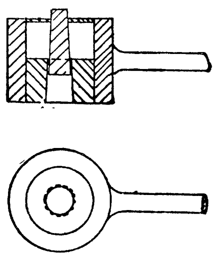


FIG. 149.

holding under the hammer; see Fig. 149, for an illustration of this tool.

The latter would undoubtedly be the best tool in one respect, since by heating the band it could be taken off the die, so that the latter could be sharpened up when required much more easily than if the die and bolster were made in one piece; in the same way the loose steel washer could be readily taken out for repairing. A guide plate to hold the punch will be required in addition to the above tools; this guide will serve to direct the punch at the start. These guides are usually made as illustrated in Fig. 148, which shows a sectional view of the tool. The guide plate is flanged over to lay on the bolster, and hold the punch in the centre while the hammer is driving the same through the forging. If the nut to be punched is less in depth than the recess of the bolster, then the guide would be better if it was cut to fit in the recess also, on the top of the nut, see Fig. 149.

The punch for this work should be made larger at the bottom than at the top, so that when the hole is punched the tool itself will fall through, and the length of the punch should be so arranged that when through and standing on the burr, the top is above the die and guide, see Fig. 149; this will save the die from a lot of bruising it would otherwise receive if the punch was short.

Collars.—Small collars varying in size from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches can be made in small quantities cheaper in an up-to-

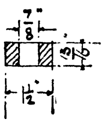


FIG. 150.

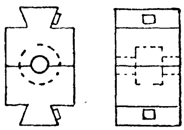


FIG. 151.

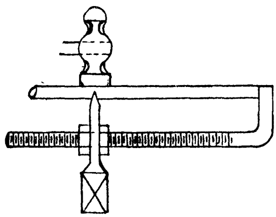


FIG. 152.

date machine shop, with the aid of turret lathes, hack saws, high-speed drills, etc., than they can be produced by a smith. It is only when large quantities are required, and special tools are used, that the smith can hold his own against the machinist with this class of forging.

Suppose we are to make some, as in Fig. 150. To begin with the smith would require a smooth, well-finished mandrel, made exactly the right size for the hole in the collar, so that the collar will slip off easily when required. The mandrel should be made of a piece of good cast steel, sate temper preferred, though drill temper would do; an objection, however, to drill temper is the tendency of the steel to break when slaked time after time, as the mandrel has to be. He will also require a pair of swages recessed to take the collar when on the mandrel, see Fig. 151, and to obtain the best results, these tools should be used at some small power or steam hammer, that is if the smith must compete with the machine shop process, and then one pair of hands can be working at the hammer, while the assistant is supplying the smith with heats from the fire.

To make these collars heat a bar $\frac{3}{4}$ inch by $\frac{3}{8}$ inch and cut the same partly through by laying it on a hardy with a gauge fixed to same as shown in Fig. 152 ; strike on the top of the bar with a hammer as shown and bend the end of the bar round the beak of the anvil, bend away from the cut as in Fig. 153, cut the bar the same way each time, this will give sufficient scarf; now turn the piece that is being worked, and that has not yet been severed from the bar, upwards, as shown in Fig. 153, and close the same, so that the mandrel will just lie

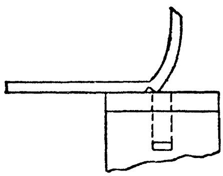


FIG. 153.

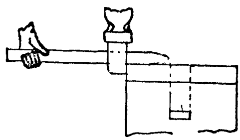


FIG. 154.

in it ; then disconnect it from the bar and place in the swage, close one end right down on to the mandrel, and bring the other end down on to the top of that, take off the mandrel and flatten the collar edgeways, so that it will turn easily in the recess in the swages. If the collar should stick on the mandrel, a few light blows with a hand hammer round the collar as it lies on the anvil will loosen it, by making the hole slightly larger, or it may be released by resting the end of the mandrel on the anvil, and working on the collar, as shown in Fig. 154; this is also a quick and ready way for drawing a thick side, or for opening a hole in a collar. Another way of getting a collar off the mandrel quickly, is to drive the mandrel through the collar over a bolster or old bore; when this is going to be the method of releasing the collar, the handle end of the mandrel should be slightly less than the working part, so that it will clear a way for itself.

We should note that the swages, referred to above as being fixed to a small power or steam hammer, can be made, if desired, to use at the anvil in the same way as an ordinary pair of swages, and even an ordinary top swage can be used if desired. When collars are made with the ordinary top swage, the weld should be worked at the underside of the mandrel in the recessed bottom swage, as, if the weld was turned to the top and met the open top swage, the welding portion would spread too much, and become too wide to turn round in the recess of the bottom tool, as it would have to do in the course of working; but this latter method would necessitate a striker to assist with the work at the anvil, and therein lies the drawback

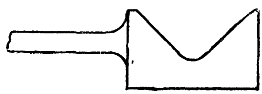


FIG. 155.

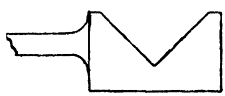


FIG. 156.

to this way of working. The presence of a striker means an increase in the cost.

We have also referred to what is called a "hardy" or "handy cutter," and we would emphasise how appropriately the latter name suits the tool, for it is really indispensable when a smith is working alone, that is, without a striker, and it is often very useful at other times.

For large collars the process of manufacture is the same as for large nuts except that the nut swage will be replaced by a V-block, or swages, for use under the steam hammer, see Fig. 155, which illustrates the V-block in question with a handle on it for holding it up. When making this tool, let the bottom of the V be left round as shown, and not cut square at the bottom, as in Fig. 156, in which case it would be very weak and dangerous to use.

Fig. 157 represents the same tool made so that it will slide on the bottom pallet and rest there without being held. It can be quickly and easily pushed off when it is necessary to work the collar on the bottom flat pallet. The welding will be best done in one of these tools, with the plain top pallet working directly on to the collar, which must be turned about as required.

A single top swage, made as illustrated in Fig. 157, is very useful to work along with these tools when finishing, or the collars may be finished in swages, when there are swages of that type large enough, as in Fig. 13. Large steel collars should be made in the same way as steel nuts so far as the punching and drifting are concerned, and then swaged as above.

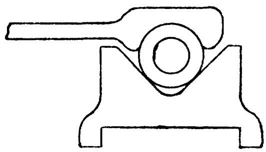


FIG. 157.

There is still a difficulty to be overcome that every smith will meet with at one time or another. We have used the word "difficulty" advisedly, because we know that such is the case with many if not with most smiths, but in reality there is little or none at all attending the matter if the smith has the merest knowledge of the rudiments of arithmetic. Say he has a collar to make $7\frac{1}{2}$ inches outside diameter, 4 inches hole and 3 inches deep. If he happens to have a $7\frac{1}{2}$ inches diameter bar in the rack, of course, he would cut 3 inches off the same, and make the collar without much ado, but he is as likely as not to be short of the exact size of bar he requires, and he may have perhaps 5-inch, 6-inch and $8\frac{1}{2}$-inch bars in stock, and he will have to use one or the other; the point is to ascertain what length he will need to cut off the bar he selects.

Let him first ascertain the cubical contents of the collar, to be made as follows. From the tables at the end of this work he will find that the

	Sq. inches.
Area of outside diameter $7\frac{1}{2}$ inches . . .	44·18
,, diameter of hole 4 inches . . .	12·56
Deduct the one from the other, and we get . .	31·62
This multiplied by 3 inches, the depth of collar, gives	94·86

Assuming that he selects the 5-inch bar to work from, by the tables at the end he will see that the area of 5 inches diameter = 19·63 square inches, therefore all he needs to do is to divide 19·63 into 94·86 and the quotient 4·83 will be the length in inches that he will require to cut off the bar to make this particular collar; and by the time he has hammered the 4·83 down to 3 inches, punched and drifted the hole, he will find that he has the 7½ inches diameter required.

When the collar has to be left solid, the process of reckoning is still more simple, say he had the same sized collar as before to make, only without the hole. In this case he will see, by referring to the tables, that the area of 7½ inches = 44·18, then multiply 44·18 by 3 inches which is the depth, and he will have 132·54, the cubical contents of the collar to be made. Say he selects the 6½-inch bar to make it from, and in the tables he will find that the area for 6½ inches diameter is 33·18; all he needs to do is to divide 33·18 into 132·54, the cubic contents of the collar in inches, and he will have 3·99 inches, practically 4 inches, the length in inches to be cut off the 6½-inch bar.

If the 8½ inches diameter was selected to make the above solid collar, then there would be three ways open for the smith to proceed; the fact of the bar being so large in diameter requires somewhat different treatment to the smaller ones; for instance, suppose that after ascertaining the length to be cut off the bar in the usual way, already explained in the foregoing instances, which in this case would be 2·33 inches or say 2⅜ inches, he could cut this length off the bar and proceed to work it down under the hammer, but in working it down he will need to be careful; it is no easy matter to do this right, especially if the power is insufficient, as in that case the effect of each blow will then probably only operate so far into the bar and not affect the centre portion thereof to the same extent, with the result that the piece when worked under these conditions will appear as in Fig. 158, the centre part at both sides will be cup-shaped. Of course, this will not matter much if the hole to be bored into the collar is large enough to clear away the whole of the cup-shaped portion.

Again, the smith could forge the end of the bar from $8\frac{1}{2}$ inches to $7\frac{1}{2}$ inches diameter, and cut off the length he required for the collar.

The area of a section of any size bar in square inches divided into the cubical contents in inches of the collar required to be made, will always give the length required in inches to be cut off that particular bar to make the collar.

Washers are used alike by builders, carpenters and engineers, and vary in size and thickness very much. We only need to devote ourselves to the manufacture of the larger sizes, such as are used by engineers, and the ordinary square washer used by builders and carpenters.

Say we require to make one of the above articles for use on some machine, and that the same has to be $\frac{5}{8}$ inch thick, 8 inches diameter outside, with a 5 inches diameter hole.

Before deciding what size iron we shall use for the above purpose, it will be well to look ahead a little and determine how we are going to finish off the washer. If we have either a steam or power hammer at hand, by which we can flatten the forging when made, it will be best to use iron $\frac{1}{8}$ inch thicker than the washer has to be when finished; but in that case the iron will not need to be so wide, and will consequently be easier to bend and weld. But on the other hand, if we are going to make and finish the washer by manual labour only, the best thing we can do is to select some iron as near as possible to the thickness that the washer has to finish to, being careful not to waste any more of the iron than we can possibly help.

It is found in practice that when a bar of uniform strength is bent in the form of a washer, the material at the inner side thickens up very considerably, while the outer rim of same is reduced in thickness very much, and the centre portion of the bar remains much the same thickness and length as before it was bent. It will therefore be seen that we must take the centre portion of the bar as our standard when calculating the length of iron or steel for making washers, collars, hoops, etc.

Now we shall proceed to make the above washer, assuming in the first place that we have either a steam or power hammer at hand; in which case we should use $1\frac{3}{8}$-inch by $\frac{3}{4}$-inch flat bar. To ascertain the length of the same, refer to table of diameter and circumference at the end of the book and proceed thus: Add first of all diameter of hole and width of bar together, thus, 5 inches hole + $1\frac{3}{8}$ inches width of bar = $6\frac{3}{8}$ inches, which gives the distance from the centre of one side to the centre of the other side, the circumference for which, as will be seen from the table, is 20 inches. We shall, however, require rather more than this to allow for cutting the ends at an angle

FIG. 158.

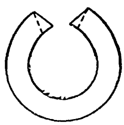


FIG. 159.

FIG. 160.

to enable the same to be brought together and laid neatly the one on the other, as illustrated by dotted lines in Fig. 159, to allow for welding; and a fairly safe way of doing this in practice is to add the width of the bar. We should then have 20 inches + $1\frac{3}{8}$ inches = $21\frac{3}{8}$ inches, which is the length of bar necessary to make the washer.

The writer, when making washers, used to jump back the inner corners in a V-tool rather more than the outer ones, thus partially scarfing the ends and forming a little of the bend, as shown in Fig. 160, and in this way do without cutting the corners as previously mentioned.

To bend the washer, hold the ends firmly over the beak of the anvil and bend them to something like the radius for, say about 3 inches from each end, then give the middle part a start by holding a large fuller or set hammer inside, while the bar is across two bearings, set a fair distance from each other. This can readily be done by putting a large fuller in the anvil and resting one end of the bar on the fuller and the other end on the anvil. Now turn up on end under the hammer, if the stroke of the hammer is large enough to allow of it, and complete the bending by lightly hammering on the ends. A little practice at this will soon enable any smith to bend a good washer.

If the ends have been partially scarfed as just described, now fuller them out, one each way and close together, until there is enough for welding; and this need not be much if the job is in the hands of a person experienced in welding, as the washer is so stiff that the material is not easily forged away. Now raise the forging to a welding heat and weld in the usual way, working first on the flat of the anvil, or under the hammer, then on the edge of the washer, with the

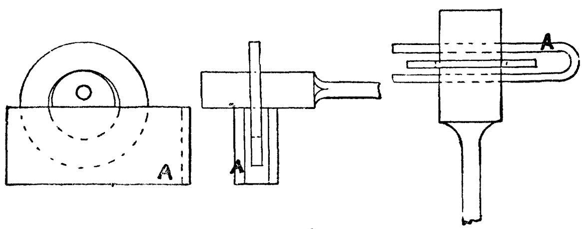


FIG. 161.

hole on the beak of the anvil. Now heat the whole of the washer, and clean off the scale and dirt, flatten to size under the hammer, at the same time throwing or splashing on some water to remove any remaining dirt; clean up on the edge with a swage or flattener, and drift the hole to the proper size.

A good method for reducing a broad side on a large washer, or for drawing a hole into the centre, and when making solid steel washers with holes too large to drift out, is illustrated in Fig. 161.

The tool marked A in Fig. 161 consists simply of a stiff piece of flat bar bent into the form of a staple. To use the tool under the hammer it would have to stand with the edges upwards, so that a mandrel or piece of plain round iron could rest across it, with the washer hanging thereon between the two sides of the bent tool just referred to. The hammer can then be brought to play on the washer, the top part of which only is affected by the blow, and all that the smith has to do is to keep turning the washer round on the mandrel with a pair of tongs so that each blow from the hammer will operate on a different part of the washer.

Now, assuming that we have to make this same washer by hand, there being no steam or power hammer in the shop. In this case the best size of bar to use would be $1\frac{5}{8}$ inch by $\frac{5}{8}$ inch; this will thicken up on the inside, and draw on the outside edge in the same manner as did the other; but it will be nearer the size required; calculate the length or the amount to be cut off the bar as before, viz. 5 inches + $1\frac{5}{8}$ inches = $6\frac{5}{8}$ inches, the distance from the centre of one side to the centre of the other; by referring to the tables, it will be found that the circumference for $6\frac{5}{8}$ inches diameter of circle is 1 foot $8\frac{13}{16}$ inches, to which add $1\frac{5}{8}$ inches for lap = 1 foot $10\frac{7}{16}$ inches, and proceed in the same way as before until welded, except that the bending will have to be done with the sledge hammers; but in this instance, instead of the washer requiring to be flattened all over, it will be found that it is too thin on the outer edge and too thick at the inside edge; the outer edge must therefore be thickened up, and the best way to do this is to place the washer on the beak of the anvil and work round the same with a swage; but if the hole should be larger than necessary, the washer should be held in a V-swage, as illustrated in Fig. 157, and while there be worked round the outside with a swage; this process will tend to reduce the diameter of the hole, whilst working on the beak of the anvil will tend to open or increase the size of the same.

Of course, in some shops there would be appliances for making these washers out of plate, by roughly shearing them to the outside diameter, in which case the hole could be punched with tools similar to those for punching nuts and collars; the washers will be finished off with the aid of the mandrel, drift, swage, etc.

For punching small washers and square ones, such as builders and carpenters use for tie rods, a simple way is to take an old joint, or fork end, say of a connecting rod, and close the same so that the washer will easily go between the fork, then the bottom hole will serve as a die and the top one as a guide for the punch; when these tools are meant to be used at the steam hammer, the punch will be best if made to drive straight through, see Fig. 162; but when for use at the anvil,

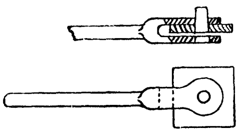


FIG. 162.

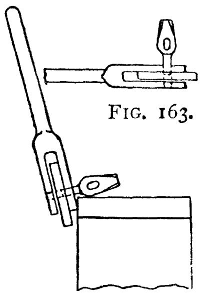


FIG. 163.

FIG. 164.

the punch will answer best if made, as illustrated in Fig. 163, with a slight taper on the end, as it will have to be drawn back the same way as it goes in. The punch can be easily withdrawn by striking the fork against the front of the anvil, as shown in Fig. 164. These tools are intended for punching hot, and the square washer should be chamfered round at the same heat, if the chamfering is required to be done.

Ferrules for Boiler Tubes.—Ferrules for locomotive and other boiler tubes are usually made from a good quality of steel that is easily welded, and at the same time is fairly stiff.

To begin with, the material is cut to length, then both ends are scarfed and the ferrule is bent; now take hold of same with the tongs, at the opposite side to the joint, and after raising carefully to a suitable heat, proceed to weld the ferrule on a special tool, see Fig. 165, which should be wedged tightly in the anvil; then, edging one side on the anvil and the other against the front of the anvil, as shown in Figs. 165 and 166, the ferrule is rounded by swaging on a mandrel, and laid down until the whole lot are welded; and now we come to the most important part of the work, i.e. "blocking," or the process of making them the proper size.

In the case of collars and ordinary ferrules, the hole is generally the most important feature of the article, and if it should be rather large or too small it can easily be adjusted with the aid of the drift or the mandrel and swages; but in the case of ferrules for boiler tubes, the outside of the ferrule is the working part, and must be made exactly to size and a true

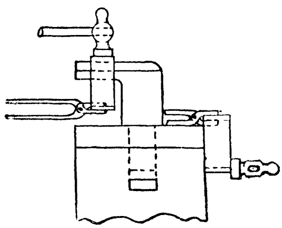


FIG. 165.

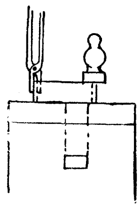


FIG. 166.

circle. To finish these on a mandrel would not be satisfactory, especially if the bars varied in thickness, so the finishing is performed in a block made of cast steel, as illustrated in Fig. 167, bored the right size and taper. The ferrules are re-heated, slightly snapped on the smallest side to give a lead both into the block and also into the tube when driving into position.

They are driven into the block with a flattener on the top or with a combined drift and flattener, as in Fig. 167; but this latter tool is very rarely used, it being considered best to make the ferrules full size and use an ordinary flattener. By this means the ferrules are made at once perfectly round, correct taper, and exactly to size.

In some works, the above ferrules are made by special machinery from a round disc of sheet steel or plate, which is dished like a cup, and the hole punched in the centre; it is then pressed into a die similar in shape to the one illustrated in Fig. 167, used for hand blocking.

Weldless ferrules are also made from weldless tubes, cut to length with saws and other machines, and blocked in a die or by swaging under a light power hammer, with swages recessed similar to Fig. 151, and hardened to ensure them keeping the correct size.

Door Bands or hinges for smoke-box doors, fire doors, gates, etc., are very simple forgings.

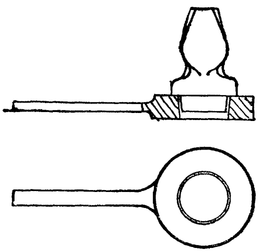


FIG. 167.

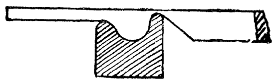


FIG. 168.

The best way to make them when there is power at hand is to use a block for forming the large end, as illustrated in Fig. 168. The block can be made in a very few minutes as a makeshift tool to lay on the bottom pallet of the hammer, and although it is termed a makeshift tool, it will be found to answer its purpose quite as effectively as any that can be designed.

Take a piece of square or rectangular material, according to the thickness and the width of the boss, heat the same and work it in the above special tool, leaving sufficient material beyond the tool to draw out later on and form the flat, then work the plain parts on the ordinary hammer pallet; now forge out the flat and work the large end again in the special tool. Work the edges alternately on the plain pallet until forged to size; it will then only need to be cut off the bar, and the small portion remaining from the bar can be cut off the knuckle with the hot sate, and trimmed up with the side swages.

If the above forgings had to be made in a smithy that was not provided with power or other hammers, then the best thing the smith could do would be to thin down the end of a bar, and bend as in Fig. 169. Insert a piece of round iron to fill up the eye, weld the eye together with the side swages, and forge the other portion on the anvil. It is advisable to have the piece of round iron slightly longer than the width of the eye so that it will fill up well at each side.

When the hole has to be forged in the eye, the end of the bar should be thinned down and bent over as in the previous case, using a drift to form the hole. Weld the end to the bar,

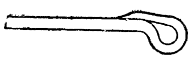


FIG. 169.

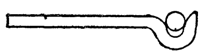


FIG. 170.

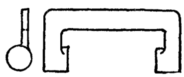


FIG. 171.

and finish off with side swages and drift. Another way of making these same forgings is by bending the end of a bar as in Fig. 170 and filling up the space with a piece of round iron at a welding heat.

Annther form of door-band or hinge is illustrated in Fig. 171, and at first sight it may perhaps seem rather a difficult task for an apprentice or learner, but it can easily be made in two halves with the special tool shown in Fig. 168.

Take a bar large enough for the boss and bend the end over short as in Fig. 172, then set down in the tool as shown in the same figure, flattening the shank down to the thickness required, then set out and cut to shape, and shut the two together.

Note.—The two ends must be forged right and left hand in the first instance, or they will not come together as they should do, and one half will have to be made over again.

Hooks for Door-Bands, see Fig. 173.—These are invariably made by welding the round peg into the flat portion. They can, of course, be made out of the solid, but no practical smith would think of making them in this way nowadays, when competition is so keen and prices are so low, simply because the time it would take to forge them out of the solid

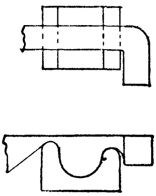


FIG. 172.

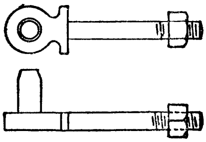


FIG. 173.

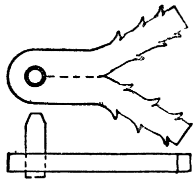
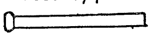


FIG. 173A.

would be so expensive compared with the welding process that nobody would buy the article when made, and we need not be surprised at this, since the welded hook will be equally satisfactory in every way and cheaper.

To make these hooks, take a piece of flat iron near the size of the body, and punch a hollow place in the same where the peg is intended to go; do this with a bob-punch, or else with

FIG. 174.



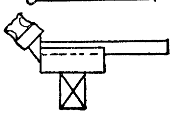


FIG. 175.

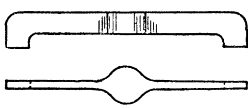


FIG. 176.

a large centre punch. Then take a piece of round bar, the right diameter for the peg, and raise one end thereof to a welding heat, jump the same sharply on the anvil, and the end of the bar will spread as shown in Fig. 174; then work the edge of the portion that has spread back with the hand hammer over the end of a swage, as shown in Fig. 175, and also swage immediately behind the scarf to make sure that the peg will go in the bore when required. Cut off the bar leaving it about $\frac{1}{2}$ inch longer than the length it has to be when finished. Now raise both pieces to a good welding heat, and place the scarfed end of the peg into the hole in the flat piece, let the striker give a couple, or at the most three, sharp blows on the peg to drive it well in at the root, then turn over and place the peg

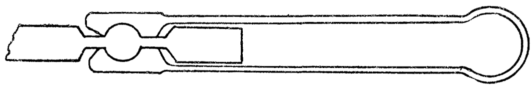


FIG. 177.

into a bore, and complete the welding by working on the large piece; and afterwards shoulder down and forge out the end for holding the hook in position. Fig. 173A is another pattern made by bending a piece of square and inserting a peg as shown, then welding the whole at one heat.

Crossbars, for manhole-lids or cleaning-hole doors in boilers, etc., see Fig. 176.

To make these crossbars, forge the bosses in a pair of pring swages under the steam hammer, see Fig. 177, working

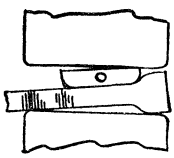


FIG. 178.

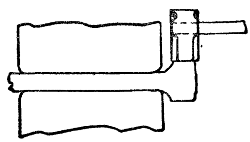


FIG. 179.

the fl[illegible]arts with the flat pallets; then flatten out the ends, allowing them to spread out wide enough to form the feet, by setting or working the same over to one side of the forging, to that side where the legs have to be, with the aid of a flat tool with the corners rounded off, see Fig. 178; or lay the forging over the bottom hammer-block, and lower the hammer on to the top of the forging to hold it, let the striker knock the end down with his sledge hammer, as shown in Fig. 179, after which trim off the ends to shape with the sate and flattener.

These bridges or crossbars are also made with a number of bosses on them, but they are all forged in the same way as described above, the only difficulty being to get them the proper length between the bosses, which are sometimes so close together that the application of the swages makes them too far

FIG. 180.

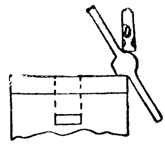


FIG. 181.

apart. When this is so, fuller out roughly, to get rid of some of the superfluous metal, as in Fig. 180, before using the swages.

To make the above crossbars without swages, use fullers to set down at each side and work the bosses round with the narrow set hammer and fullers as in Fig. 181.

Another shape of crossbar is shown in Fig. 182. Forge this out as already explained in the previous instances and draw

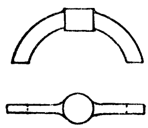


FIG. 182.

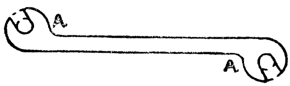


FIG. 183.

the ends straight, after which bend them to the shape over a block or the beak of the anvil.

Spanners.—Of late years, bolts and nuts have been made more to standard dimensions than used to be the case; consequently, spanners have become more uniform in size; and this has given enterprising firms the opportunity to make spanners with special tools, in large quantities for sale to their less go-ahead neighbours, who, however, sometimes have to call upon the smith for a special size or shape of spanner. We intend to deal now with the latter case.

Spanners as per illustration, Fig. 183. To make the above take a piece of flat mild steel, and shoulder down where marked A A in illustration, at opposite sides of the bar, with a large fuller, then forge out the middle portion over a flat tool under the hammer, as at Fig. 184, by working the forging with one jaw downwards, and afterwards turning over and working with the other one in a similar position; the spanner forging can then be kept in proper shape and drawn to size and length. Now cut the ends round and punch the hole, work up to a

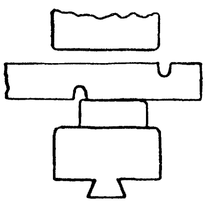


FIG. 184.

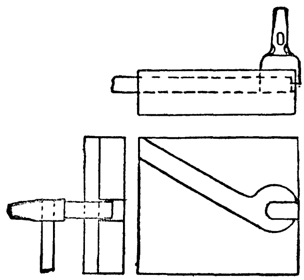


FIG. 185.

fairly good finish with the side swages and flattener, with a drift in the hole slightly shorter than the jaw, as shown by the dotted lines in Fig. 183. This will facilitate matters very much and save a lot of time that is usually spent in keeping the ordinary glut in the fork while swaging round the end. Now cut out the bit of steel left with a good hot sate; then fit to the proper glut, which should be done in a very few minutes if the instructions given above have been properly carried out.

This same spanner can also be made as follows: Forge out the centre portion as before, round the ends up to size an shape, then punch out the jaw with tools similar to those illustrated in Fig. 185. The bottom die is simply a piece of cast steel with a slot in one side, with two suitable guide plates riveted to the top to hold the spanner in position while it is punched. It will be seen from illustration Fig. 185, that the punch in question has a lip forged on one side as a guide for the length of the jaw.

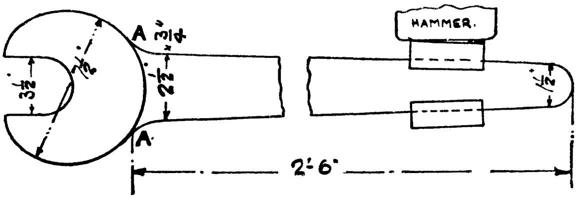


FIG. 186. FIG. 188.

Large spanners, as illustrated in Fig. 186, and over that size for heavy work are usually single ended, and are made in two ways, the first of which depends on whether the shop is provided with ample steam power, and the other is a provision in case the reader finds himself located in a shop where there is

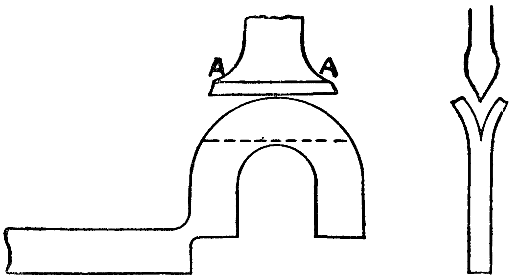


FIG. 187.

no power at all, in which case the whole of the work would have to be done by hand.

In the first instance, that is assuming that there is a hammer large enough to deal with this size of spanner, he would proceed to forge out the shank, and punch and cut out the jaw, exactly as in the case of the smaller spanners, except that the shank in this instance would be central; but when there is not sufficient power, or none at all, he will have to proceed on different lines altogether; the spanner will then have to be made in pieces and built up as follows: Take a piece of iron, large enough to make the jaw, and see that it is sufficiently large to begin with; remember the material can always be more easily reduced than increased; say we use a piece of iron 3 inches by $1\frac{1}{4}$ inches in the rough, bend this to shape as in Fig. 187, then split the crown lengthways down the centre, and open the same well out as shown. Now take a piece of $2\frac{1}{2}$ inches by $\frac{3}{4}$ inch and upset the same in a V-tool, do the upsetting well, err on the large side rather than otherwise, let it be well spread out at each side so that there will be ample material when welding together for a fuller to work on A A, in Fig 187, and make sure that there is a good joint at this place; see that the shank portion goes well into the split in the crown of jaw, raise both to a welding heat, place the bent or jaw portion on the beak of the anvil and drive the shank well home into the split just referred to, fuller on each side at A A, and weld on the flat with the sledge hammers, or with the steam hammer if you have one; see that the jaw is about the right size where it has to span the nut, and then finish off the same by paring with the hot sate, and cleaning up with the fullers, side swages and flattener; and in passing we may note that the pallets in the steam hammer when in fair condition, make the very best flatteners known, and can be used for this purpose with great effect, and that too, very much oftener than is usually the case.

It is advisable to have a drift with a shank to it, in the form of a large anvil fuller for the above work, to use while finishing round the back at A A.

Now taper off the shank and shut a piece of 2 inches by $\frac{3}{4}$ inch on to the same, to make up to length, and forge to proper size and taper, swaging the edges with a pair of $\frac{7}{8}$-inch or 1-inch swages, which, in the case of the solid spanner, as well as the above, could be done under the steam hammer with the ordinary spring swages by holding a piece of thin flat bar on the end of the top half of the swages nearest to the small end of the spanner handle, see Fig. 188.

Some smiths would, no doubt, like to do without the shut in the handle part, and, while it is quite possible to obviate the shut, it is far the best when making the head to only have a short piece to deal with. If the shank is to be made in one piece, the crown must be placed on something lower down than the beak of the anvil, or else the striker must have a platform to stand on so that he can reach to drive the shank home.

A lap joint may be used instead of the split joint referred to above, but the former does not make nearly so good a job as does the split joint, because the tendency, when working in the

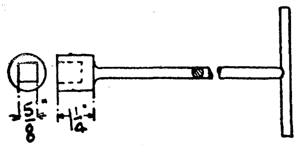


FIG. 189.

case of the lap joint, is all the time to be reducing the material, whereas in the case of the spliced joint, the forging is gathering material while being driven in and thus affording a better chance of the weld being really good and sound.

Box or Socket Spanners, see Fig. 189.—To make the above spanner commence by forging out the shank from a piece of round mild steel $\frac{1}{8}$ inch larger in diameter than the box part has to be when finished; have the box part bored in the machine shop to the right depth and diameter; the latter should be barely large enough to take the drift across the corners. When this has been done, the smith only needs to heat the box end part and insert the drift, after which he must swage round the outside until fitted to the drift, and it is with this object in view that we suggested at the start that the box part should be forged $\frac{1}{8}$ inch larger in diameter than the same has to be when finished, otherwise there would not have been sufficient material to allow for the swaging.

Another way to make this same spanner is to make a collar with the hole large enough to take the drift, then jump the end of a $\frac{5}{8}$-inch diameter bar and forge the same to $\frac{5}{8}$ inch square, or use $\frac{5}{8}$-inch square bar and round the shank part down afterwards; raise both the end of the shank part and the collar to a welding heat, place the collar on a peg which should be made

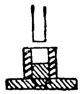


FIG. 190.

FIG. 191.

so that it will stand on the anvil, see Fig. 190, drive the shank part into the collar, jumping it on the peg, then weld round in the swages.

Box Spanner for Hexagonal Nut, see Fig. 191.—This spanner is made in exactly the same way as the one we have just been considering, only instead of trying to jump the 1-inch bar large enough to fill the $1\frac{1}{4}$-inch hole, use a $1\frac{1}{4}$-inch round bar and shoulder the same down to 1 inch diameter after the

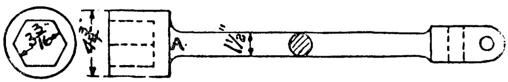


FIG. 192.

two are rough welded together; this makes a neater job, and gives a better fillet, providing proper fullers and round-edged set hammers are used.

Box Spanner for a 2-inch Nut.—To make a box spanner for a large-sized nut, say one suitable for a 2-inch bolt, as illustrated in Fig. 192. It should be noticed before starting that the box part is necessarily much larger than the shank has any need to be, therefore, it will be best to make a collar suitable for the box part and let it be $\frac{3}{4}$ inch deeper than the hole has to be when finished, when the collar is made according to instructions given elsewhere, and fitted to hexagonal mandrel, proceed to spread or scarf the edges of same at one side, as in Fig. 193, to give a good face for welding on to, and also to allow for waste while doing so. To make the shank part, take a piece of round iron, say 4 inches diameter, shoulder the same down and forge out the shank to say 8 inches or 9 inches long by $1\frac{3}{4}$ inches diameter, not $1\frac{1}{2}$ inches as shown in sketch, Fig. 192; the shank must be left large enough; it will waste a little during the following process. Now cut off the bar and work up the head in a bolster until the diameter equals the largest part of the scarf on the collar; the bolster should have a good fillet round the hole, or if the smith has no bolster, he can work round the back of the shank with a large fuller as in Fig. 194,

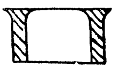


FIG. 193.

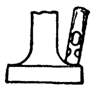


FIG. 194.

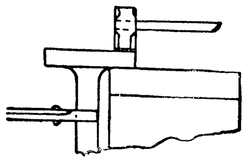


FIG. 195.

or he can work the same on the edge of the anvil, as in Fig. 195, or on the beak of the anvil in a similar way. Now we have both pieces ready for welding together; place them in the fire. We are going to assume that one smith has charge of the heating of both pieces, although it is customary in cases of this kind for the smith at the next fire or one close by to assist by heating one of the pieces; however, when the collar is a good white heat all over, take hold with a pair of tongs, illustrated in Fig. 51, and heat the scarfed side; when both are at a good welding heat, bring out the collar, and let the striker take hold of same with a pair of bow tongs or pliers and place the same on the anvil, hot side at the top; no peg is required here as in the other instance; bring out the shank and place on the top of the collar, press them together with your own weight on the tongs to fasten them, lift up and jump the two together on the anvil, and work round with the set hammer or fuller in the same position as Fig. 194, or the shank may be placed on the collar and the set hammer used at once; turn down into the bottom swage and work at the forging with the hand hammer and a light striking hammer where the two scarfs have met. It will most likely be necessary at this point to have another light welding heat to make the weld complete; if it does, take it at once; it is a waste of time to go on working a forging up when you are doubtful about the welding being good enough; if there is any doubt, remove the same at once by reheating, then you will get on much better, much quicker, and so save time and worry over the job; finish off with the drift and swages as before, and swage the shank part to size, i.e. 1½ inches diameter.

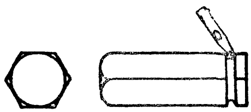


FIG. 196.

FIG. 197.

Note.—The drifts used in making the foregoing spanners should be about twice the depth of the hole in length, with very little taper on them; in fact, to make a really good-fitting spanner, they should be parallel. As for extracting the drift when finished with, nothing is easier if they are made the right shape, as in Fig. 196, and worked in the right way; to withdraw them, let that part of the drift that stands outside the spanner lie on the anvil with the end of the spanner against the edge of the anvil, hold a small fuller in the groove round the drift, with the head of fuller leaning towards the spanner, see Fig. 196; by working round the drift in this way it will soon be released; striking the drift on the side will also loosen it, but this will increase the size of the hole slightly.

In the case of box spanners, there must always be an arrangement at the opposite end of the shank for turning the spanner, We will take what is called the T-handle first, see Fig. 189, to make which, take a piece of $\frac{5}{8}$-inch diameter bar, about $10\frac{1}{2}$ inches long for the crosspiece, and another piece for the shank, the length of which is governed by the length of the spanner. Upset the crosspiece well in the centre, and bob punch the same out to one side, then upset and scarf the end of the other piece and weld on to the place prepared in the crosspiece, working round the same with a suitable fuller, and on the beak of the anvil. Another way to make a T-handle is to jump the crosspiece, and thin out the centre wedge-shaped; then jump and split the shank with a small fuller, open out the ends so that they will go over the wedge scarf on the crosspiece; weld together and work up with fuller and swages as before.

FIG. 198.

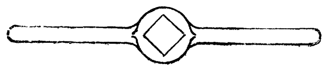


FIG. 199.

This handle can also be forged from the solid as follows: Take a piece of, say $\frac{5}{8}$ inch by $1\frac{1}{2}$ inches bar, and forge out a sufficient length of same to make the shank; then cut off the bar and punch a hole in the flat part, not too near where the shank starts from, and spilt the flat portion from the hole to the end with a hot sate, see Fig. 197; now open out the ends and bend them back to form the T, and work up with fullers and swages as before.

A very useful tool, and one that would be handy when making the above handles, is illustrated in Fig. 198; it is simply a bottom swage without a shank, having a hole punched or drilled in the centre as shown. It is intended to be used over the hole in the anvil, or on the swage block, and it will not need a very experienced eye to see that when the centre shank of a T-handle is placed in a special tool of this kind, and a swage brought to bear on the top of same, it will not take long to finish it off.

There are also loose handles made to serve the same purpose, see Fig. 199. The end of the shank of the spanner in this case is made square to fit the handle, which is also used as a tap wrench. This form of handle makes a very simple forging, and we think it is hardly necessary to enter into detail respecting the making of same. We will, therefore, only add that when odd handles of this kind are required, it is best to forge out of a flat bar and punch the hole, but if a large number are required, it is advisable to form a ball with special tools, as illustrated, in making the centre part of hand-hammers and forging out the ends to size, then flattening the ball and punching the hole.

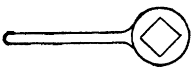


FIG. 200.

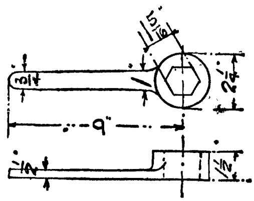


FIG. 201.

Fig. 200 illustrates a single handle which is used for the same purpose, as well as for water, gas, and steam cocks. It is made in the same way that eye-bolts are manufactured, see Fig. 131 ; the hole is then punched with a square punch.

Figs. 191 and 192 show the shank ends made large enough to admit of two holes being drilled in same, one under the other, and one at right angles to the other, so that a loose bar or lever may be slipped through to turn the spanner. The shank end referred to is made by welding a collar round the shank when the job is done by hand ; but when the smith has the use of a steam or other hammer, it is best to work it down out of the solid.

Fig. 201 illustrates a spanner with solid eye. This should be forged out of a bar 2 inches square, and if iron is the material used to make the same, see that the grain runs in the right direction, that is to say sideways, and along the edge of the handle part, or the spanner end will split open when punching and drifting; after forging out the shank, cut off the bar, raise the forging to a welding heat, and round up the boss to close the grain as much as possible, flattening the boss to $1\frac{3}{4}$ inches thick, punch and drift, and by the time the drifting is done it will not be much too thick.

Clutch Spanner.—This type of spanner is illustrated in Fig. 202. To make the same, take a piece of material, right diameter for handle, and commence by bending down the end

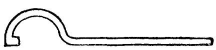


FIG. 202.

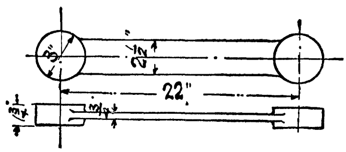


FIG. 203.

of the bar and working it to fit the grooves in the nut, flatten the part that goes round the nut in a bottom swage and bend to fit the nut.

Links for Valve Motion, etc., as illustrated in Fig. 203.—Formerly these forgings were made in two pieces, and were machined separately, after which they were returned to the smithy and shut together; but since mild steel was introduced to the trade, it has become the practice to make them in one piece, mainly to avoid the shut, but also to save expense of same.

To make these links, take a piece of mild steel about 2 inches by $2\frac{3}{4}$ inches and stamp out the boss at each end of the piece with a pair of rings, as illustrated in Fig. 204, which shows the position of the bar when ready for stamping; see that the rings are set exactly one above the other and watch carefully as the stamping proceeds to see that they do not drift apart; if they do get out of position, it is best to stop stamping at once, and work the boss back into the correct position even if has to be done by hand, for if the bosses once get out of line with each other, the more you persist with the stamping, the more will they go out of position; forge out the centre portion with the flat pallets; pare or cut away the spare bits left between the rings round about the end of the forging and swage up same with side swages. Note, stamping in this way will pull down the steel from 2 inches in depth to about $1\frac{3}{4}$ inches, spreading in proportion, thus giving 3 inches by $1\frac{3}{4}$ inches boss.

The quantity of material necessary to make the above link may be calculated approximately with the aid of the tables at the end of the book, and thereby save a lot of trouble in getting the centres of the forging the right length, and with the correct amount of material in same.

Take the bosses first—

Area of 3 inches diameter . .	= 7·06 square inches
Thickness of boss $1\frac{3}{4}$ inches × 2.	= 3·5 inches
	3530
	2118
Cubic inches in 2 bosses . .	24·710

Then for flat portion—

Area of $2\frac{1}{2}$ inches × $\frac{3}{4}$ inch .	= 1·87 square inches
Length of same, say . .	21 inches
	187
	374
Cubic inches in flat . . .	39·27
Add cubic inches in bosses .	24·71
Cubic inches in forging . .	= 63·98

Assuming the piece of bar selected to make the forging from has to be 3 inches square, in which case the area of the section is 9 square inches; divide this into the cubical contents of the forging, $9 \div 64 = 7\frac{1}{9}$ inches, say $7\frac{1}{4}$ inches, which is the length of 3-inch square bar required to work with.

To make the same links, without the rings for stamping the bosses, begin by settling down the steel 3 inches from each end, then forge out the centre portion, and work up the bosses with the set hammer or fuller, as illustrated in Fig. 205, then cut off the outside corners and swage the same.

It is hardly probable that the above links will have to be made without the aid of a steam or power hammer, but, if such

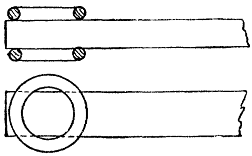


FIG. 204.

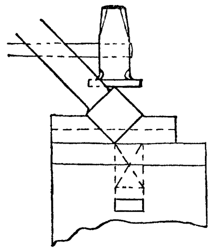


FIG. 205.

should be the case, and in anticipation of similar forgings with deep bosses when the following method of working would be the best, and that too, even with the assistance of a steam hammer, we will consider the making of these links by hand.

The most satisfactory way to begin is, to take a piece of bar, and upset the same about $3\frac{1}{2}$ inches from the end, then

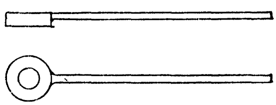


FIG. 206.

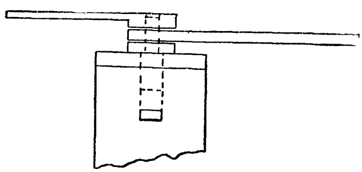


FIG. 207.

punch a hole in same where the centre of the boss is to be, let the hole be well under the finished size—say it has to bore out to $1\frac{1}{2}$ inches, then make it $1\frac{1}{4}$ inches diameter. Now make four collars with the same size of hole, two for each end, out of 1 inch × $\frac{1}{2}$ inch bar bent edgeways; when the collars are made, weld a piece of light bar iron to each of them, as shown in

Fig. 206, so that they can be thoroughly heated, which could not be done while holding with the tongs. Now fit a short peg, $1\frac{1}{4}$ inches diameter, and not more than $1\frac{3}{4}$ inches long, into the swage block or the anvil, to serve as a guide, when welding the collars on to the bar, as in Fig. 207; now place one of the collars on the peg to pack up the bar while the first collar is welded on, so as to bring the work slightly above the top of the peg; raise one side of the bar and one of the collars to a good welding heat, and place together as shown in Fig. 207, and weld with the flattener on the top, work round the side of the collar nearest to the centre of the forging with a swage and see that only light blows are struck while doing the latter; cut off the light bar and repeat the above process with the other collar on the opposite side; this done, take a light welding heat round the end of the forging, and work up with the light hammers, followed by the side swages.

The bosses at the end of the above links can also be made in the following way if desired; in the first place, punch the bar, then make the collars and rivet them in position to the bar, after which heat the whole thoroughly and weld all together at one heat. This method of working will answer very well, while the depth of the boss is comparatively shallow; when the bosses increase in depth and become what may be called deep ones, the same process can be followed, but it must be remembered that in this case the task is not anybody's and everybody's job; it is one thing to heat the shallow bosses thoroughly, and quite another matter to do so with the deep ones, without wasting the material on the outside of the bosses The knack of heating a large body thoroughly, without wasting the material on the outside, can only be gained by practice and experience.

Figs. 208 and 209 illustrate two very excellent tools for working up round the bosses, whether the same have been welded together or forged out of the solid. Fig. 208 is simply a side swage with a slot cut through it to take the flat portion of the link while the smith is working round the boss.

Fig. 209 represents a forked tool with a bolt in same, for adjusting the tool to the thickness of the flat bar; this tool is used mostly for bosses formed away from the end of the bar, or at the corner of a crank lever; when it is in use, it is fixed in the swage block or anvil.

Another good tool is the set hammer, rounded out at the

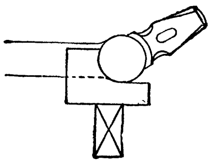


FIG. 208.

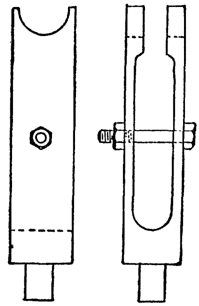


FIG. 209.

sides, as shown in Fig. 210, to fit close up to the boss, and it will be found a great help, if there is a block at hand with a hole in same large enough to lay the boss in, while working on the flat portion round about the boss.

Fig. 211 shows a lever with a large boss on one side of the shank, and a small one at the other end. Commence

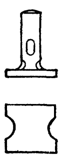


FIG. 210.

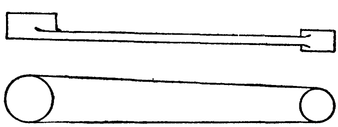


FIG. 211.

with a piece of material large enough to make the big boss, and set the same down at the point marked A in Fig. 212, and forge out the piece at the end to the size of the small boss, see dotted lines in same figure; set down at B sufficient to make the centre portion and forge out the same, then round up the bosses, as in Fig. 205. Or, instead of setting down as at first, the large boss might be stamped with a tool, as illustrated in Fig. 213, which may be made with or without the handle.

We should bear in mind when using one ring only, as in this case for stamping purposes, that the best way to do so is to start by placing the ring on the bottom pallet, and place the work on the top of the ring, and then the operator can see if his job is set fairly over the top of the ring, and he can then turn his work over if required and place the ring on the top when the iron has been marked.

To make this lever by hand, weld the large boss on to a piece of material that is itself large enough to make the small boss, as in the previous instances, and forge the small boss out

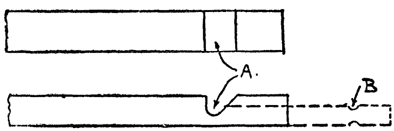


FIG. 212.

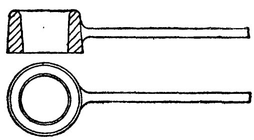


FIG. 213.

of the bar, or weld all three bosses on. Some firms, who use levers similar to the above, but who do not require them in numbers large enough to compensate themselves for the expense attending the process of changing pallets or stamp blocks, will have a number of cast iron blocks made, Fig. 217, one for each size of lever, and these blocks or dies are placed on the bottom pallet of the hammer; the levers are forged so much more in depth and less in breadth or diameter than they are finally intended to be, and cut off the bar, after which they are reheated and the boss is driven into the block awaiting it under the steam hammer, and in this way a lot of handwork is saved. Fig. 214 represents the lever before being stamped, and Fig. 215 the same lever after the stamping process has been performed, and in many cases the lever is made by cutting halfway through a bar that is large enough to make the shank, then bending over the end of the bar one or two thicknesses as required by the size of the boss, and with a welding heat stamping or working by hand in the block, see Fig. 216. They will also have spring tools made or provided for forming

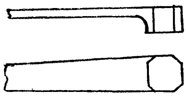


FIG. 214.

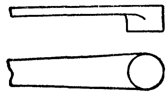


FIG. 215.

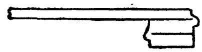


FIG. 216.

the small bosses, as in Fig. 218, and regarding these tools we should note that they must have a good lead on them, as at A, Fig. 218, or the forging will fasten itself in the tools.

The end of the lever is usually roughly cut round before stamping in the spring tools, and after the latter process is

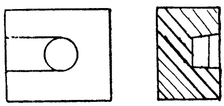


FIG. 217.

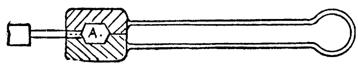


FIG. 218.

done, the centre part is either forged out or cut away, according to the quantity of material required to make the length needed.

Fig. 219 is another pattern of lever. It is made in much the same way as the others, stamping or setting down the centre boss first, and forging out the ends to the size of the

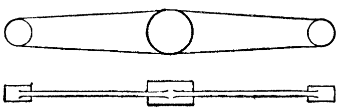


FIG. 219.

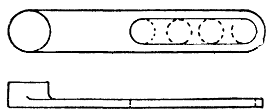


FIG. 220.

small bosses, then forging between the bosses, and finishing off as before.

And we should note that for forging down between two points at short distances like these levers, when the hammer pallets are too broad to work between the bosses, that the best substitute for the hammer pallets is a pair of spring tools, with flat pallets, of which there should be at least two pairs in the shop, say 2-inch and 4-inch. The 4-inch will answer for working up to any length by moving the forging to and fro.

Fig. 220 is another shape of lever, but it is forged in much the same way as the others, only in this instance there is a long slot hole forged in the flat portion. To make the slot, punch a hole one at each extremity of the place where it has to be, but about ½ inch short of the full length, and one in the middle (the small circles in the slot in Fig. 220 denote where

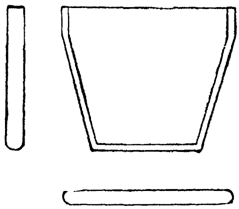


FIG. 221.

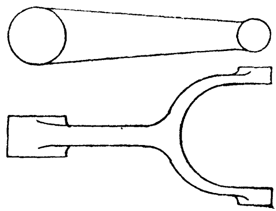


FIG. 222.

the holes should be punched); then cut out the pieces between the holes with a hot sate, and work up on a drift made right for the job. The drift should be as shown in Fig. 221, and the bolster to use in conjunction with this drift should be a piece of flat iron, bent as in Fig. 161.

If the slot hole is required to be square ended, then use a square punch in place of the round one, but do not have the corners of the punch and drift sharp, or they will cut into the material and start a fracture, and so make a bad forging. We have already called attention to this matter elsewhere, but as it is so very important, it cannot be too strongly emphasised.

Fig. 222 illustrates a lever with a forked end, and while we are considering the subject of levers, we may as well turn our attention to the above forging, though it is a much more difficult task than anything we have dealt with yet, and will require considerable skill and experience to perform the same.

Mild steel is the best material that can be used in making a forging of this description; it is easily worked, and the forging has a good appearance when finished, owing to the homogeneous and seamless nature of the material.

Iron can be used for such forgings, but it should be of a very good quality, and close grained, and even then the forging may exhibit the seams before it is finished.

Begin by selecting the piece of mild steel; let it be large enough to make the biggest boss comfortably, then taper the material towards the other end, which should be left large enough to make the two small bosses when split down the centre as shown in Fig. 223. Now shoulder down the forging

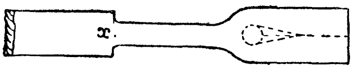


FIG. 223.

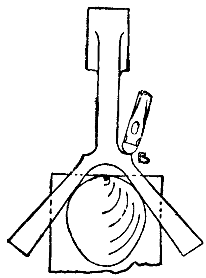


FIG. 224.

as at x in Fig. 223, and cut off the bar, round up and finish off the large boss. Now we come to the fork end. Begin by punching a round hole as shown in Fig. 223, and split the forging from the end up to the hole just made, pare off any jagged bits that may present themselves, open back the ends, taking care they do not crease at B in Fig. 224 during this process. The best way to open them out is to start by driving in a fuller from the end, and as soon as they are wide enough apart to span the beak of the anvil, place them on the same, and open by working a fair size fuller, say 1 inch, on the shoulders, avoiding the risk of creasing at that particular place, see Fig. 224. If it should happen that there is no full-sized sketch of the fork at hand, and there is no chance of getting one supplied, then the best thing to do is to make one, and measure what each end has to be from the centre of the fork; it can easily be done by laying a piece of twine round the centre of the part to be measured, then forge out the ends to the length while they are straight; and form the bosses one at each end of the fork, as shown in Fig. 225. Now close the legs of the fork inwards, and set on a suitable drift, a piece of round bar, or on the beak of the anvil.

Note.—This lever may be required with the small bosses placed on the inside of each arm of the fork; when such is

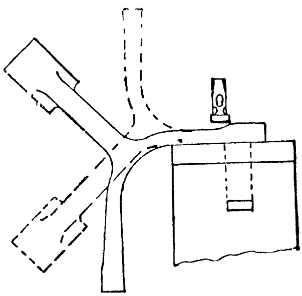


FIG. 225.

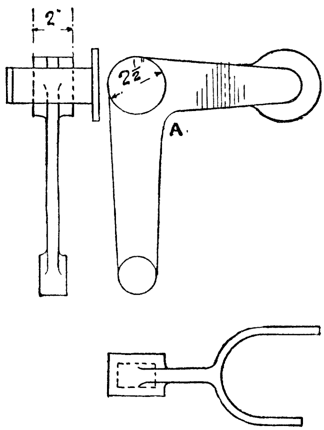


FIG. 226.

the case it is only necessary to reverse the process of forging the ends, as shown by dotted lines in Fig. 225.

Fig. 226 represents a bell-crank lever with a forked end, the fork having one arm larger than the other. Possibly a learner, or for that matter an improver, or even a smith, when eyeing the sketch over, may feel somewhat staggered at the complex nature of the article, especially if they do not happen to have seen anything of the kind made; but after all, the forging is not so awe-inspiring as all that, and while it is such jobs as these, that find out those smiths that are wanting in resource, and that have less tact, less ingenuity, and that are less thoughtful than others, it is at the same time just such jobs that often serve to put a man on his merits, and prove his worth or otherwise as an all-round man. The very awkwardness of the task is the virtue of the job, and the man can see that when he has finished the forging his efforts will not only tell in his immediate interests, but they will single him out as one having ability and judgment, as well as decision. This all goes to show how necessary it is that a smith should see to all his interests, and exercise himself in all matters that tend to train, to educate, and to organise his faculties, and prepare himself for unexpected eventualities.

We will now consider how to make the bell crank in question, with the aid of ordinary smiths' tools and appliances. Take a piece of steel and forge the same, as shown in Fig. 227,

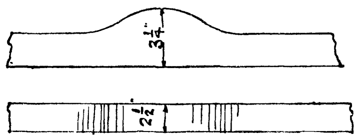


FIG. 227.

then bend by placing the forging thus made across a large swage or V-block under the hammer, as shown in Fig. 228, with a knobbler on the top as indicated at x in the illustration just referred to, and work up as shown in Fig. 229; at this point we should note that it is a matter of great importance in making this lever, that the bending just done should be so performed that the subsequent working of same will be favourable; that is, we should look ahead, and bear in mind that when we begin to stamp the boss at the corner we shall have to forge the web, as shown on the inside at A, Fig. 226, and this will open out the lever considerably, so our best plan is to bend the forging well in now, say to 80° instead of 90°, and at the same time taking care that the parts marked B B in Fig. 229 are in line with centre and ends; work them down with a set hammer, as shown in the illustration just referred to, better too much than not enough. Now stamp the corner or centre boss with rings, as illustrated in Fig. 204, and as explained when considering the making of previous forgings; or, as an alternative shoulder down with fullers, as shown by dotted lines in Fig. 229; but by far the best and most satisfactory way would be to use the rings, and if there are none to hand, make a couple; the difference in the time taken to make the boss with the fullers and with the rings, will certainly more than repay for the cost of the rings. Now forge out the long end, and the small portion between the boss and the fork; the latter will have to be done with fullers and narrow set hammers. Now

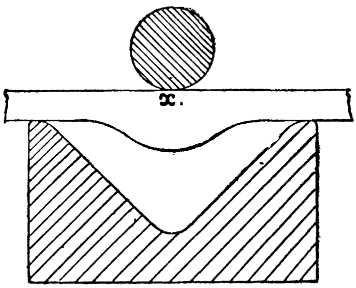


FIG. 228.

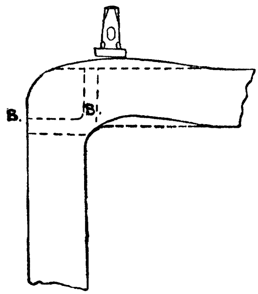


FIG. 229.

the fork; make this part of the forging in a similar way to the lever illustrated in Fig. 222, except when splitting from the hole to the end; in the lever referred to it will be seen that the split was made evenly or midway between the two arms, but in this case the split should be made unevenly, that is, it should be directed nearer to that side of the fork where the small arm has to be, so that the larger one can be got by flattening out the extra material left at that side by taking the split nearer to the small arm.

Fig. 230 illustrates a three-ended crank, and the most satisfactory way of making this forging is to weld the centre arm into the other one, weld on the bosses, and then forge out the ends of the crank, cut off the end with a sate curved to about the right radius. The best and simplest way to weld on the centre arm, is to follow out the instructions already submitted on page 108 when considering the making of spanners, i.e. where the question of welding the shank to the jaw of a spanner

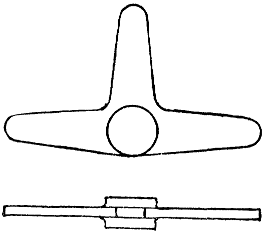


FIG. 230.

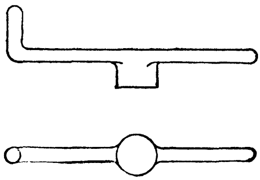


FIG. 231.

is considered, except that in this case the bar will be straight, and will be worked on the flat instead of on the beak of the anvil.

Fig. 231 illustrates a lever which is often used in connection with brakes. To make the lever, take a piece of square material the right size for the boss, and containing sufficient weight to

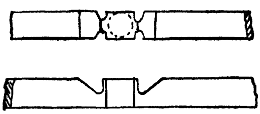


FIG. 232.

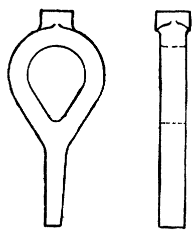


FIG. 233.

make the arms, heat the same and shoulder down with a piece of round iron under the steam hammer, as in Fig. 232; or, if there is no hammer at hand, do the same with fullers at the anvil, then turn the forging half over and shoulder it down that way up, as illustrated in Fig. 232, with the piece of round, and follow it with the side fuller.

Now forge out the ends and round up the boss with fullers and set hammers, as in Fig. 181, and with swages on the parts where they can be employed.

Small Lathe Carriers, see Fig. 233.—When making the above it is advisable to slightly flatten a piece of round mild steel, large enough and heavy enough to make the forging; then heat and punch a slot, or two round holes in the flattened part, cutting out the material between the two round holes; open the forging out by inserting drifts, and work to shape on same and on the beak of the anvil; forge out the tail for driving with.

Very large lathe carriers and similar forgings should be made the same way as are the brake levers, see Fig. 231, except that the shanks in the case of large lathe carriers are of different

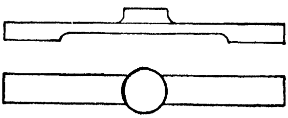


FIG. 234.

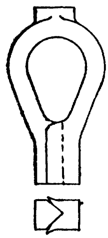


FIG. 235.

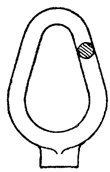


FIG. 236.

section, and should be left thicker at the ends, where they are to be welded together, see illustration Fig. 234, which shows the forging ready for bending; Fig. 235 illustrates the same forging bent ready for welding. It is most essential in this sort of tool, that the weld should be a thoroughly good one, or otherwise it will open in time, through the heavy work it has to do. It is advisable, therefore, not to weld the two flat faces at the end of the arms together, but to have them scarfed to fit one inside the other, as at A and B; the forging will then be very much stronger at the weld than it would have been if the two flat faces had been welded together.

Swivels for Chains, Hooks, etc., see Fig. 236.—These forgings can be made in the same way as lathe carriers; the only difference between the two forgings, is, that in the case of the lathe carriers, the sides are somewhat rectangular or square, while the sides of the above swivels are round in section, and worked into the shape of a link at the end away from the boss, whereas in the lathe carrier there is a sort of tail formed for driving with. We should, however, note with regard to these forgings, especially when the swivels are made by the method suggested in the case of large carriers, that it will be advisable to leave both sides of the arms square at the root, adjoining the boss, say for 1½ inches or so therefrom, until they have been bent, as then the process of bending will not crease the arms at this part so quickly, as would be the case if they were forged round in section before the bending was done; a glance at the illustration A and B, in Fig. 237, will make this clear;

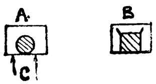


FIG. 237.

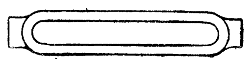


FIG. 238.

for instance, take the case of the round shank, as in section A: if this is bent it begins to crease at once, where marked *c*, and later on, if the bending were continued, would develop into a fracture; but experience proves that with a square rooted shank or arm, the bending process can be effected with less risk, and the sides can easily be worked round with a fuller afterwards. Weld the ends of the arms together as in the case of the eye-bolt, see Fig. 135.

Coupling or Buckle for Tightening Screws, Fig. 238.—These articles vary so much in length and general dimensions that we cannot undertake to say that any one of the following processes could be best used in making them. We shall, therefore, try to so illustrate these couplings, that when a drawing or sketch is submitted for, say, the reader to make one from, he may be able to select for himself the best way to adopt, and have no difficulty in making same. The usual way to begin is to take a piece of material equal in section to a little more than one half of the ends. Say the ends are to be 2 inches diameter; in that case select a piece of material 2 inches by $1\frac{1}{4}$ inches, and forge out the two sides, as shown in Fig. 239; then shut the two together at one end, rounding them up at the same time, work up the weld between the two sides with a foot fuller, as illustrated in Fig. 240. This foot fuller is best fitted with an iron rod firmly riveted in; wood shafts are not strong enough to stand the vibration caused by the head of the tool not standing directly over the working part. Treat the other end of the coupling forging in the same way.

Another way to forge is to take two pieces of material the right size for the sides, and after jumping up the ends, weld a piece in between to form the round ends, as shown in Fig. 241.

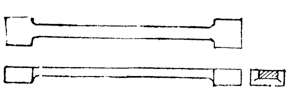


FIG. 239.

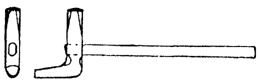


FIG. 240.

FIG. 241.

The centre-piece should be large enough to make the gap the right width and the end right diameter.

Another way of proceeding is to make two ends, as in the case of the lathe carrier, before being welded up, see Fig. 242; scarf each end of the arms and bend one end outwards as shown, so that it will be out of the way when welding the other, and not cause trouble by fouling with it and thus preventing the first shut from coming together properly; make the weld marked A, in Fig. 242, on the thin end of the anvil, if they are wide enough to go on same; if not, use a cranked tool, as illustrated in Fig. 243, to weld them together. Some smiths would use a saddle tool, as shown in Fig. 244, for this purpose, but the cranked tool is far the best for shutting purposes, as it permits rapid manipulation of the forging from the flat side to the edge, and thus allows all parts of the weld to be hammered quickly while the heat is still good. Now close down the other side and weld it on the same tool.

Another method suitable for making a small coupling is to forge the centre portion out of a piece of round right size for the ends, as in Fig. 245, punch holes as shown and cut from one to the other, then drift out the forging to the width the gap has to be, and forge on tool 243 or 244, or on drift and bolster as in Fig. 221.

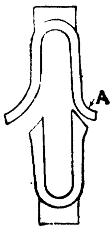


FIG. 242.

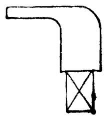


FIG. 243.

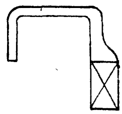


FIG. 244.

Fork Ends, see illustration, Fig. 246.—This particular shape of fork end is more generally used than the others.

When one or two forgings are required similar to Fig. 246, it will be advisable to forge out of the solid. If there is a steam hammer at hand, and a pair of tools as illustrated in Fig. 177, proceed to forge the boss in them, leaving sufficient material projecting from the swages to make the portion

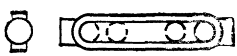


FIG. 245.

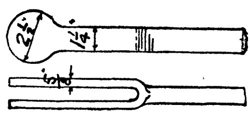


FIG. 246.

marked A B in Fig. 247. Forge out the end, rectangular, 2 inches by $1\frac{1}{2}$ inches, and shoulder the same down at C, $\frac{1}{2}$ inch shorter than the jaw is to finish to, and then forge out the round end. Now punch a hole as shown at D, with either an oval or a small round punch, and cut off the bar; now cut out the material between the end of the forging and the hole, as indicated by dotted lines in Fig. 247; then insert a drift or glut, and proceed to work on the shoulders in order to lend a good finish to the forging at these parts, or place the fork in a tool as shown in Fig. 248, and strike on the end of the drift; then close the sides of the forging on to the drift; do this on the flat of the anvil with a flattener on the top, swage round the bosses to obtain a good finish; see that the sides are both one length, and quite square one with the other. To make the same forging without power is altogether another matter; in that case we shall have to be more careful as to the size of the material, and not waste our strength by taking a larger piece of iron or steel to work at than is absolutely necessary. The bosses are the largest part of the forging, and there are two of them to be made

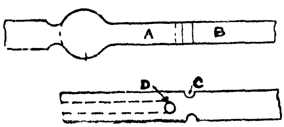


FIG. 247.

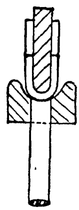


FIG. 248.

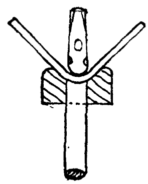


FIG. 2

out of the original bar, so $2\frac{1}{2}$ inches $\times$ $\frac{5}{8}$ inch $\times$ $2 = 3 \cdot 12$ square inches, area of section through the two bosses, and $1\frac{7}{8}$ inches square $3 \cdot 51$ or $1\frac{3}{4}$ inches $= 3 \cdot 06$, so $1\frac{7}{8}$ inches will be the most suitable size for our purpose.

Begin with a good welding heat about 6 inches up the bar, then flatten same to about $1\frac{1}{2}$ inches thick, with the grain along the narrow portion, shoulder down at C, Fig. 247, 1 inch shorter than the fork has to be when finished, forge out the shank part $1\frac{1}{4}$ inches diameter, cut sufficient off the bar to make the bosses, take a light heat on same and roughly swage round the end; punch the hole as before, and this time split the forging down the centre from the end to the hole, instead of cutting the material out as we suggested when making the forging with power, because in this case we are working with less material and will require all we have in the bosses and sides (read paragraph on page 122 dealing with levers with fork ends). The bottom of the fork may be shaped in a tool as illustrated in Fig. 248, or with a fuller on the inside while open as in Fig. 249 ; close the sides on to the drift as before.

This same fork end is sometimes required with raised bosses as shown in Fig. 250, and when that is so, a piece of larger sized material must be selected to work on. Proceed as before so far as the roughing and opening out the sides of the jaw are concerned, taking care to get the right quantity of material between the root of the jaw and the bosses ; then forge the

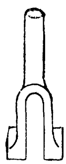


FIG. 250.

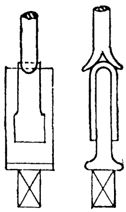


FIG. 251.

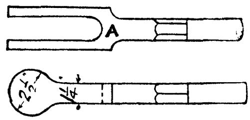


FIG. 252.

raised bosses in the same way as the fork end in lever shown in Fig. 222.

The above forgings are sometimes made by welding the shank on to the jaw, but this method of working does not meet with our approval, and although we are going to explain how the same is done, we do not recommend it. Take a piece of $1\frac{1}{4}$-inch round iron about 9 inches or 10 inches long, upset the same at one end, and split with a small fuller, see Fig. 251 ; the ends are then opened out and a piece of flat iron is bent U-shaped to form the jaw, the same being narrowed in at the small part of the jaw ; this makes it slightly thicker and better to weld on to. The two pieces are now raised to a welding heat and hammered together on a tool in the anvil, see Fig. 251, and finished off as before.

Another pattern of fork end, illustrated in Fig. 252, has a square root to the shank, the bottom of which, between the round and the square, is made octagonal, and the shoulders marked A are more pronounced. The best way to make this forging is out of the solid.

This particular pattern of fork end is the best shape to adopt when the forging has to be made in two halves, with a round bottom to the fork. The two sides should be forged out of $1\frac{3}{8}$ inches square, as shown in Fig. 253, leaving them a little thicker and wider at the part marked A in Fig. 253, to allow for waste during the welding together, which may be done by heating separately and placing together on the anvil side by side, one of which is resting against a swage or other tool placed in the anvil; the striker should then give a blow to fasten them together, and the forging can then be turned and worked in the usual way; by adopting this plan of putting to-

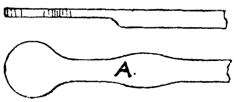


FIG. 253.

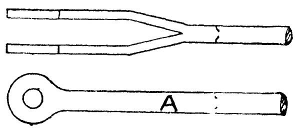


FIG. 254.

gether, the smith can see that the pieces are going together in correct relation the one to the other; or, as an alternative, the two sides may be placed together while cold with a piece of packing between the bosses, and held with a pair of tongs while being heated and welded together. The previous method suggested for welding together will give the best results, because in that case, the parts that are to meet, and that are to be merged into one can be heated more thoroughly when taken separately. A foot fuller is a useful tool for the bottom of the fork, and should be used for same. When the two sides have been welded together, fuller down at the shoulders where marked A in Fig. 252, and forge out first to the square then the octagon, and afterwards swage the round end and set the fork on the drift; see that the sides are equal in length, and the forging is finished.

Fig. 254 illustrates another form of fork end, which is usually used in connection with bridge and structural iron work. It is, we may say, always made by forging two sides and then welding them together, but we should think that the cost of making these forgings conld be reduced considerably, if a hot saw was placed in the smithy, as then they could be made much more expeditiously; for instance, if made out of the solid, and split up the centre with the saw, they would be made in two heats at the most, and perhaps in one, as after sawing they could be opened back ready for the drift, and punched under the hammer or press, and set on the drift. But very few smiths' shops are provided with a hot saw, so we will devote ourselves now to the old method of making these articles, as that is the method which is most likely to be useful to our readers.

Begin by taking a piece of iron equivalent in breadth and depth to one of the bosses, preferably a little narrower and thicker, as the finish of the forging will be improved if a little flattening is done during the making. Have a pair of pallets in the hammer, one half of which will shape the boss and a portion of the shank, as shown in Fig. 255; the other half of the pallets to be flat for working on the flat portions of the forging, and working the end marked A to size required; first shape the boss by holding the bar edgewise in the hollowed portions of the hammer pallets, then flatten same and forge out the end on the flat faces of the hammer tools, leaving the ends large enough to allow for welding together; punch the hole over a die, similar to that illustrated for collars, etc., and cut off the bar. When welding the sides together, it is usual to use a pair of special tongs for holding same while heating and forging out the shank; they are very similar to the ordinary flat bits, only that one of the bits has a round stud forged on to it, see Fig. 56 A; the stud referred to fits into the holes in the sides of the jaw, and keeps them even in length; it is a common practice to put a washer between the bosses, but in this case not so thick as in the other instances, because the bottom of the fork being pointed instead of round needs no working up with the foot fuller when welding; weld the two sides together, forge out the shank, and with the same heat open out the arms and set or finish on the drift or glut.

Fig. 256 represents still another form of fork end, to make which, in small sizes it will be best to punch a square bar with a slot punch and forge to size on a cotter drift; set down at A,

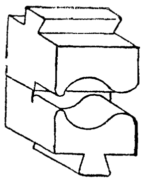


FIG. 255.

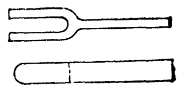


FIG. 256.

Fig. 257, and forge out the end, then cut off the bar and pare the ends of the fork round.

When large fork ends, shaped as in Fig. 256, are in request we should say set down first at A and forge out the shank, then cut off the bar, punch a round hole and cut out as shown in dotted lines, Fig. 258, or split down the centre and open back the arms of the fork, convenient for forging. Before leaving

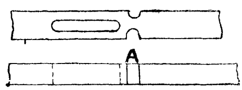


FIG. 257.

FIG. 258.

this subject we should note that when there is much forging to be done at the sides, it is best to open out to right angles, see Fig. 225, so that the part to be worked can be readily got at with the necessary tools, or forged out under the hammer. It is a mistake to try to do a lot of forging on a saddle tool, as some smiths will persist in doing, instead of adopting the above course, and any smith that has tried both ways will readily admit that this is the case.

Fig. 259 represents a connecting rod with a long fork and a strap, used very much for mining machinery. To make the above, begin by taking a piece of material (mild steel preferred) sufficient to make a part of the forging, say from D to B, and before we proceed with the explanation, we would say, that we do not recommend making this rod with short ends at A for shutting, as shown in foregoing instances, because by that method, there would in this instance, be no saving in time or labour, and the distance between the shoulders of the fork is not long enough to make a good reliable shut. We therefore would suggest that the material referred to, should be forged to a suitable size for the strap end D, say 2 inches thick by $2\frac{1}{4}$ inches wide, the round portion between the fork and the strap should then be shouldered down, and the remaining

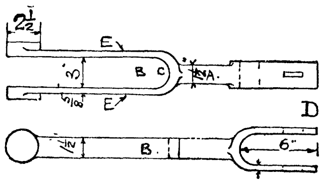


FIG. 259.

piece at the end, that is to form the bottom of the fork C to about B, should be forged out until it is about $1\frac{5}{8}$ inches thick by 2 inches wide, see Fig. 260. Now punch a hole D in Fig. 260 through the $2\frac{1}{4}$ inch end, and split up the centre, or cut out a piece as shown by dotted lines, and finish off the strap end first; while these ends are being forged, it will be best to open out the arms until they are almost straight, to get the large radius required in the bottom of the fork, see Fig. 224; this should be done on the beak of the anvil. Now "set," as in shop phraseology the process would be expressed, or, in other words, close back the arms on to a drift or on to a piece of round, and cut to length on a saddle tool, or the thin flat end of the anvil, then turn round and punch a hole, C in Fig. 260, through the $1\frac{5}{8}$ inch end, split up the centre, and work out the fork B in a similar manner to D, leaving the ends thick enough for shutting, forge out separately the two sides E, E, and finish off same, except the end to be shut on to B, which should now be the next job while the arms of the forging are bent back, or the arms of the forging may be bent into their proper and final shape, and the shut made after this has been done. It is quite an open question, whether it is best to make the shut while the arms are open or when they are bent to shape: quite as good a shut can be made in the one case as in the other.

If the above forging is to be made in wrought-iron, it will be best to punch the holes at C and D one way, that is in the same direction, and twist the forging at A afterwards, on account of the grain in the iron.

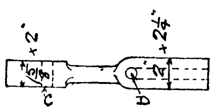


FIG. 260.

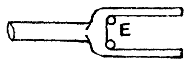


FIG. 261.

In Fig. 261 we have illustrated what is called a strap end. It is similar to the above with one exception, viz.; the bottom of the jaw at E in the illustration is made square instead of round. These are usually forged solid and cut out by machinery, but in the event of any reader having occasion to forge one out, it would be best for him to forge solid, punch two round holes, one at each corner as shown in Fig. 261, and cut from end to holes and from one hole to the other.

When these forgings are made with one fork only, the other end being a plain round, square, or rectangular shank, it allows other methods of working to be brought into play; for instance, the shank can be forged out, and the same placed in a bolster under the steam hammer while the ends are worked out in the form of a T when the ends of the flat part thus produced can be bent to form the jaw.

The T is sometimes made by welding the shank to a piece of flat bar, which method will sometimes end in the presence of a bad looking tear at the edge of the scarf when the bending is done, and for this reason we do not recommend it for any high-class work. In some forgings, however, such as handrail pillars or stanchions that have a flat foot at the bottom for bolting or riveting to a platform or some similar structure, the welding has to be done as stated above. But at the same time, there is more than one way of doing it, and the circumstances of the case only can decide which of those ways is the best to adopt. For instance, say we require to weld a foot to a long shank or stem, it perhaps would not be convenient, perhaps not possible, to place the stem downwards in a bore or bolster, to enable us to work on the back of the flat, while if the shank was only about 12 inches or 14 inches long the latter would be easy enough, and in this case, providing the mouth of the bore was cut away to form the radius required at the root of the stem, it would be the best way to adopt. Again, it might happen that the section of the shank was such that no bore in the shop would suit it, and in that case, it would be decidedly to a smith's advantage to be competent to proceed without same, so with that object in view, we will try to illustrate some of the different ways of dealing with this kind of forging.

To begin with, and as an example, say we wish to weld a shank $1\frac{1}{4}$ inches diameter by 12 inches long to a piece of flat bar $2\frac{1}{2}$ inches by 1 inch, as shown in Fig. 262. Start with the piece of $1\frac{1}{4}$ inches round; prepare the end for welding by raising quickly to a welding heat, upset the end as in Fig. 263. (Note.—Heating the piece quickly will give the shortest possible heat, and therefore make the most suitable end.) Now lay in a swage with the shoulder against the edge, as shown in Fig. 264, and work back the scarf with hammers to the shape shown in Fig. 265. Now take the piece of flat bar $2\frac{1}{2}$ inches by 1 inch and bob-punch a hole in the centre of same, as described in making bottom swages by hand; raise both to a welding heat, lay the flat piece on the anvil and place the prepared end of the round shank in the hollow formed by the bob punch; let the striker give three or four blows to drive it well home, then turn over and put the shank in a bore if there is one the right size, and work on the plain side of the flat. The sides of the flat piece will now be bulged out, and may be cut off or worked into the flat foot by working on the edges; and when important work is in hand, this latter practice is generally

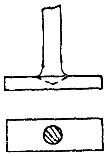


FIG. 262.

FIG. 263.

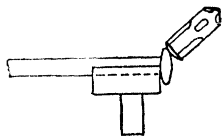


FIG. 264.

adopted, by taking another welding heat on the whole, and working to size and shape.

Now suppose the shank was a long one, say a hand-rail, pillar, or stanchion, scarf the end of the round as before, and bob-punch the flat piece as in the last case, and when welding the two together, lay the flat on the anvil with the hole upwards, place the prepared end of the round in the hole in the flat

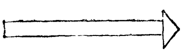


FIG. 265.

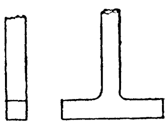


FIG. 266.

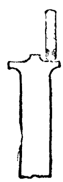


FIG. 267.

part made by the bob-punch, and press home the round; then lift up the lot, i.e. the round and the flat together, and drop on the anvil two or three times. Complete the weld by working on the scarf with a fuller or round-edged set hammer.

Suppose we required to make a forging as shown in Fig. 266, and that it had to be done by welding, instead of forging out of the solid; we could proceed as before, except that the stem being as wide as the foot, will not need an overlapping scarf at two of the sides; nevertheless, it will be well to have a little material at these two places to work on. Another way to make the forging would be to scarf the end with a small fuller as shown in Fig. 267, and fuller out a groove across the foot to receive the same as shown, see Fig. 268; and we might require to weld a flat stem to a flat foot, similar to the butt end of an eccentric rod, as in Fig. 269; in this case, an oblong hole should be punched in the foot and the flat stem scarfed to suit. When welding these together, make sure of welding the ends A A at the first heat, it will then be an easy matter to reheat along the sides B B and weld them one at a time.

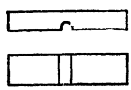


FIG. 268.

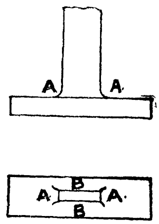


FIG. 269.

All these methods give better results than the welding of two plain faces together; because it is, in a sense, splicing one into the other, and the hollows or grooves insure their being welded together in the right place.

Handrail stanchions, or pillars, we have already illustrated and explained the making of the foot for same, so to complete the forging it is only necessary for us to say that the balls are usually made by bending collars, made out of half round beading iron and welding the same on to the shank in special tools; one pair of which is recessed with a ball in the centre, while the other pair is made with one end blank. Sometimes the balls are required to be flattened to a given thickness, and in other cases they are simply drilled to take the rail without any flattening at all.

Another style of hand-rail pillar, or stanchion, is illustrated in Fig. 270, the only difference being that instead of a flat foot it has a collar forged on, with a continuation piece below the same, screwed to receive a nut. It is used in connection with iron and steel platforms, where the end can be put into a hole; the nut is screwed on underneath to tighten against the collar. It is usually done by welding a collar made out of square iron, of a small section, on to the round bar, with tools similar in design to those for welding loose collars on a mandrel, see

FIG. 270.

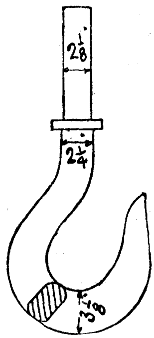


FIG. 271.

Fig. 151. It is usual when bending the collars to leave them slightly open so that they may be readily slipped on to the round iron; heat the round bar where the collar has to be placed, upset the same a little, slip on the collar and close down the same, raise both to a proper heat, and weld in the tools mentioned above. These tools should be well greased when put away, so that the working parts will not deteriorate by corrosion.

The above stanchion can also be made out of the solid with tools similar to the above, except that they are fitted to the hammer or made in the form of spring swages to use at the steam or power hammer.

Hooks.—Fig. 271 represents a hook as used for a 7-ton crane, but before we proceed to consider the manufacture of these hooks, we must call attention to the necessity for exercising the greatest care and judgment in the manipulation of the forging. We need, perhaps, hardly remind our readers that the lives of many fellow workmen may depend on the quality of the hook. The material used in the manufacture of same will, in all probability, be specified by the engineer who has ordered the hook, and in that case, so far as choice of material is concerned, the smith's responsibility ceases when he has made the hook as specified.

If, however, the smith finds that he has no specification to fall back upon, and that he not only has to do the work, but that he has to choose the material also, then, perhaps, the following remarks will be useful under the circumstances; we have known hooks made of iron and mild steel, and we have never known a mild steel hook to break, but for all that, we do not feel ourselves at liberty to strongly recommend mild steel for this purpose in preference to good iron; because experience, according to reports that reach us, shows that mild steel fractures do occur, and that none of our scientific or practical men, who have examined them and made the most searching tests and analyses, can understand or account for same; if mild steel is used, be sure that it is mild and of good quality.

However, whether the hook is made in iron or mild steel, some part of the work will be the same in each case, so we can proceed; take a piece of material large enough for the collar, shoulder down at both sides with a piece of round iron under the hammer, see Figs. 33 and 34, and forge out the short end to about $2\frac{3}{8}$ inches diameter; that will allow $\frac{1}{4}$ inch for turning; cut off the bar and forge out the other end. We must note that the largest part of the hook has to be $3\frac{1}{8}$ inches diameter, and the length of same when ready for bending should be [illegible]$3\frac{1}{2}$ inches, that is from the top side of the collar to the end, which length is found by laying a piece of string round the centre of a full-sized sketch. The hook should not be forged a straight taper from A to D and again from D to C, Fig. 272, but should be what would more appropriately be called a fishback taper; the easiest way to forge such a taper, if there are no special swages, is to use a loose swage or V-block on the bottom pallet of the hammer, with ends turned down to steady it and to hold it in its place, and pack up one end of the tool with a piece of flat bar to obtain the taper; the thickness of the

FIG. 272.

packing may be varied according to the amount of taper required, and it can be used at either side of tool, see Fig. 273. The hook is now ready for bending: and it is here where most of the mistakes are made; for instance, cutting or nicking the material with a sharp-edged tool, bending too much in one

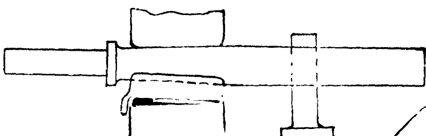


FIG. 273.

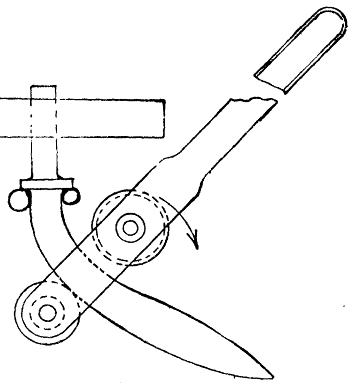


FIG. 274.

place, bending at too low a heat, etc., and all these points should be guarded against. First take a short heat at A and place the end B in a block or in some other position where it can be held securely, and bend as near as possible to shape with a large pipe or lever slipped over the end C, or by striking with the sledge hammer at C, and now, if there is a proper bending block and tools similar to those illustrated in Fig. 274, the body of the hook may be bent thereon by arranging a suitable collar and pegs to hold the hook, with the lever and grooved roller. Fig. 274 shows the arrangement with the hook in position ready for bending.

But suppose we have to bend the hook without the aid of the bending arrangement referred to, we should begin by first bending at A as we did in the previous instance, then bend the body of the hook over a large swage block with a large hook swage, see Fig. 275, taking care that the bend is uniform by moving the hook and the swage to and fro, and seeing that the swages do not cut or crease the hook in any way; when the bending has been done as far as advisable in this way,

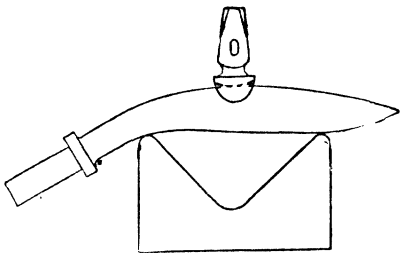


FIG. 275.

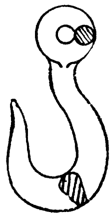


FIG. 276.

the forging may be turned up on end for further bending under the hammer, providing the stroke of the hammer is long enough to allow of this being done; if not, it must be done with the sledge-hammers. The section through the bottom of the hook in this case is a plain flat, which can now be forged under the hammer; some hooks are forged taper towards the outside edge, see Fig. 276, and where this is not done in special stamping blocks, it is best to flatten on a taper tool under the hammer.

Small hooks are made in exactly the same way, except that the bending may be done over the beak of the anvil, rather than spend time fitting up tools, especially when small quantities only are required.

Another form of hook is illustrated in Fig. 276; this shape of hook is used chiefly for chains. Begin by first making the eye; take a piece of round mild steel large enough for the body of the hook and upset the end of same until it is large enough to make the eye, by punching with a small punch and afterwards drifting the hole out to the size required; work up on the beak of the anvil and with the bob-punches and link-swages.

The same process may be followed if the hook is being made of iron instead of steel, besides the other alternative methods suggested in the manufacture of eye-bolts, see p. 75.

The tools described for making the sides of fork ends, see Fig. 255, may also be used for forging these hooks and eye-bolts when the dimensions agree in each case. Begin by using a flat bar about the width and thickness required, stamp the eye, round up the body of the hook with the flat part of the pallets, flatten the eye by passing through on to the back part of the pallets, punch the hole, cut off the bar, and work up the eye with tools, as in the case of eye-bolts; bend the eye back over the beak of the anvil, or in a swage with corners rounded off, and bend the body of the hook in the way already explained. For further hook bending see the summary under Bending.

Hoops.—A blacksmith may safely assume that he is likely to be called upon at any time to make a supply of these all-important articles, since they are so common in the engineering and other trades. Hoops do not appear to be very important forgings, but unless a smith is very careful in reckoning out the length of his material, or if he does not understand the proper way to ascertain that length, he will cause himself a lot of unnecessary work and waste a deal of time over them; and, with a view to simplifying matters and helping him in this respect, so far as the necessary calculations are concerned, we have appended hereto a tabulated statement of diameters and circumferences which will assist him very considerably if used in conjunction with the following rules; but before we proceed to these rules, we should note that in measuring diameters of hoops with a view to ascertaining the length of material necessary to make the same, we should bear in mind that experience proves that if the length is based on the inside diameter, the bar when cut and bent will be too short to make the hoop in question, and on the other hand, the same source of information teaches that if the outside overall diameter be taken as a basis for calculating the length, the bar when cut and bent will be too long to make a hoop of the specified size. The rule must be, therefore, to measure the diameter for this purpose from a point midway between the inside and the outside diameters of the hoop, or, which amounts to the same thing, take the inside diameter of the hoop and add thereto the thickness of the bar; for instance, say we require to make a hoop 14 inches inside diameter out of 1 inch square bar; in that case, take 14 inches, the inside diameter, and add 1 inch to same, which is the thickness the hoop will be when made out of 1 inch square bar, and we have 15 inches as the mean diameter of the hoop; refer to the table of diameters and circumferences, and opposite the diameter 15 inches will be found 3 feet $11\frac{1}{8}$ inches circumference, and if this length of iron was bent into a hoop, so that the ends would meet, the inside diameter, if measured, would be found to be 14 inches, as required; but the weld is not made, and in order to do this without diminishing the diameter of the hoop, we must add to the length of the bar in each case a sufficient allowance for this purpose; the amount usually added in a case like this is the thickness of the bar, which would bring the length up to 4 feet $0\frac{1}{8}$ inch. Some smiths, of course, require more material for this purpose than others, but the general allowance for upsetting and welding in such a case is the amount we have mentioned, that is for bars up to 1 inch thick; but this allowance does not necessarily increase in the same ratio as the size of the bar being used; for instance, if a 2-inch bar instead of a 1-inch had been selected, an allowance of $1\frac{1}{4}$ inches for upsetting and welding would be ample for most smiths; and we may note in passing that this rule will apply to any width of iron or steel, so long as it is bent on the flat and not edgewise.

Now cut the length 4 feet $0\frac{1}{8}$ inch off the bar, upset about 2 inches from each end, and scarf ready for welding the ends together. In the case of the 1-inch square bar, the simplest way to do the scarfing, and also the most satisfactory way, is to proceed as if we were going to shut two plain pieces together, then bend the ends that have been scarfed to the curve of the

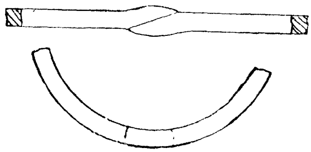


FIG. 277.

hoop as far as the heat will allow; do this with the scarf on edge, as shown in Fig. 277, so that, when bent round, the ends will come together, as shown.

This hoop may be bent cold, if a fairly strong set of rolls are at hand, but it would be better to heat for rolling, especially bearing in mind that the hoop we are making is rather small in diameter.

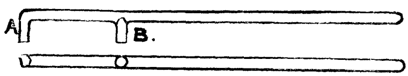


FIG. 278.

If we have no rolls for bending purposes at hand, we may, perhaps, have a block or ring, that we can use instead, that is something like the size of the hoop we are working on; in which case fasten the same to the bending table and arrange a stop of some kind to hold one end of the hoop; and after heating the bars fasten one end and pull the other round to the block with the tongs, or with a lever specially made for the purpose; a very useful and suitable one for such a job as this is illustrated in Fig. 278. Fig. 279 illustrates how the lever is worked; for instance, it is hooked at A inside the foundation ring, and the projecting stud B presses against the side of the bar to be bent. Follow round as shown, taking a fresh piece of the bar being bent each time, and it will soon all be brought up to the block. A in the illustration shows the first position of the lever, D and C represent the bar being bent, B shows the second position of the lever, and so it goes on until the hoop is bent as required.

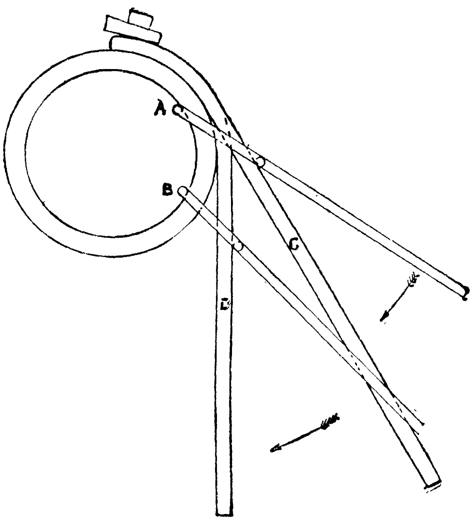


FIG. 279.

But if there happens to be no block as well as no bending rolls, then the hoop must be bent in another way; heat as much of the bar as you can, if possible the whole of it, then take hold with a pair of hoop tongs, and hold with one end resting against the anvil, or on a block, and work inside with a large fuller or round edged set hammer, until the back is bent all the way along it, see Fig. 280, when it may be placed on end, and hammered to complete the bending. Heat the scarfs and close neatly together; raise to a suitable welding heat, and weld first on the flat of the anvil, then on the beak of the anvil, or on a special tool placed in the hole at the square end of the anvil, as illustrated in Fig. 281.

The hoop now requires rounding and levelling, and one method of doing this is to heat the hoop all over, and then drive it on to a cast-iron cone, as illustrated in Fig. 282, after which it is levelled on the levelling block or table. Another

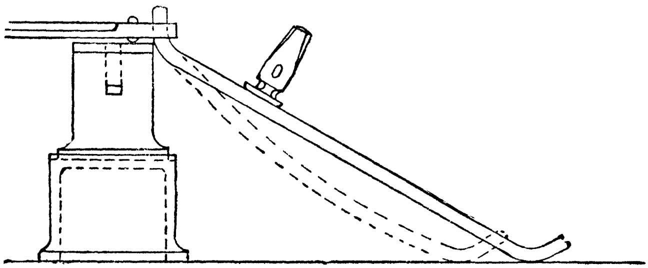


FIG. 280.

method of rounding hoops is by means of a cast-iron circular block made in segments, usually six in number. The segments can all be made from one pattern, the centre part of each segment being cut out to make room for a drift, see Fig. 283. The hoop is laid round the segments, in the centre of which a drift is used to force the segments outwards, to round up the hoop. If the segments happen to be too small for any particular hoop, the difficulty can be overcome by bending pieces of wrought-iron to fit round each segment, and so increase the size of same as required.

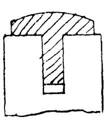
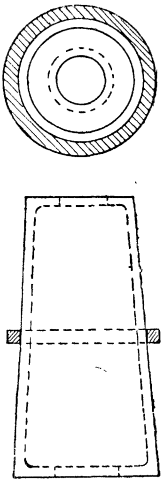


FIG. 281.

We will now assume that we are to make a hoop 14 inches inside diameter with 2 inch square iron. The first thing we want to know is what length of 2 inch square iron shall we need to make the hoop. As we explained before, take the inside diameter of the hoop, which in this case is 14 inches, add to it the thickness of the bar, which is now 2 inches, and when the two are added together we have 16 inches as the mean diameter of the hoop, and on referring to the table of diameters and circumferences, we find that for a circle 16 inches diameter, the circumference is 4 feet $2\frac{1}{4}$ inches, add to this say $1\frac{1}{4}$ inch for upsetting, and we have 4 feet $3\frac{1}{2}$ inches as the length of bar necessary to make this hoop.

With the object of showing another method of scarfing, Fig. 284, we shall go through with this forging. First take a heat on the end marked A in Fig. 285, upset as before, taper the



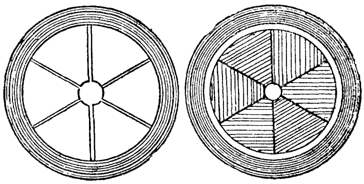


FIG. 283.

FIG. 282.

FIG. 284.

end wedge-shaped, and pare a little of the thin end thereof, so that the inner side of the scarf will be shorter than the outer side; bend the end to something like the radius of the hoop over the beak of the anvil. It is better to do this bit of bending now, than leave it to be done on the block, with the other bending, and we shall find that a bent end is better to wedge against a round block. Now upset the other end of the forging and taper as before, but this time split the end with a hot sate, and open out to the full width, so that it can receive the other wedge-shaped end when bent. The process of bending will be the same as in the last hoop; but suppose when the hoop is bent and ready for welding, it should require tightening up to bring the ends closer together, in that case give a blow with a heavy sledge hammer on the inside of

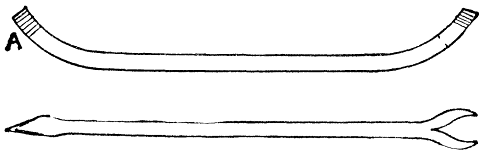


FIG. 285.

the hoop over suitable bearings, when the hoop is large enough to permit, see Fig. 286, or it may be done by bending in the heated ends from AA until they meet, see Fig. 287; of course this will slightly alter the shape of the hoop, but that is a matter of no consequence, seeing that the hoop will have to be blocked later on; it is, however, of the greatest importance that

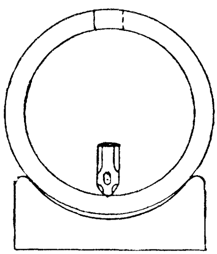


FIG. 286.

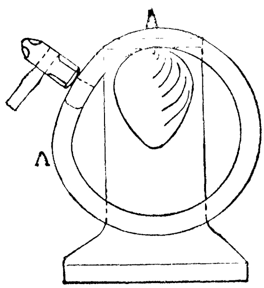


FIG. 287.

there should be sufficient material for welding; it will require a little practice to get these scarfs to come close up inside and outside alike, but if there is a small hole or space not filled up with the tapered end fill it up with a small wedge or piece of iron when closing up for welding. The blocking process will be the same as in the last hoop. Now take another example:

say we require to make a hoop 3 feet diameter inside, out of 3 inches by 2 inches bar bent with the flat, so that the hoop will be 3 inches deep, see Fig. 288. The hoop in this case, may be made in precisely the same way as the one we have just been considering; it is not necessary, therefore, to repeat all the details here. The length of material also can be ascertained as before. But as another method of scarfing suggests itself, we submit an illustration, and if our readers will refer to Fig. 288 we think they will grasp the idea at once.

It may occasionally happen, in the experience of a smith, that he has a rather stiff hoop to weld, and his fire not being equal to the occasion, he is unable to get a proper welding

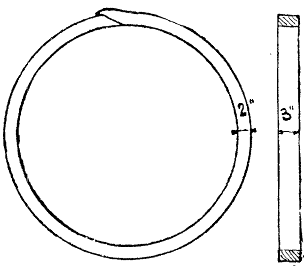
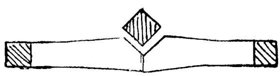


FIG. 288.

FIG. 289.



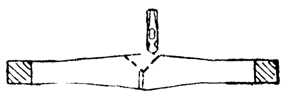


FIG. 290.

heat right through the section of the hoop; in that case his best plan will be to bend the hoop, after sufficiently upsetting the ends, and bring them well together, then cut a piece off each end, forming a V extending nearly half-way through the forging or thereabouts, as illustrated in Fig. 289, then take a welding heat on same, and against the time the heat is ready, have another piece of material, large enough to fill the V, heated and weld into the same, then turn the forging over and treat the other side in the same way; pare or cut away the overhanging pieces after the welding is completed and finish off with the flattener. Instead of cutting out the V as shown, some smiths will take a welding heat on the butted joint, and form the V by driving a fuller first in one side then in the other, as indicated in Fig. 290, with the idea of welding the middle lip this way; they then fill up with a piece of other material as before, but this seems a waste of time and labour, because if two good gluts are properly welded into the V's, one at each side of the hoop, the forging will be quite as good as it can be. Some little work with the flattener will be necessary on the outside, to bring the same to a good finish, after cutting away the spare material. The diameter of the hole in this case is too large to hang on the beak of the anvil in the ordinary way. Some smiths will have a hole dug in the floor under the beak to drop the hoop into, others again will do the same work by having a tool in the anvil, and working sidewise at the forging, and others will do it by working chiefly on the inside.

Suppose we had to make a hoop the same diameter as in Fig. 288, and with the same size of bar, but this time with the bar bent edgewise. We should require to calculate the length of material in the same way as before, viz. 3 feet + 3 instead of 2 inches, because, in this case the bar is to bent edgewise; this gives a mean diameter of 3 feet 3 inches, opposite which, in the table referred to before is 10 feet $2\frac{1}{2}$ inches circumference, to which add an allowance for upsetting. We do not recommend to scarf this hoop by pointing and splitting, but would recommend either to V up the weld, or scarf same as in Fig. 277.

To make a hoop, say 3 feet 4 inches inside diameter of 7 inches by 1 inch material, or any similar section. First ascertain the length of material that will be required, by the method already explained, have the same cut off the bar; have one end scarfed plain by cutting a corner off the same, or by fullering it out, as shown in Fig. 291; then split the same up the centre just a little beyond the scarf, and raise one half of the scarfed portion upwards, and turn the other half in the opposite direction, as illustrated in Fig. 292, and treat the other end in exactly the same way; but note, do not split too far beyond the limit of the scarf, or more work will be occasioned than is necessary, through the extra material requiring to be worked down. It may happen that the bending machine is not strong enough to bend these hoops cold, in which case it will be necessary to heat them for rolling.

When the hoops are bent, and the scarfs brought closely together, lay them on one side until nearly cold; then with a rail bender or jim crow, on the part furthest from the weld, with the screw inside the hoop, screw up until the ends of the hoop are sprung tightly together. The reader would notice when we started to speak of these particular hoops, that we made no mention of upsetting during the scarfing process, for the simple reason that if the above springing in is properly carried out no upsetting before scarfing is necessary; the secret of success in this case is the springing in previous to heating the hoop for welding.

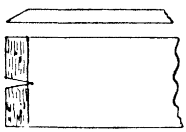


FIG. 291.

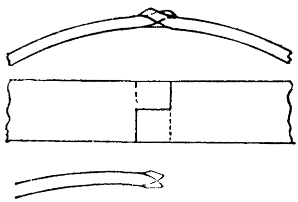


FIG. 292.

The spring put into the hoop with the rail bender forces the ends together, and causes the forging to do the jumping or upsetting, and assists the welding itself too as the work proceeds. It will be found that this method will insure the best possible weld, as all the forces brought into play are tending to assist with the weld.

There are several ways of handling large hoops while welding same, and in our opinion the best way of doing so is that which we illustrate in Fig. 293, assuming that there is a light jib crane in the smithy that will reach over one of the fires large enough to do the work. The tuyere in the fire selected should be at least 2 inches bore for this work. It will be seen from Fig. 293 that the idea is to work on the balance system, dispensing with the winch of the crane altogether, and by doing this we save the wages of one man, and the hands that are engaged on the job have direct and complete control over same; the balance weight or weights should be a little less than one half the weight of the hoop, handles, etc. taken together, when working a single chain against a double one, as shown, so that

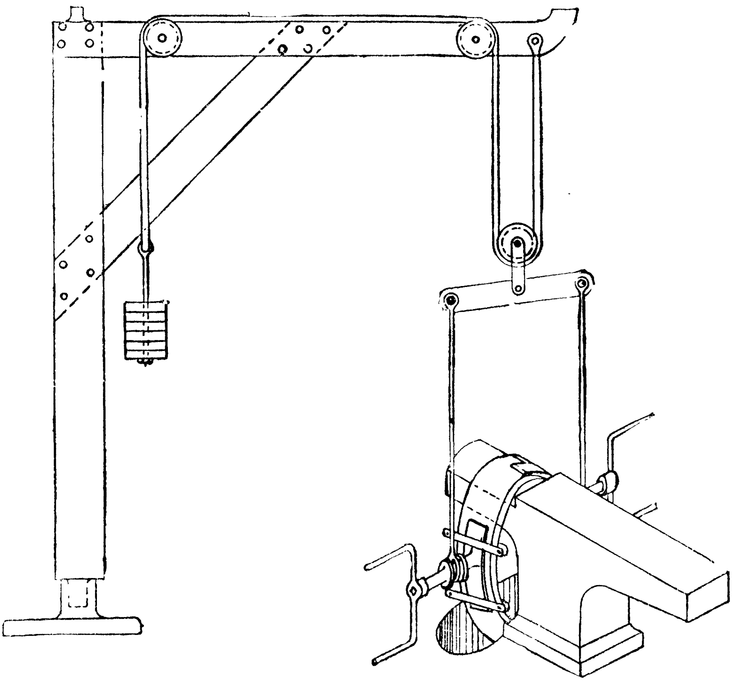


FIG. 293.

the work will stay on the blocks when it is wanted there, without holding and without being released from the chain; the two men who bring the work from the fire will then be at liberty to work on the job and assist with the welding if required.

The hoops in question, although made of mild steel, require to be thoroughly welded, and to have a good finish put on them, and the whole of the work should be done in three welding heats at the most with ordinary sledge hammers and flattener. First take a good heat on the centre portion, and have three or four sledge hammers at work on same, then take a heat on one side and have the sledge hammers at work there, then turn up quickly on edge, on the flat continuation of the radial block, and hammer it there; the other side should then be treated in the same way, and the weld finished off at this heat; the hoop will then be practically finished.

When tyres are shrunk on in the old-fashioned way they are heated all over and then forced on the wheel while hot. When they are intended to be fitted in this way, the same heat that does for shrinking will also do for blocking or truing up the circle; but when the tyres are to be fixed on the wheels by the latest process, viz. by compressing the same while cold on to the wheels, the compressor, in this case, will also at the same time round up the tyre.

The scarf we have just referred to, see Fig. 292, is undoubtedly the best known way of scarfing hoops for cart or van tyres, and all light hoops with any spring in them, because, when once sprung the one into the other, there is no further trouble to keep them in position, nor is there any fear of their coming apart at a critical moment during the welding.

The best way to weld small tyres, say up to 3 inches by $\frac{7}{8}$ inch, is to work them sidewise against a special block, see Fig. 294. They should be completed in two heats by two men accustomed to the work.

A, in Fig. 294, is a special block; B a stand for same; C the ears or bearers which carry the hoop while being welded at the front of the block; D a pair of legs made of about 1 inch square bar fitted into the block at one end, to come level with the block; the other is bent down to the floor level, and these are arranged to come one at each side of the fire. E represents a peg in one of the ears C to keep the hoop up to the block while working at the front; F is the tyre.

Take a heat with the hoop reared up in the fire at such an angle as will cause one half of the hoop to be ready first; if possible, weld a little more than one half of the hoop at the first heat at the front of the block, as shown in Fig. 294; then lift up over the high part of the block and slide back on to the

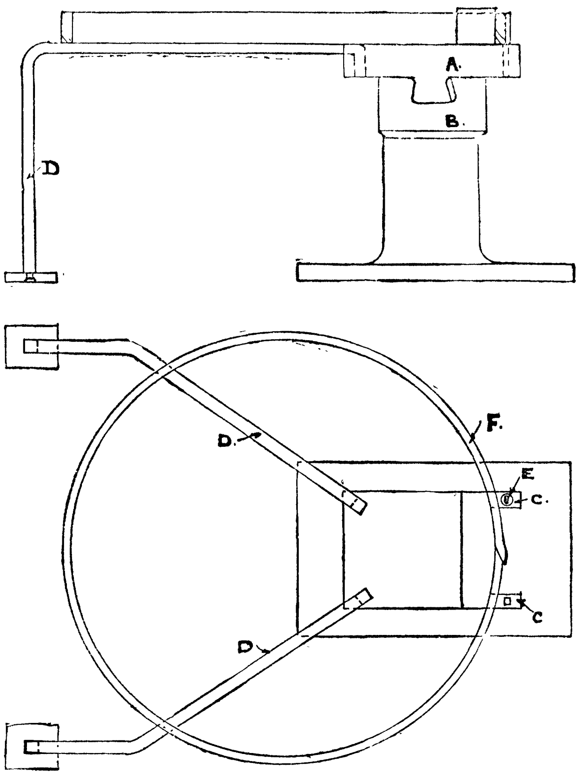


FIG. 294.

flat part of the block and work on the edge, and also inside if necessary · then turn the hoop over and repeat the process on the other side, and finish off with a flattener. The smith, while on this job, will use his ordinary hand-hammer, and the striker a sledge-hammer weighing about 8 lb. or less, according to the work, with a short shaft to same. He will get his blows in quicker and better with a short shaft when striking sidewise.

A smith may be called upon to make a hoop with a flat bar bent edgewise; the process of reckoning the length of material

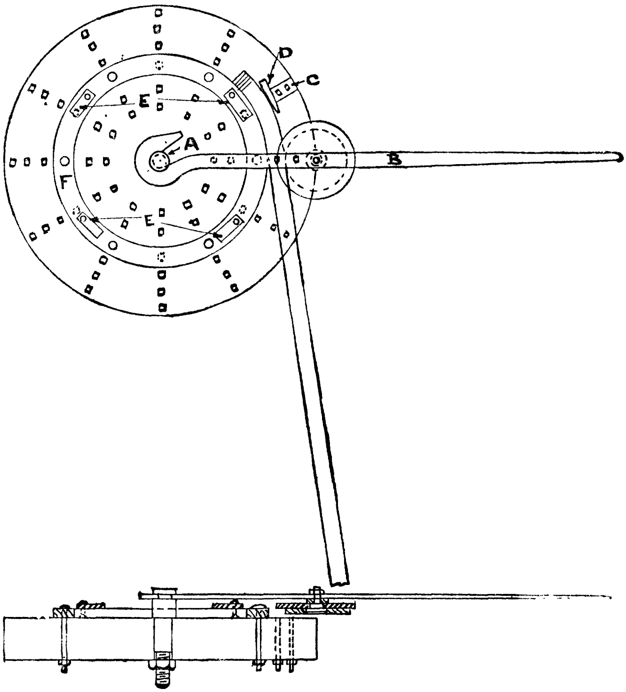


FIG. 295.

is just the same as before, i.e. take the inside diameter and add the width of the bar; say the diameter is 2 feet 4 inches and the bar 2 inches × $\frac{1}{2}$ inch; 2 feet 4 inches + 2 inches = 2 feet 6 inches, the circumference for which is 7 feet $10\frac{1}{4}$ inches; add to this a little allowance for upsetting and welding the same.

The small sizes, say up to 3 inches by 1 inch, are scarfed and bent together as in Fig. 277; the larger-sized hoops of this kind are best Vd or glutted, as in Fig. 289, for welding together. The bending is usually done on a flat table with a foundation ring bolted thereon, to which the hoop is bent; for illustration see Fig. 295.

A is the centre-pin, B the lever hooked at the end to enable it to work easily on the small part of the pivot A (the hook makes it very easily removable); C is a stop to wedge against to hold the bar; D is the wedge; E are small plates riveted loosely to the foundation ring; they are intended to swing round over the hoop as it is bent and prevent it from riding over the foundation block; F is the foundation ring for bending the hoop against.

Oval Hoops.—In the case of oval hoops, the length of material is calculated as follows: add the major and the minor

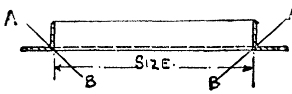


FIG. 296.

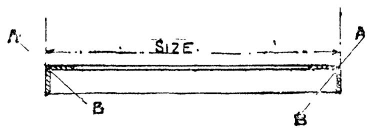


FIG. 297.

diameters together, that is the largest diameter and the shortest, or the length and breadth, and divide by 2, and proceed with the quotient as before. Say we have a hoop to make 12 inches by 9 inches inside diameter, add 12 inches and 9 inches together = 21 inches, divide by 2 = $10\frac{1}{2}$ inches, which is the mean diameter of the hoop, and is used to find the circumference as before.

Angle Iron or Steel Hoops.—This is a matter that is really outside the province of a general smith, and belongs to another branch of the trade, but it so often happens that the ordinary smith has to lend himself to the task, that it is as well he should know something about angle work.

1. To ascertain the length of material.

(*a*) When the flange is on the outside of the ring or hoop, as in Fig. 296, take the inside diameter and add twice the thickness of the root of the angle, as shown on line A B in Fig. 296.

(*b*) When the flange of the angle bar is bent on the inside of the ring or hoop, as in Fig. 297, the hoop is usually measured across the outside, and in this case the thickness of the material at the root of the angle, as at A B, Fig. 297, is multiplied by 2, and then deducted from the overall dimensions.

The result in each of the above instances is the mean diameter; with this information ascertained, proceed as before, i.e. refer to table for the circumference.

A Warning.—We wish to impress on our readers that in practice it is not safe to rely too implicitly on any rule for calculating the length of material required to make angle

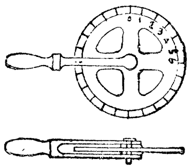


FIG. 298.

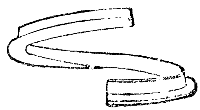


FIG. 299.

hoops. We therefore, recommend them in practice to cut their bars a little longer than calculated; then if they err, it will be on the right side, and they can cut away what they have to spare when the hoop is bent.

When welding small angle hoops, scarf one end to a thin edge and lap the other end over it, and after adjusting the hoop to the correct size, cut off the spare material.

Large angle hoops are better V'd or glut-welded, and when making a large angle ring, cut a bar long enough to have a few inches to spare, then bend to size, and, if available, measure the place where it has to fit with a circular 2-foot rule, see Fig. 298. Then apply this same rule to the hoop in hand and carefully mark off the length just ascertained on to the hoop itself; it would be an easy matter now to cut off the spare material, but we have to make some provision at the ends for welding, this cannot be done with the ends close together, so heat the back of the hoop and put a twist in same, by, as it were, pulling one end upwards and pushing the other end downwards, as illustrated in Fig. 299; prop up the high end while it cools; each end can be heated separately, cut, upset and fullered back. The fullering and upsetting are usually done on the corner of a block, either horizontally or against one of the perpendicular corners of same, as shown in Fig. 300. The hoop is then reheated at the back where it was twisted, and brought back to its former position, and the ends set close together ready for welding. The scarfs of the hoop should now appear as in Fig. 301, the inside view of the upright flange being the same.

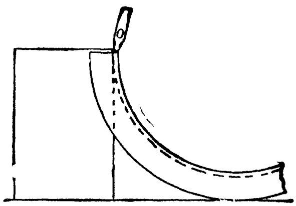


FIG. 300.

FIG. 301.

Take a welding heat on the inside flange; this is the most difficult part of the job. It is usually done by laying the hoop on the fire, and piling large coke up the inside to make a good fire and obtain the necessary heat; nearly every smith will lay a fire brick on the back of the scarf, and experience proves that it is a good idea. While taking this heat, have an assistant at another fire heating a piece of good iron, large enough to fill the V, allowing for a good hammering, and when both are ready, bring out the ring, place it against the top corner of the block, and lay the piece of iron in the upright scarf first, see Fig. 302, work or weld the same with ball-ended hammers: then pull the bar down to the position indicated at B in Fig. 302 and weld up the corner and the scarf A; cut off close to corner in scarf B so as to leave the open scarf along the horizontal flange. Repeat the above process in the case of scarf B; now take reheats as required until all are soundly welded, then trim off with sate, hammers, and flattener.

An angle ring bent with the flange inside, as in Fig. 297, is much easier to weld, because the thin edges of the flanges are not so much exposed to the fire and liable to burn and waste, as when they come on the outside of the ring. The corner should be welded first.

Fig. 303 represents a coned hoop, made of flat bar 3 inches by $\frac{3}{8}$ inch. To make this hoop, first ascertain the length of material as follows: take the inside largest and smallest diameters, add them together and divide by 2. *Example.*—15 inches + $15\frac{1}{2}$ inches = $30\frac{1}{2}$ inches, and this figure divided by 2 = $15\frac{1}{4}$ inches, which is the mean inside diameter, and with $\frac{3}{8}$ inch added for the thickness of the material = $15\frac{5}{8}$ inches,

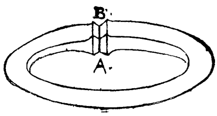


FIG. 302.

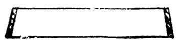


FIG. 303.

the circumference for which, according to the tables at the end of the book, is 4 feet $1\frac{1}{16}$ inches, or in other words, the length of bar to make a hoop $15\frac{1}{4}$ inches inside diameter with bar $\frac{3}{8}$ inch thick, and an allowance for upsetting and welding, say $\frac{5}{8}$ inch, is 4 feet $1\frac{11}{16}$ inches.

Scarf the ends as in Fig. 288 or 292; then the bar must be cambered or bent on edge to make one edge longer than the other. A full-size sketch should be made for this purpose, see Fig. 304. Draw lines A B and C D the same width as the bar and parallel one with the other, mark off the centre line G H from which on line A B mark E $7\frac{1}{2}$ inches to the left and E $7\frac{1}{2}$ inches to the right; on C D mark F $7\frac{3}{4}$ inches to the left and F $7\frac{3}{4}$ inches to the right of the centre line. These points E E and F F are equivalent to the diameter of the hoop at each side. Now strike lines through E F at each side up to centre line, set a pair of trammels to points E G, strike this radius through points E E about another 16 inches at each side, and the same with points F G; bend the bar edgewise to lie on this; it will then be cambered right for making the hoop taper or cone-shaped as shown, without any further extension on the large edge.

Another way of doing the same thing is to make the hoop in the ordinary way to the smallest diameter, and stretch out the large side when blocking.

Tyres for cone-shaped or dodged wheels are often made like an ordinary hoop and then drawn on one edge by hammer-

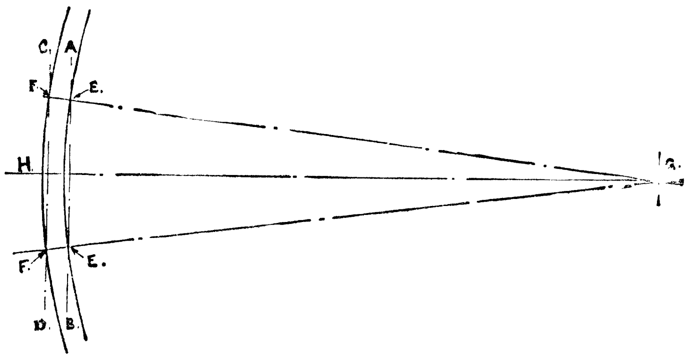


FIG. 304.

ing inside with the thin end of a sledge-hammer, fullering it out with the same.

In other cases where a patent tyre-setter is used to bring he tyres in to the rim of the wheel, the hoop is made large enough to drop over the wheel, and the taper dies of the press force the same up to the wheel, crushing in the small side.

Circular 2-foot Rule, see Fig. 298.—A circular 2-foot rule should form a part of the equipment of every smith's shop. The same should be divided into $\frac{1}{4}$-inch, $\frac{1}{2}$-inch, or 1-inch spaces, whichever may be thought most suitable, for measuring hoops and the places where they have to fit. It is, of course, not absolutely necessary that the disc of the rule should be equal to 2 feet and set out in inches; any size will answer by marking a starting point on the disc and another on the article to be measured; then run the circular rule round, count the number of revolutions, and mark the exact point on to the rule where it comes to the starting point again; the size of hoop required is the result, except that it must be made so much less for contraction. The circular rule referred to is mostly used when hooping cart or carriage wheels. First the wheel is measured, then the hoop or tyre is made so much less in circumference. The tyre is then expanded by heating same all over, put on the wheel and slaked, and as it cools it shrinks to its former size, tightening up the woodwork and fastening itself on.

The amount of shrinkage allowed should be in proportion to the size of the wheel and the amount of pulling up which the woodwork requires. Say we have a 4 feet 6 inch wheel with joints and spokes rather loose; in this case the tyre should be about $1\frac{1}{4}$ inches less in circumference than the perimeter of the wheel. For a wheel 2 feet 6 inches diameter, with fairly close joints, about $\frac{1}{2}$ inch is considered ample allowance for shrinkage.

When shrinking a hoop on to iron, the difference between the two diameters need not be so much, because iron does not give like wood, and too much allowance for shrinkage would put an undue amount of strain on the hoop; if the latter is made $\frac{1}{4}$ inch less in circumference when hooping on to iron, it will be quite enough shrinkage to allow.

Fig. 305 represents a piece of angle-bar bent to form a bracket, or knee. To make a forging of this kind it will be necessary to have a block to work on, with some arrangement for holding the angle-bar up to the block.

Fig. 306 illustrates a block, together with a strap arrangement for holding the angle to the block by means of cotters, marked D, which are driven through the holes in the end of the straps; see letter E which shows the cotter in plan. B is a raised portion of the block, which is about $\frac{1}{8}$ inch higher than the thickness of angle bar, to clear the same. Heat the angle at the part required to be bent, then fasten it to the block with the cotter, and pull the other end of the angle-bar to the block at C. The top flange will buckle at the corner, while this bending is going on, but it must be kept straight or flat by hammering with sledge hammers. When the bar is brought up to the block at C fasten with the other cotter D, and then work it up to a good finish round the corner with the flattener.

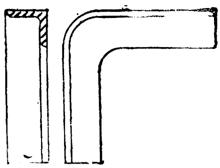
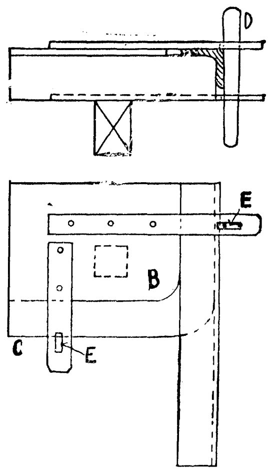


FIG. 305.



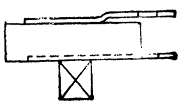


FIG. 307.

FIG. 306.

Note.—A plain block with a corner the right radius would do the above work providing the angle-bar could be securely fastened to it. The straps, in this case, could be arranged and made so that by bending them as illustrated in Fig. 307 they would clear the angle-bar.

If only a plain short end is required on the forging, a strap may be made as in Fig. 308 to hold the first end, but for miscellaneous work open straps are the best—they hold quite as well, and the forging is easily taken out.

Fig. 309 illustrates another good strap for the same purpose.

Fig. 310 illustrates a bracket similar to the previous one, except that the corner is square instead of round. We may point out that the only practical way to get this corner up square is to cut the bar and then bend and weld the same up again as per the following instructions. The only special tool required is a plain square block to weld the corner on and work up the vertical flange. It will be best to fit wrought iron brackets and suitable packing pieces to the block referred to, for holding the angle in position while it is being welded and worked.

Fig. 311 will explain the above arrangement. A is the angle bracket, B the block, C the wrought iron brackets, D the

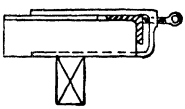


FIG. 308.

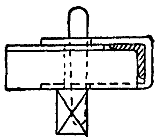


FIG. 309.

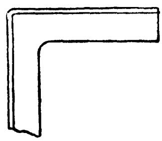


FIG. 310.

packing pieces, of which there should be several thicknesses at hand, according to the angles to be worked. They should be cut out or bent, as shown in the side sketch, so that by loosening the screws, one may be lifted out and another put in without taking the screw right out. The brackets should be fixed at a sufficient distance from the corner to allow that part of the forging to be properly worked up with the flattener, etc.

To make the bracket as illustrated in Fig. 310, begin by marking the bar with a centre-punch where the corner is to come, and mark with a cold sate from that point to the inside at an angle of about 45°, see Fig. 312. Now heat and cut with a hot sate inclined as shown, so that the flange when cut through will be ready scarfed. Do not cut right across the flange, but only into the root of the angle, see Fig. 313. Taking a casual glance at Figs. 313 and 314 a reader might perhaps conclude that the angle, as illustrated, was ready for bending; but that is not the case, as if the angle was bent at this stage, we should have a job to make the corner work up square on the vertical

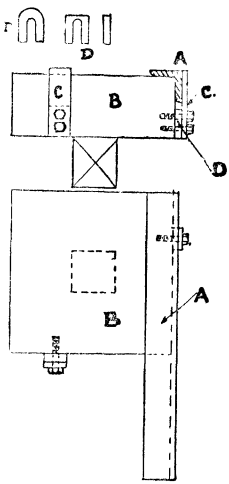


FIG. 311.

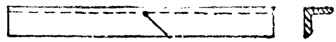


FIG. 312.

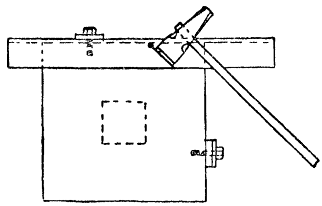


FIG. 313.

flange, where it would be short of substance; and to avoid this and to gain a little material, take a large link, or a piece of round iron bent like a staple, lay the same on the anvil, and lay the vertical flange of the angle-bar on the link, or staple, so

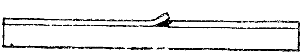


FIG. 314.

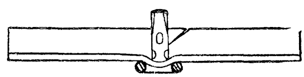


FIG. 315.

that the point where the corner is to be will come over the centre of the link or staple; now set down the flange of the angle-bar into the link, or staple, with a fuller, as shown, see Fig. 315; now open the cut in the bar, as shown in Fig. 316, so that the other flange will pass underneath. Place one end of the angle-bar in the wrought iron bracket at one side of the block, and pull the other end round to one of the sides where there is no bracket fixed; the angle will now appear as represented in Fig. 317. Straighten out the creases or bends, A A, made with the link ; now lay in the block with the vertical flanges in the brackets, close down the top flange, and cut away as much

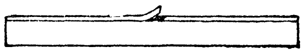


FIG. 316.

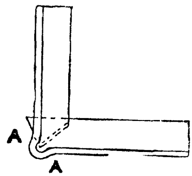


FIG. 317.

of same as is not required for welding, see Fig. 318. Now place the part to be welded on the fire with a piece of fire brick in the corner, enough to cover the whole of the weld, heap up sufficient coke round the forging to go through with the heat; commence with a medium blast, and as the fire

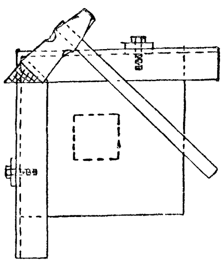


FIG. 318.

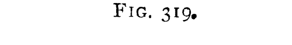


FIG. 319.

burns away, feed it by poking coke from the sides, down and underneath same, with a small rod; be careful not to let the fire burn hollow between the tuyere and the work in hand. When the proper heat has been obtained; bring out the forging and weld on the block. When a bold radius is required on the inside flange, some smiths will heat a piece of round iron in another fire, and weld the end on to the inside corner of the angle along with the other weld; others will rough weld, and while hot, will drive a large burr or a piece punched from a thick bar of iron into the corner, and then reheat and finish off as before.

Again, some smiths when making this corner in angle bar, will cut a piece out of the flange, as in Fig. 319, then scarf both ends and bend, but this is neither so quick nor so good a method as the one we give above, and there is also the risk of cutting too much out, which cannot very well happen in the

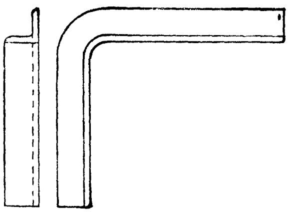


FIG. 320.

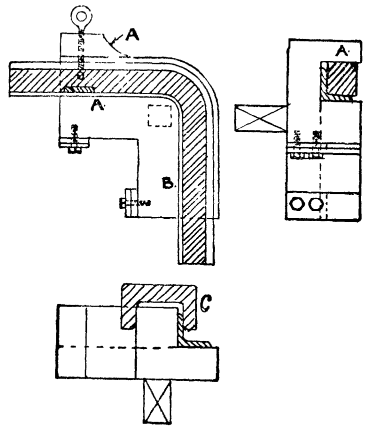


FIG. 321.

other case, where the spare material is not cut away until the corner is bent to the correct shape. Fig. 320 represents a piece of angle bar, bent, with the flange outside, and like the corner we have just been considering, will require a special block to bend or make it on; and even if there are only a few of these corners to be made it will pay to have a block cast for the purpose. Fig. 321 illustrates a design of block that will be found to be very useful and very suitable. Fasten the angle along one side by wedging with a drift against the stop marked A in illustration, or fit a stout screw through same, pull the other end of the angle round to the block at B, and fasten with a clamp or dog, as shown at C; then work the corner up to the block with a flattener.

Fig. 322 represents a similar corner as the last, also made of angle bar, but in this case the corner is sharper than in the last, and made up square on the outside flange. An intelligent reader will see for himself that when this bar is bent round the block it will pull the outer corner thin and narrow, and he will also see that if the corner is to finish up square, it means that some welding has to be done to extend the rounded corner out to the square; the best way to obtain this corner is to cut across one flange, bend, and then weld.

The block illustrated in Fig. 32. is designed to meet the requirements of this forging as well as the previous one. We

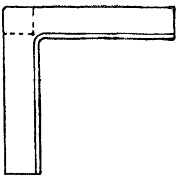


FIG 322.

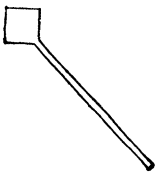


FIG. 323.

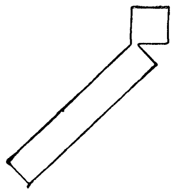


FIG. 324.

may point out that wrought iron brackets, similar to those used in Fig. 311, are a great help when fitted on the inside of the block as shown.

Take a heat on the angle bar, cut straight across one flange from the root to the outside edge, bend the other flange round the block, turn over, and lay the forging in the brackets with the cut flange resting on the top of the block; scarf both ends with a fuller, then take a piece of flat bar, wide enough to fill up from one scarf to the outside edge, and cut a piece off the same sufficient to form a square; weld a piece of light bar to one corner, as shown in Fig. 323, or only partially cut off the bar and bend as in Fig. 324. This piece of iron should be $\frac{1}{8}$ inch or $\frac{1}{4}$ inch thicker than the angle so that it will bear a good heat and the necessary hammering without becoming too thin.

Now heat the angle at one fire and the square piece (or in workshop parlance the "dab") at another, and weld both together on the block. Be careful not to work on one side of the dab too much before the other side is united, or it will draw away, and necessitate filling up with another piece of material. When the welding is done pare off the spare material.

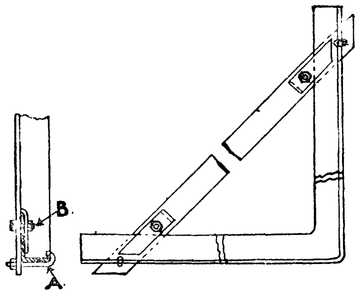


FIG. 325.

When corners, like those illustrated in Fig. 310 and 322, have long ends to them, as shown in Fig. 325, it is advisable to strap them to their correct positions before welding, with a diagonal stay and two hook bolts, as shown at A, or with two

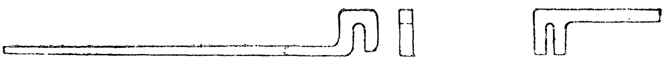


FIG. 326. FIG. 326A.

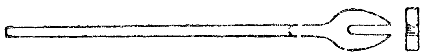


FIG. 327.

clips as also shown at B; if desired, or deemed necessary, both may be used.

Figs. 278, 326, 326A, and 327 illustrate three handy bars or levers for use on angle iron work, i.e. for twisting, bending, and lifting.

Fig. 328 is another lever also used for bending; it is intended for putting on the end of an angle bar, for pulling round when more leverage is required. It is made by taking a piece of strong angle bar, and welding a piece of round into same, then shutting on to a bar of suitable length.

Fig. 329 is meant to illustrate a lever for a similar purpose; it is held on to the work by driving a drift into the jaw of same as indicated at A.

Wrought Iron Tuyeres.—This is a subject that we said in an earlier chapter we would refer to again, and in doing so we will first note the principal points to be aimed at in using tuyeres, so that we may quite understand them, and the purpose they have to serve, before we commence explaining how they are made, then we shall better understand what we are about, what

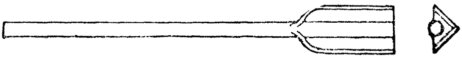


FIG. 328.

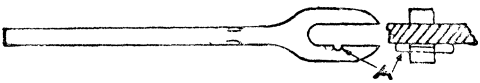


FIG. 329.

we are aiming at, and the importance of each step in the manufacture.

The purpose of a tuyere is to conduct the blast to the fire; this could be done without much ado by means of an ordinary tube, were it not for the fact that the tube would get hot and burn away or choke itself up. It is then such difficulties as these that make the ordinary simple methods of conducting blast through a tube impracticable in case where a fire is concerned, hence it is that some design is essential that will prevent the continual and too rapid waste that takes place in ordinary methods where the tube is in contact with the fire, in order to obviate, or rather to minimise, the expense and loss of time incurred by stoppage and repairs.

To protect the mouth of the tube, therefore, where it enters the fire, a sort of water-jacket is arranged, as illustrated in Fig. 330, and connected with a water-tank, either directly or by means of pipes, so that a constant circulation of water may flow round the nose of the tuyere to prevent the same getting too hot. The construction of the tuyere will, therefore, be according to the method of circulation adopted; in either case the water space at the nose of the tuyere should be about the same; take a $1\frac{1}{8}$ inch tuyere as an example, the nose of which should measure on the outside from $3\frac{1}{2}$ inches to 4 inches diameter, and it is advisable not to exceed these measurements which are proved by experience and practice to be quite sufficient; experience shows that there is nothing to be gained by exceeding these dimensions, and only waste can follow an increase in the heating surface, as in that case the water is converted into steam and evaporated sooner than it otherwise

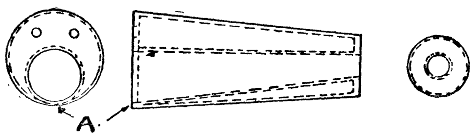


FIG. 330.

would be, and that is not the object; all we seek to do is to keep the tuyere from burning away with as little evaporation as possible. These tuyeres may be anything in length from 12 inches to 24 inches.

There are two kinds of wrought iron tuyere in general use, and perhaps the most common one of all is that illustrated in Fig. 330. It will be seen from the illustration that the inner and the outer tubes are brought close together at the large end of the tuyere; this is done to give space for fixing the supply and return water-pipes, so that it will not be necessary to make the outer shell of the tuyere unduly large.

It is the same in the case of tuyeres as with other forgings; the question arises, how can we best do the work, and what quantity of material will be required. To make the outer shell, we shall require a piece of plate $\frac{1}{4}$ inch or $\frac{5}{16}$ inch thick, and to ascertain the size take the diameter of the ends and proceed as in the case of hoops. Of course, to get at the shape exactly the plate would have to be set out in just the same way as we explained in the case of coned hoops, Fig. 304, but the setting out is not really necessary, and it will prove an advantage to the operator to leave the ends square, and pare away the overhanging plate as he proceeds with the work, as we shall show later on. Scarf one side of the plate; the other will be best left as it is; now bend to shape over a large swage or other block, and weld the tube up the joint as illustrated in Fig. 82. Repeat the above process in the case of the inner tube, and weld on a similar but smaller tool; slightly close in the ends of the inner tube, and open the ends of the outer one, as illustrated in Fig. 331. This is done in anticipation of the

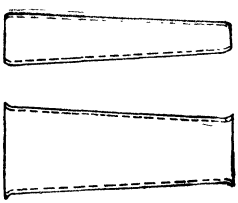


FIG. 331.

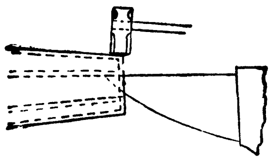


FIG. 332.

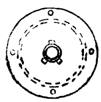
work which has yet to be done before the tuyere is completed, which will increase the size of the inner shell, and reduce the outer one at the ends when welding them up. Make the washer for the small end $\frac{5}{8}$ inch thick, with a hole in same large enough to drive on the inner tube while hot; then burr the end of the tube over to prevent the washer coming off; the outside diameter should be made right size for fitting to the outer tube; heat the nose of the outer tube and fit the inner one with the washer on into the same, and fasten them at the point marked A in Fig. 330, either with a cramp and drift or by lightly welding together to avoid any slipping while taking a heat on the nose; now take hold with a pair of tongs, or use a light portabar as in Fig. 384, heat the nose, and close up any open places; return the tuyere to the fire and take a welding heat at the small end, holding the back end well up, and turning the tuyere round while in the fire; then weld on the beak of the anvil as illustrated in Fig. 332, pare away the overhanging plate, cutting same in such a manner as to close the joints together, not to tear them apart; take another light welding heat, and weld round the nose again, swage round the outside, and clean up the face with light hammer alternately until a fairly smooth end has been obtained. Do not try to work up with heavy blows or the work may be strained and perhaps torn apart, necessitating the whole of the welding process being repeated, which will not be so good a job when done a second time, on account of the additional waste. Now fill up the large end, between the inner and outer shells, with a part of a washer roughly shaped to suit, drive the same in hot, and turn bits of the overhanging plate over the same to hold it and weld up. This welding will take several heats; try about 4 inches at a time, elevating the nose end of the tuyere while in the fire, so that the inner as well as the outer shell will be welded at the same time; pare off the spare plate and swage up as was done in the case of the nose end. The tuyere then only requires drilling and tapping to make it ready for use.

Another style of tuyere is illustrated in Fig. 333. It is so designed that the outer shell can be bolted to the tank side, while the inner shell passes through the tank, and is connected at the opposite side thereof with two nuts, one inside and one outside of the tank as shown, or with one on the outside only.

The hole in the tank side, where the outer shell of the tuyere is bolted up to, is made the same size as the inside diameter of the outer shell, so that, practically speaking, the water space in the tuyere is a part of the tank.

To make a tuyere on the above principle, take a piece of good wrought iron or mild steel tube, say $\frac{1}{4}$ inch larger in the bore than the nose has to be inside when finished, and carefully close in the end with swages, and weld or contract a washer on the same; make the outer shell as in the case of the previous tuyere, but in this case it will be best to shear the large end to shape before bending; then, after the bending has been done and the seam welded up, it should be flanged in the same way that tubes are flanged for testing purposes, which method is explained in connection with Fig. 83. Now slightly open the small end as before, mark off and drill the bolt holes in the flange, because we shall want them in the next process. Now fit the two parts together, and take a piece of plate as large as the flange and make a hole in the centre large enough to take the inner tube, cut three notches or keyways in the same, as illustrated in Fig. 334, and drill the bolt holes same as in the flange of the tuyere; bolt the plate and the flange of the tuyere together, and fasten the inner tube with keys or wedges;

FIG. 334.



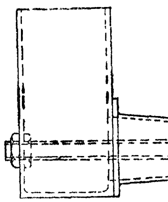


FIG. 333.

the whole is now firmly held together. The projecting piece of the inner tube can now be firmly gripped with a pair of tongs, and the tuyere handled as required for welding up the nose, which process will be exactly the same as in the last case.

The majority of wrought iron tuyeres in use to-day are made according to one or other of the above designs. There are, however, other arrangements of tuyeres, such as the instance where the inner pipe is turned down to pass through the bottom of the tank, and again where it is turned to come out through the end; and where a short end is arranged to slide into the tank, in which case a through pipe is cast in same, and holes are made round about the outside of same through the side of tank to feed the tuyere with water; but none of these

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designs differ very materially so far as the making of them is concerned, so we will proceed to consider the question of repair.

If the nose of a wrought iron tuyere has been burnt through a lack of sufficient water, as already explained elsewhere, it will need repairing, if still long enough to serve again. First take out the tuyere, and if it is much damaged, cut off the portion that is burnt, as illustrated in Fig. 335, viz. with the tuyere on the beak of the anvil, and the sate cutting down the side, so as not to close in the shell any more than we can help; after cutting the outer shell through, the washer had better be torn off the inner tube if it will come off fairly easy, then close in the end of same, and open out the outside tube, see Fig. 336;

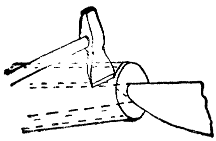


FIG. 335.

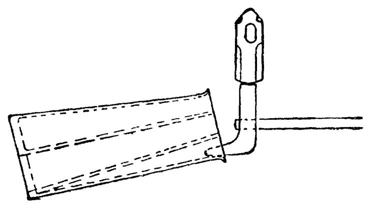


FIG. 336.

make a new washer to suit, drive it in hot, and weld up as before explained. Sometimes the tuyere is only slightly damaged and can be repaired by heating another piece of iron, and welding a bit to the tuyere where defective.

Annealing.—By annealing is meant the act of softening, and is resorted to in order either to accelerate cold working, or to increase the elasticity of the material, and make it less liable to break or fracture. It is performed by heating the material and cooling the same afterwards as slowly as possible.

To do this successfully all cold air must be excluded from the material while cooling. The usual and the simplest way of annealing iron and steel is to cover up the heated forging in dry slaked lime or coke siftings; but special articles, such as files, gun-barrels, taps, etc., are usually packed in special furnaces, arranged so that when the whole of the articles have been raised to the right heat, the air or draught can be absolutely shut out, and the whole left to cool down very slowly, occupying sometimes as much as from 40 to 60 hours in doing so.

Many firms make a practice of having all their lifting-chains annealed periodically, at regular intervals, to release any internal strains in the material set up by lifting.

Blocking, as the word implies, is the act of fitting a forging to a block, see Hoops, p. 151.

Bending.—This is a trade term that hardly needs explaining. It implies the act of making a piece of material assume a required curve or turn, or a succession of curves in some form or other, as for instance a hoop, hook, scroll, corner, or angle.

The process of bending is performed in various ways according to circumstances; for instance, light hoops, such as coach and wagon tyres, are usually bent by rolling in a bending machine, which, by the way, consists of three rollers, arranged so that the one in the centre will press downwards on to the bar that is being bent and that lies between it and the two bottom rollers; or one of the bottom rollers is arranged to act as does the top in the above instance, only that in this case it presses upwards against the bar which is placed between it and the top roller.

But many jobbing smiths do not possess a bending machine, and, consequently, have to find other means of doing this part of their work; and the result is that some really simple, but at the same time ingenious, contrivances find the light of day, proving once again that "necessity" is indeed the mother of invention. In some small blacksmiths' shops the difficulty is overcome by bending two or three pieces of strong angle-bar to different radii, say 12 inches, 18 inches, and 24 inches, which are either riveted or bolted to a plate, which is afterwards fastened on to the outside of the shop wall in a position that is easily accessible.

To use this appliance, take the bar that is to be bent and place the same between the stop and the curved angle-bar on the plate, select that angle-bar for the purpose that happens to be nearest to the radius of the curve required for the bar to be bent, then press the opposite end downwards; this done, push the bar a little further in, and press the bar downwards again; repeat this process again and again, until the end that has as often been pressed down, is now too short, and, consequently, too stiff to be treated in that way again; then take the opposite end, i.e. the one that has hitherto been pressed downwards and

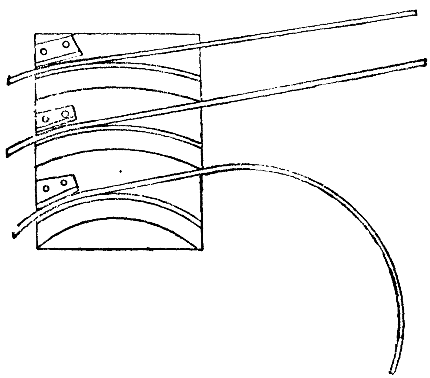


FIG. 337.

insert that end between the selected angle on the plate and its accompanying stop, and this time push the curved end downwards as usual; and repeat the process, pushing forwards and pressing downwards as before, and very soon the hoop will be bent to shape as required.

This bending apparatus is amply illustrated in Fig. 337, where the three bars are shown in position ready for bending; the bottom bar has been previously bent in the apparatus, and the other end is shown in position ready for bending that part of the bar until it meets the portion already bent. It is only necessary to say that the short pieces of angle with the flange downwards, placed above the curved pieces of angle-bar, are intended to serve as a stop when bending.

In some instances the bent angle bars are extended at one side beyond the limit of the plate, as illustrated in Fig. 338, and a bracket is fastened at the end, as shown, and arranged to hang over the ledge or flange of the angle bar to form a stop to bend against.

In the case of all light hoops, such as those used for barrow wheels and other similar purposes, the most suitable tool to use is a piece of flat bar bent to a suitable radius, with a shank to

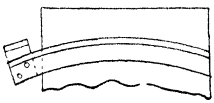


FIG. 338.

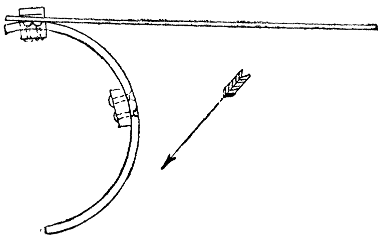


FIG. 339.

same, made to fit the anvil or swage block, or to hold in the vice. A clip should be forged or riveted to the flat rim to hold the hoop, see Fig. 339; which illustration also shows the method of bending with this special tool.

For bending other hoops, see p. 148.

For bending crane hooks, see p. 144.

When a large number of crane hooks of any one kind have to be bent, it will certainly always pay to make a special tool for the purpose. Take, as an instance, the crane hook in Fig. 271; if there were a lot of these to make, a special tool, made as illustrated in Fig. 340, would enable a lot of the bending to be done under the steam hammer, if not all of it. After setting the hook down as shown in the tool, it may then be turned on end under the hammer and bent to shape by judicious handling.

Chain hooks may be bent in a similar tool, see Fig. 341. In this case the ears or lugs of the brackets should be arranged so that they will just admit the eye of the hook between them;

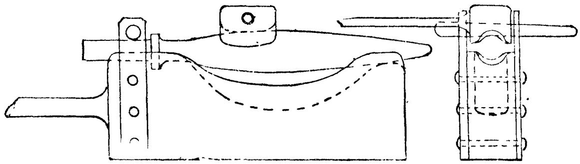


FIG. 340.

the hook can be secured and held in position by passing a key or drift through the eye as shown.

Scroll bending is a very important branch of the trade, especially where ornamental work is the staple industry. This sort of bending is done in several ways, the best of which for wide flat bars is illustrated in Fig. 342. In this illustration, A represents a block on which is cast a raised portion marked B;

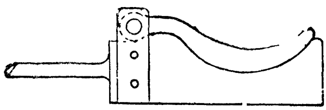


FIG. 341.

the height of B is governed by the width of the bar; say the widest bar to be bent is $2\frac{1}{2}$ inches, then the raised portion should be full $2\frac{1}{2}$ inches high. The bar is first tapered and bent over the beak of the anvil as shown in the first position; it is then heated for a good length from the tapered end and fastened tightly into the centre of the block with a drift marked C in the illustration. The bar is then bent to the block, using a lever as shown at D, if required, to bring up any parts that are not already closed right up to the block. If scrolls are required with more turns than the one illustrated, they are easily done by having loose pieces, as for instance, F in the illustration before us, which can be fitted with dowels to drop into the holes marked G. Scrolls with any number of turns can

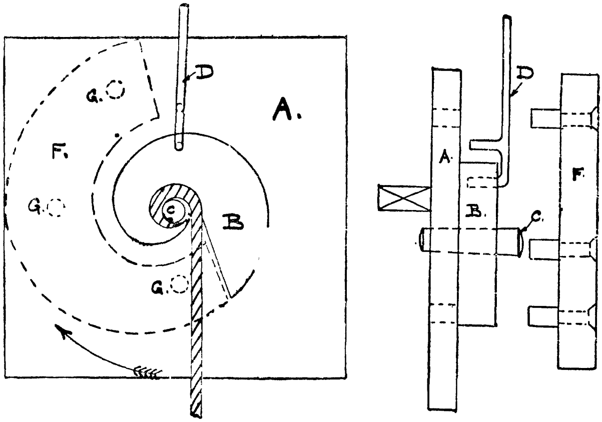


FIG. 342.

be bent in this way, and the operator can rely on them all coming out alike.

When a scroll is required only now and again, it is usually made by bending a wrought iron bar on which to bend the

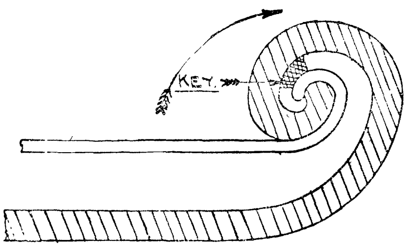


FIG. 343.

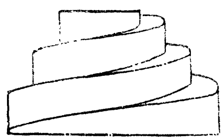


FIG. 344.

same; the end of the bar is tapered and bent over the anvil as before, and then put into the bending bar and pulled round in the direction indicated by the arrow in Fig. 343.

Scrolls made of small rectangular, square or round bars, with a number of coils, are usually bent on a spiral block, as shown in Fig. 344, and then pressed or hammered down flat; the advantage of a block like this is that any number of turns may be made without any other parts; where a scroll has been bent without special tools, the fork tool, Fig. 114, along with the lever, Fig. 326 A, will be found very useful for setting the same.

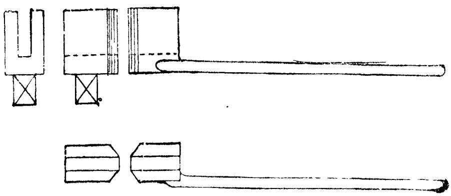


FIG. 345.

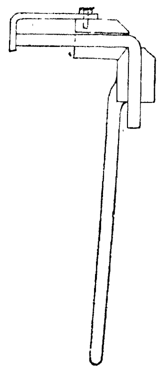


FIG. 346.

Square Corners.—Fig. 345 illustrates a pair of tools adapted to bending or forming square corners on flat bars. They are simply a pair of forked tools, cut or chamfered at one side of each as shown to an angle of 45°. One tool is made to fit in the hole in the anvil, the other one should have a handle forged on, either at the bottom, top, or at one side, as illustrated in Figs. 345 and 346.

The forks should be a sliding fit on the bar, and when a bar is going to be bent it should be marked with a centre punch at the exact place, before heating; the centre dot will then be a guide when bending. If there happens to be a fair number of bars to be bent in this way, and they are required to be all of a length, then a gauge can be fixed to the side of the tool to measure from. A bent corner is illustrated while lying in the tools in Fig. 346.

The tool that fits in the hole in the anvil, besides answering for this purpose, will also do for twisting purposes when required.

A tool for bending a rough square corner is illustrated in Fig. 347; it is a piece of stout bar, bent over square, and shouldered down to fit the hole in the anvil with a cotter hole through the shank to fasten the tool as shown; the bar is then placed underneath and the end hammered down over the corner of the anvil if it is not too sharp for the purpose. Some smiths have this tool to stand a good height, as in Fig. 348, and bend

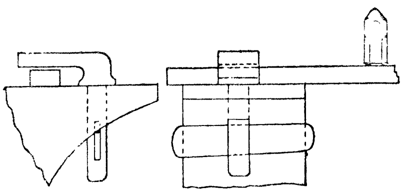


FIG. 347.

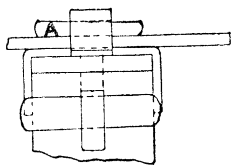


FIG. 348.

pieces of flat bar over the anvil with different radii corners, then by using the tool with the radius required, and the above tool to hold the work, any kind of corner may be bent and finished on the same; if the tool is too high to hold the work, the space between may be made up with a wedge, see A Fig. 348, which holds the work more securely.

Some smiths use a vice for bending such corners, but this is a bad practice for the following reasons: the edges of the vice are too sharp and often cut the material at the inside corner, and, apart from this, the jaws of the vice are not deep enough to bend a flat bar with the end more than 5 inches or 6 inches long, except by bending at the side of the vice, and when hot material is used it softens the teeth of the jaws, and in consequence they soon become blunt and unfit for their work.

Should a corner be required, that is sharper at the outside than any of those we have been considering, it will be best to bend an easy corner without any creases and then work alternately on the outside of same with light hammers, as shown in Fig. 349.

The best way to make a corner, round inside and square outside, with ordinary bar iron, is to cut across the bar with a hot sate, about half way through, then bend, as in Fig. 350, and weld a piece of round bar into the space formed by cutting and bending; this welding is best done with light hammers as indicated in Fig. 349.

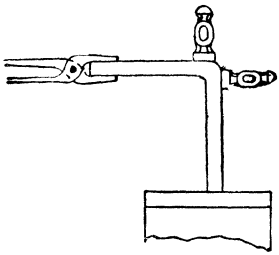


FIG. 349.

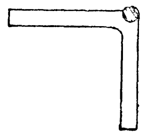


FIG. 350.

These corners may be made by forging a swell on a piece of material where the bend is to be, and then bending same at that place with the swell on the outside to form the corner, as when making bell crank levers (Figs. 227, 228 and 229); this done, work the material forming the swell until the corner is square as required.

Fig. 351 represents an arrangement for bending corners in round, square or flat bars; in repetition work, and where duplicates are essential, this tool is invaluable, and with it the corner can be bent so that it is almost square on the outside. A represents the bar with the corner as it would be bent in this tool; B is the block or body of the tool, and can be made either in wrought iron, mild steel, or cast iron; if made of cast iron, it should have a wrought iron shank cast in, and the part marked X is made to receive the loose blocks C and D; there may, of course, be various sections as well as different sizes, to be bent with this tool, therefore each different size or section will require suitable blocks inserted instead of C and D, as shown in the illustration; E is a loose piece between the two blocks, and shows how the length of the bar may be controlled; F is a key for tightening up the block D against the bar; it is best made of a piece of stiff steel tapered with a flat side to press against the block; G represents a pair of straps fastened

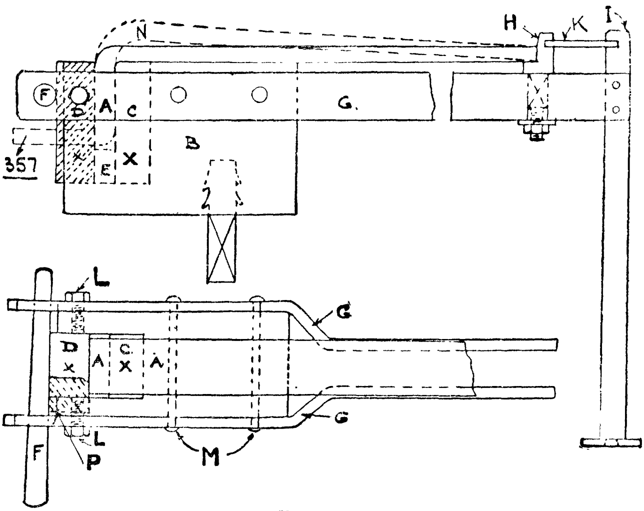


FIG. 351.

to the side of the tool B, with rivets or bolts and nuts; these bars should extend back far enough to take the longest bar required to be bent; the space between them should be about 1 inch to allow the stop H to be fixed at any distance from the tool between the bars. I is another stop, which, besides serving as a distance piece between the bars marked G, also serves as a leg to support the same; K is a piece of round iron, one end of which is let into the stop H, and the other end into that marked I, and serves as an additional support to H; the length of K will be governed by the position of H; L L are set screws to hold the bars G near to the holes for the key, where bolts cannot be put right through, as will be seen on referring to same; M are the rivets or bolts for holding the bars marked G to the body of the tool, and pass right through the same.

Now say we have a lot of flat bars to bend, 2 inches by $\frac{5}{8}$ inch, with one end $3\frac{1}{2}$ inches long, and the other 2 feet 4 inches. First select the necessary suitable block C for this section; in this case D will be a plain block, and the stop E must be placed in position to ensure the length of material being correct in each case; set the stop H at the right length for the 2 feet 4 inches end of the bar, cut a bar the estimated length, say 2 feet $8\frac{1}{2}$ inches, and try it before cutting the lot; heat the same at the proper part and fasten in the tool, pull the long end down to the stop H; it will then be as shown at N. At first sight the bar in the illustration would seem to be cut too long, but such is not the case; and this is the point to notice, after the end of the bar has been brought down against H, no amount of hammering can make it longer, and as the portion marked N is flattened or swaged down, the excess of material must go into the corner and make it come up better than otherwise it would do if the end had been loose, instead of lodging against the stop H. The reader will see that the bending can be done very expeditiously in this way, and the ends of the bars when bent will all come out to one length. Square bars can be bent in the same way with this arrangement.

For bending round bars, the blocks C and D will be made so that they will grip the bar evenly between them. They should be forged separately to outside dimensions, and then strapped securely together with a piece of thin sheet iron or tin between them, and the hole bored the same size as the bar intended to be bent. One half of the hole should be in one block and one half in the other; a similar groove should be cut in the top of the block marked C, and when bending round bars, use a top swage in place of the flattener at N.

Fig. 352 shows a very similar tool fitted up to make a bend with two long ends; in the first place, see that the shank that fits in the anvil is situated far enough back to allow a good portion of the tool to hang over the anvil; a pair of straps,

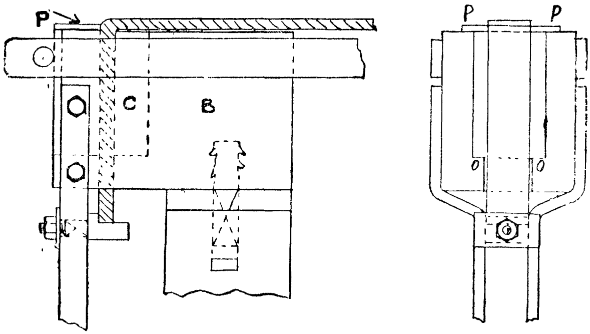


FIG. 352.

similar to those marked G in Fig. 351, should be fitted to hang down in front of the anvil. Stop marked H in Fig. 351 will also be required, so that the end of the bar can rest thereon; the tool B should be cut away for the bar to pass through,

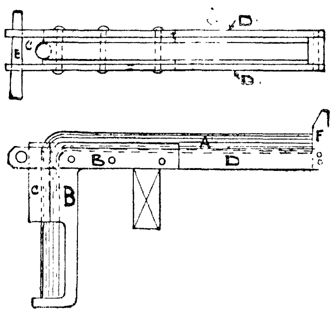


FIG. 353.

leaving as much as possible under the block C to support the same. D is held up by small ledges at each side as at O O, or it may be forged to hang on the top of the tool as at P P.

If a tool is required to work one size of bar only, it would be best made as in Fig. 353, either of wrought iron or mild steel. A is the forging in hand, B the tool made like an ordinary bottom swage forged and bent over the front of the anvil, with a piece forged out or shut on as a stop for the end to rest against; C is the loose block, D represents two straps riveted or welded to the tool B, E is the key, F the stop and distance piece between the bars or straps marked D.

There are other arrangements of this same tool, one of which is illustrated in Fig. 354, where, instead of carrying the

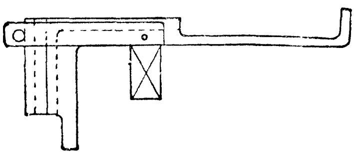


FIG. 354.

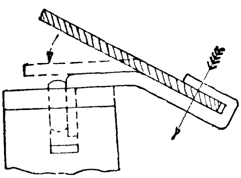


FIG. 355.

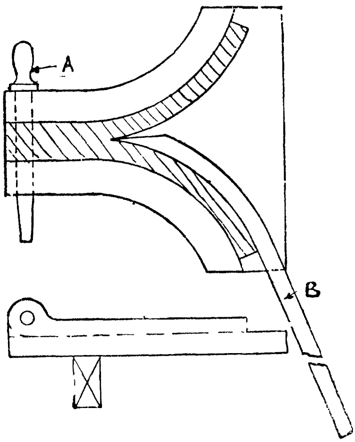


FIG. 356.

two straps back, a piece is shut on to the tool, and the end of same bent up for the stop.

Suppose a number of bars, flat, round, or square, have to be bent to an angle of say 30°, 3 inches from the end; a tool, made as shown in Fig. 355, will answer all requirements, and so far as making the bends is concerned, it will be found that this tool will so facilitate matters that they can be manufactured far quicker and better than by bending them on the anvil, and setting them to a template. The tool, in fact, in addition to its other duties, answers the purpose of a template at the same time. Fig. 355 illustrates the tool bent for this particular angle, but it can quite as easily be adapted to any other angle that is required. It consists simply of a piece of flat bar, with one end turned over to fit the work in hand, while the other end is bent down square and wedged into the hole in the anvil; the bar is shown in position ready for bending by simply pulling the bar down on to the horizontal portion of the tool.

If the forging is required to have a hole in same near the end, and it happens that the distance from the hole to the bend is of the first importance, a hole may be drilled through the tool, and a pin or drift placed in same while bending, as denoted by the arrow in the illustration before us, which passes through the tool and the bar.

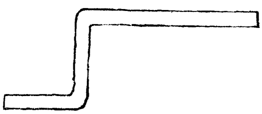


FIG. 357.

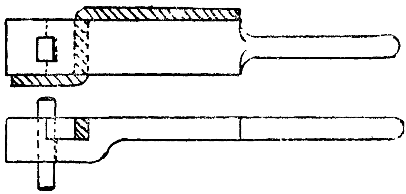


FIG. 358.

Again, we not unfrequently meet with forgings where two pieces have been shut on to a wider piece, or a bar has been split down the centre, and the wings or sides thus formed require to be opened out as in Fig. 356; the solid portion should then be held securely in a block, and there are many ways of doing this which cannot be described without knowing the shape of the forging as a whole. One example is illustrated in Fig. 356, which shows one way of holding a forging similar to a door band while opening out the arms or wings; after inserting the pin in the forging and through the holes in the block, the ends are opened out and curved to shape with lever as shown, marked B in illustration.

Fig. 357 represents what is called a double bend; we have already illustrated and explained special tools for bending a single corner, and the same tackle can be utilised to make double corners by introducing a suitable block for same, see dotted lines in Fig. 351 showing Fig. 357 also.

Another method of making a tool to do this sort of work is shown in Fig. 358. The bar out of which the double corner is to be bent is placed in the slot as shown, and one end is bent one way and the other end in the opposite direction, or this particular sort of bend may be made in another very simple way as illustrated in Fig. 359. A represents the bar out of which the double bend is to be made; it is fastened on to the block F by a cotter marked C passing through the ears, lugs or straps marked B, as shown in the illustration before us; an ordinary round key may be used if the straps are made rather longer, and a flat piece of iron is used between it and the bar

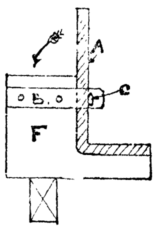


FIG. 359.

FIG. 360.

to be bent. The first corner is bent, then the bar is released, turned over and placed in position as shown, when the other corner may be bent as indicated. If the bend is small and easy, the best and quickest way to make it is with the aid of tools, as illustrated in Fig. 360; they should be used under the steam hammer or a press.

Link Bending.—For ordinary short links, there is no better way of bending them than with the tongs, as illustrated in Fig. 125, but for bending large heavy links, the above method would be too clumsy and too tiring to the workman. There are, however, several methods of bending large links expeditiously, and we will now proceed to illustrate and explain the same, together with the appliances most suitable for the purpose.

First.—When the links are to be welded at the end, see Fig. 361. In this illustration we show an appliance that is simplicity itself, for the purpose. A is a raised portion of the block, cast exactly to the shape and size that the link has to be when bent. B is a screw working through a raised portion, cast on the side of the block. C is a loose block to be placed between the point of the screw marked B and the bar to be bent. The side of the block C that is in contact with the bar, should be made slightly concave to obtain a good grip on the bar, and by way of illustrating another method of fastening the link in the tool before it is bent, we show another raised portion

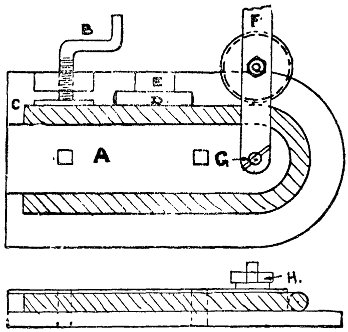


FIG. 361.

on the block marked E. D is a wedge inserted between the bar and the lug marked E, with the thin end of same pointing towards that side where the work is being done, so that the tendency will be to tighten, rather than otherwise, the grip on the bar.

We would point out that it is not intended that there should be two lugs on the main casting, one for the screw and one for the wedge; if the screw is adopted, of course the wedge is unnecessary, and vice versâ. Referring again to Fig. 361, F is the bending lever, and is fitted with a suitable roller, set at a proper distance from the bar.

Note.—If rollers are set too close to the work they will not bend the same correctly, and will probably pull the bar in two pieces. G is the centre pin on which the lever works; H is the cotter through the centre pin, to hold the lever marked F on the pin. The bar can be placed in position on the block, then bent, and withdrawn without taking off the lever, so in these circumstances it is best to have the lever made secure so that it will not fall off. Fig. 362 illustrates another way of bending these same links. A is a loose grooved pulley slipped on to a peg, which is fitted into a swage block; B is the lever and the block combined, the sides of which are made concave, and the end round as shown; C is a strap bolted or riveted to B; D is a screw fitted in same to hold the bar secure while

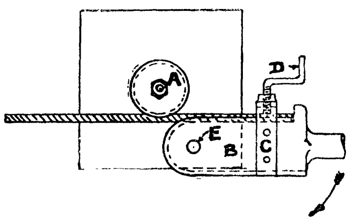


FIG. 362.

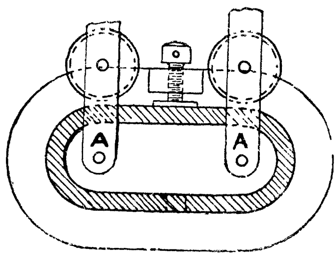


FIG. 363.

bending; E is another peg, like A, fitted into the swage block, on which the lever B is pulled round, as denoted by the arrow, to bend the link against the grooved pulley A.

It is very often specified that links are to be welded at one side instead of at one end; when this is so, two bends will be required, and in Fig. 363 we illustrate an excellent tool for the purpose. It consists of a cast-iron block with a raised portion made the same size that the link has to be when made. A A indicate the positions for the two pegs for the levers to work on; the bar is secured to the block, as shown, with a screw as already explained. Two levers manipulated at one and the same time will be the best and quickest way of proceeding, but one lever will do the work by operating first at one end of the block and afterwards at the other, and in either case the levers will have to be lifted off the pins to take the bent link off the block, so we recommend the design illustrated by B in Fig. 295, for the lever ends with pins to suit the same. The screw in this particular case will be the best way of securing the bar to the block.

Fig. 364 illustrates a very useful tool for bending all such corners as that marked F in Fig. 364. A is a piece of flat bar forged to form a handle at A_1, the length of which will be governed by the weight of the work to be dealt with. B shows two straps for holding the work and the key. C is a loose piece between the work and the key, it should be grooved as

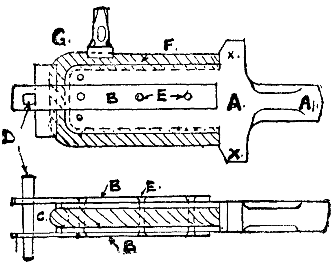


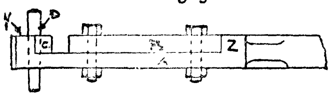
FIG. 364.

shown, to obviate bruising the bar, and also to make sure that it will obtain the best possible grip. D is a key driven through the two straps to hold the bar. E are countersunk rivets that hold the straps B B to the tool. F is a bar showing how it will appear when bent on the tool. G G are holes through the tool, which may be used for swinging purposes, as in the case of the tool in Fig. 362, which is intended principally for link bending; suitable pegs, and a roller or pulley would be necessary to enable the tool to be used in this way. If the swinging arrangement is not adopted, and if the bar has to be bent this would have to be done with the hammer.

The reader should note that the shoulders or stops marked X are illustrated only to show how to force the material back into the corner when closing down if a special sharp corner is required. It should also be noticed that when shoulders are forged on this tool as at X, it cannot be used for making bends with longer ends than those for which the tool was specially designed, whereas, without the shoulders, the tool can be used to make this shape of bend with the ends any length that may be required; the tool A would require to be hollowed out at the end, and at the sides, for bending rounds, and a top swage should be used round the outside of the bar as shown, when closing down. Squares and flats can be bent with a similar tool, the only difference being that it would have a square end and sides.

Figs. 365 and 366 show another tool for doing similar work; it is rather different in design, but the following explanation will

FIG. 365.



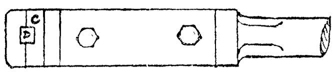


FIG. 366.

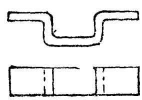


FIG. 367.

no doubt enable the reader to understand what is meant. A is the body of the tool; B a plate made suitable for the job in hand, and fitted up to the shoulder Z, it should be firmly bolted to A; C is a loose packing piece; D the hole for the key, which is best made square, but should have round corners.

Staples and similar articles having four easy corners, as illustrated in Fig. 367, are often bent at one process with tools, as illustrated in Fig. 368, of which we give the following explanation: A is a forged tool; B a shank forged on the same to enable the tool to be used at the anvil; when this tool is intended for use at the steam hammer, the shank referred to is not required, but a handle, as shown at C, will prove very useful for lifting the tool up and holding it under the hammer;

D is the top tool over which a flattener is shown, illustrating how the ends of the forging are worked down on to the top of the tool A; but when these tools are used under the hammer, the top pallet covers them all over, and the flattener marked X in the illustration is not required.

The above arrangement of tools will be found to answer very well, when there is an easy radius on the corners, but if the latter are required to be fairly square, well, then the arrangement referred to above will not do at all, because the corners on the tool would require to be square and fairly sharp, and consequently the material would not slide over them, and the tool would shear or cut the bar in pieces.

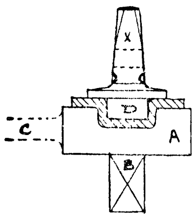


FIG. 368.

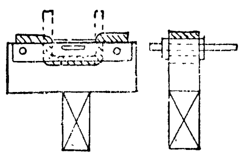


FIG. 369.

The best and safest way, in such a case, would be to bend the two centre corners with a tool, as shown in Fig. 358 or 364, after which place the forging as illustrated in the tool, Fig. 369.

This tool is much the same as Fig. 368, except that the corners are sharper. A block, with a key-hole in same, is placed in the gap to hold the forging, as illustrated, with the two straps, one at each side, or, as an alternative, the loose block may be held with a lever, as illustrated in Fig. 370, and bend the other two corners down with the hammer and flatteners.

Shackles.—These forgings vary very much in shape and size, but as an illustration, we select the one that has the most bending attached to it. We recommend that the ends be bent in the tool illustrated in Fig. 355, during the same heat that the balling and punching is performed, then take a heat on the centre portion and bend, as illustrated in Fig. 371. A is a forged tool shaped to suit the shackle, with a hole drilled to take the pin C; a flat cotter hole X is cut through the other way, and a handle or lever is forged on as shown; a piece of flat bar is bent as at D to slip over the pin, between the head

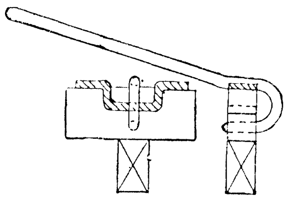


FIG. 370.

of same and the eye of the shackle, to hold the first end up to the block by means of the flat cotter in the hole marked X; by this means a single cotter and pin can be made to do the work. When the material is fastened thus, pull the handle right round and the material will bend against the roller G, then

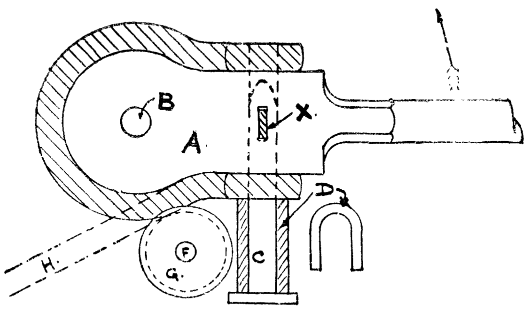


FIG. 371.

remove the cotter, take off the piece marked D, pass the pin through both eyes and tool, cotter the same on the outside, and set round the bow if any further setting is required; the distance piece marked D is unnecessary if two pins are used, a short one for the first process and a long one for the next; or one pin for each side and two cotters, as shown in Fig. 372. B is the hinge pin or pivot on which the tool A is pulled round

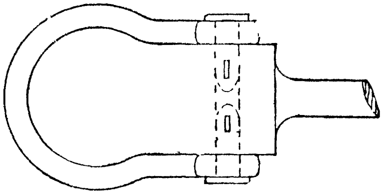


FIG. 372.

F is the pin for the roller; G the roller itself; H represents a shackle in the first position ready for bending, or if preferred,

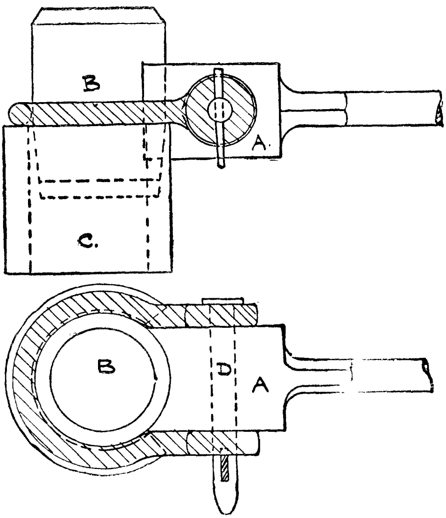


FIG. 373.

rough bend without any special tool, and finish with the above tool less the roller and pivots.

Another special tool for the same purpose is illustrated in Fig. 373; the part marked A represents a mandrel made the same thickness as the width of the shackle between the eyes, with a pin hole through the same; B is a drift quite separate, of course, from the mandrel intended for shaping the bow; C is a bolster with a piece cut out at one side to allow the shackle to lie level thereon. A piece of flat bar iron would serve very well for the bolster, if simply bent round, so that the ends instead of being closed together were left sufficiently apart to allow the mandrel to come between, so that the shackle can lie flat on the bolster, as shown, when being drifted or blocked as in Fig. 373; D is a pin, with a flat cotter hole in same, to

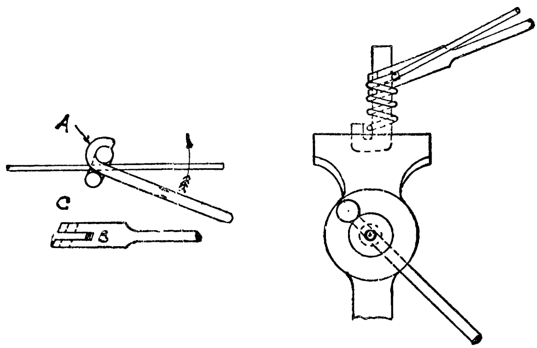


FIG. 374. FIG. 375.

hold the ends of the shackle up to the mandrel, while the ring is being drifted.

Coil Springs.—These articles can always be bought cheaper from the large spring factories than they can be made in an ordinary smithy; but sometimes economy is best served by having a few made there, especially when they are wanted at once, and there is no time to send away for them. A few hints, therefore, on this particular class of work, will not be out of place. Say we wish to make a spring 10 inches long, to work easy on a $\frac{5}{8}$-inch rod, with $\frac{1}{8}$-inch diameter spring wire $\frac{1}{4}$-inch pitch. The simplest method we know of is to take a bar $\frac{5}{8}$ inch diameter, bend one end over as shown in Fig. 375, then make a lever, as illustrated in Fig. 374; place the round bar in the vice in a vertical position, and the end of the spring wire in the fork, and commence to bend with the lever, hooking the part marked A on to the $\frac{5}{8}$-inch bar, and pulling the same round that bar, so that the part B presses against the wire, and bends it to the bar; C is a lip at the bottom side of the lever for regulating the pitch, which is not essential if the spring is to be a close pitch; in that case C would be in the way. We have assumed in the above instance that the spring wire is annealed sufficiently to bend cold; it will, of course, spring away from the $\frac{5}{8}$-inch bar enough to give plenty of clearance on the same. Now shape the ends or grind them off level as occasion may require. For hardening, see special paragraph on the subject.

Bending Table.—When bending links, as illustrated in Fig. 361, the swage-block is by far the most convenient form of table, especially when we bear in mind the large number of times the operator has to walk round the same with the lever; and the large number of holes it contains gives it another great advantage, as there are sure to be two out of the lot situated a suitable distance apart for securing the bending tackle. It is quite possible that the stand on which the swage block rests will require fastening, to obviate the chance of it turning round with the side pull; but this can easily be done by pointing four pieces of strong angle bar and driving same into the ground, one at each of the corners. If the floor happens to be wood, then strong spikes or $\frac{1}{2}$-inch coach-screws fixed round about will answer quite as well.

But in the case of hoops, as described in another part of this work, angle rings, and similar work, with which a smith is often brought face to face, then the swage-block is not suitable, for obvious reasons, and recourse has to be made to the levelling table, which is generally, and, if not, it should be, a large cast-iron block, with a quantity of 1-inch square holes therein, placed 6 inches or 8 inches apart; the holes are not only useful, but they are essential when other appliances have to be bolted thereon, as, for instance, the various bending arrangements that we have referred to, as well as rings for blocking purposes and pegs for bending against. The levelling table, in addition to the square holes referred to, should always have a large hole in the middle of the plate to take the drift when using such blocks as those illustrated in Fig. 283.

The pegs just referred to are usually pieces of $1\frac{1}{4}$-inch round iron, made square at one end to fit the holes in the plate, and are used, when bending, as shown in Fig. 376, which illustration also shows how a loose collar placed on one of the pegs increases the radius of a bend, and the holes in a block do not detract from its usefulness for levelling purposes.

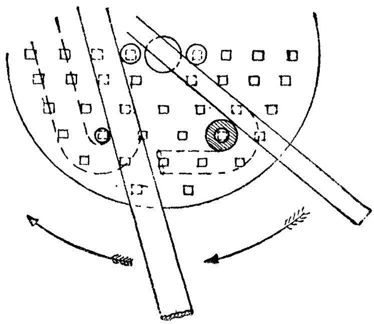


FIG. 376.

A face plate off an old lathe, or any similar plate, is always very acceptable in a smithy where no other block is provided. These plates should be packed up to a suitable height, say about 2 feet, and arranged so that bolts may be passed through from underneath.

Fig. 377 illustrates a cast-iron ring intended for bending hoops too; it should be square in section so that angle-bars may be bent with the flange inside or outside as indicated at Y and Z; it will also do for bending ordinary hoops as well. When bolts are used to fasten the same to the table by passing through the ring itself, they should be countersunk or let in level, as at A_1 and A_2; the part marked A is a crossbar which is cast on the ring to facilitate bolting it to the table; B B are lugs cast on the inside for the same purpose. They are, of course, intended as alternative methods for fastening the foundation ring. It cannot be expected that all the holes in the ring will tally with those in the plate unless the one has been made to suit the other, but it is possible that one or two of them will come in, and further staying may be performed by means of pegs and bolts as occasion permits; C represents a stop, and D a wedge, as explained and referred to in Fig. 295.

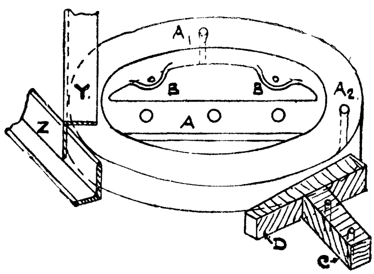


FIG. 377.

When bending hoops of a small diameter and light section, we should recommend the process referred to in paragraph on hoop-bending, p. 149, and illustrated in Fig. 295. But in the case of hoops having a large diameter, and made of stiff bars, it would undoubtedly be best to use the more powerful lever illustrated in Fig. 279; and another point when bending hoops, especially angle bar, is to keep the end of the bar well up, do not let it drag heavily along the face of the block.

Fig. 378 illustrates what is called a hinged cramp, it is a very simple arrangement and a very effective one. The following explanation will, we think, make matters plain. A is a piece of square material with a fork forged at one end, as shown in the view A^1; a hole is drilled through both projections of the fork to receive a bolt, and through the block in the opposite direction, and this latter hole is tapped to receive a screw as shown. B is another piece of square material, bent as shown in the illustration, with one side forged out to fit the fork in the end of the block marked A. Three or four holes are drilled in the arm that has been reduced to fit in the fork referred to in A, for adjusting purposes, so that the tool can be used for cramping various thicknesses of material; a slot-hole is made in the other arm of the forging, marked B, this time in the opposite direction to the bolt-holes referred to. This latter hole should have ample clearance for the screw marked E, so

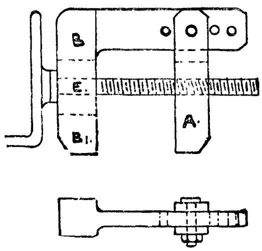


FIG. 378.

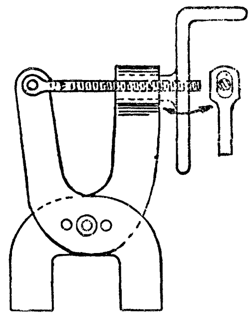


FIG. 379.

that by turning the cross handle of the screw the cramp is opened or closed, as the case may be.

Fig. 379 illustrates another form of hinged cramp; it very much resembles a pair of strong tongs, with a screw attachment at the end of the reins for tightening up. In this case the screw has a forked end, through which it is pinned to one of the reins; the other rein has an eye in the form of a slot-hole made therein, and the loose or threaded end of the screw passes through this hole; a wrought-iron handle or lever, as shown, is tapped to suit the thread of the screw, and placed thereon. By this means the cramp is opened and closed, as indicated in the illustration before us. Another feature to notice in this tool is that additional holes are drilled in the centre, so that by moving the hinge-pin, the range of grip can be increased or reduced at will, which adds to the value and the usefulness of the cramp.

Fig. 380 illustrates what is known as the common cramp. Sometimes a screw is fitted to this tool as shown in the illustration. When this arrangement is used, a piece of plate is generally fixed between the end thereof and the material to be cramped. A wedge can be, and often is, used in conjunction with this cramp. When a wedge is used we should advise that a peg be introduced to steady the cramp while driving in the wedge, see Fig. 381.

Similar cramps to the above, but made to fit the work, are often very useful to drive on, to hold the work up to the block; this is especially the case when bending angle bars, which is a more troublesome job on account of the unequal section.

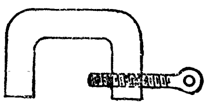


FIG. 380.

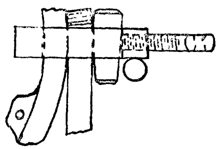


FIG. 381.

Camber.—In the trade the word camber is understood to nean a curve bent to a radius, or part of a circle, like the arch of a bridge, see Fig. 304.

Caseharden.—By this expression we mean the act of iardening the outside or case, of iron or mild steel. It is generally in the case of wearing parts of machinery that this practice is resorted to, especially when the parts in question would not do to be hard and brittle right through. The implest method of hardening in this way is by means of yellow prussiate of potash, an example of which is given when dealing with the bottom swage made of iron.

Another method is to pack the pieces in an iron box, and over the same with granulated bones, scraps of leather, horse-oof, or some of the special patent casehardening mixtures;

then place a cover on the same, and lute or plaster round with fireclay or some substitute for same, such as the mud out of the grindstone trough; then place the box in a furnace, raise slowly and thoroughly to a good red heat, and keep them so for from four to eight hours, according to the size of the parts and the depth of case required; then take them out and plunge into cold water. Do this as quickly as possible, because when hot iron or steel are exposed to the action of the air, an amount of scale always forms on the surface. The heating process just referred to with the bone, etc., carbonises or converts the outer portion or case of wrought-iron or mild steel into one of a harder nature similar to cast steel, leaving the inside quite soft.

Cogging.—By cogging is meant drawing out or reducing a bar, or a portion thereof in section by rapid forging, beginning at one end and working towards the other.

Contraction or Shrinkage, which is the same thing, is produced in cooling metals. Iron or steel, when heated, expand considerably, and when allowed to cool gradually will assume their normal length. The difference in the length of a piece of iron or steel when hot and the same piece when cold is termed the contraction or the shrinkage. This difference between the two conditions of iron and steel has to be borne in mind when shutting or making any forging to a dead length. When hot, a rod or bar should be from $\frac{3}{16}$ inch to $\frac{1}{4}$ inch longer to the foot than the dimension it has to finish to when cold. As a practical illustration of the above remarks on this subject, we would suggest that the reader take a piece of a bar and mark two dots on the same with a centre punch, say 12 inches apart; then set a pair of compasses so that one leg thereof will be at one of the dots just made, and the other leg on the other dot made with the centre punch; then heat the bar between the dots and try the compasses again, and it will be found that the points of the compasses come short of the two points to which they had just previously been carefully and accurately set, proving that the material had expanded very noticeably even in that short distance. Now allow the material to cool gradually in the ordinary way, and when cold try the compasses again, and they will be found to span the distance correctly between the two centre punch impressions; but if the bar, instead of being cooled gradually in the ordinary way, is slaked off in cold water, it will probably be found to be $\frac{1}{32}$ of an inch shorter, which result is brought about by being cooled quickly and suddenly.

Drawing.—See "Cogging," which is the same thing.

Drifting.—Implies expanding or opening existing holes to a larger size by inserting and forcing a taper drift in same.

Expansion.—See "Contraction."

Forging (*v*).—By the word "forging" is meant the act of shaping any one or more solid pieces of iron or steel, according to specified requirements, by heating same and then hammering, pressing, bending, or welding.

Forging (*n*).—When the word is used as a noun, it serves to denote the finished article; for instance, a connecting rod when forged or finished is a "forging."

Fullering.—By fullering is meant the act of shouldering down a piece of material, as in Fig. 232, preparatory to cogging or reducing same from one size to a smaller one; for instance, say a 4-inch round bar is to be forged down at a certain place to 2 inches diameter; in that case, the bar will be fullered all round at the point where the reducing process is to end. This should always be done before the drawing out or cogging is begun; by attention to this process at the start, a much better shoulder will always be secured than would be the case if it was attempted to be done by forging only. Fullering also implies forging, drawing, or spreading the material in one particular way, by using a fuller or piece of round bar, as we have already explained elsewhere.

Hardening.—The word explains itself. The process of hardening is performed in several ways, and is applied to both iron and steel. The method of hardening depends upon the material to be treated, and the use for which that material is to be applied when hardened.

Cast steel, as understood by the term generally, denotes the "carbon steel" made by the crucible process, and has many different grades of temper.

We will take first the ordinary turning tool steel, and suppose we have a lathe tool to harden. Raise the steel to a dull red heat at the cutting end and slake the point in water, but in doing this, do not plunge the point in water, and hold it there rigidly and perfectly still at any stated depth while the cooling is taking place; but commence with the point and gradually lower the tool into the water, keep moving it quickly up and down while at the tank, dipping it irregularly each time; and when the point is sufficiently cooled draw it out of the tank, clean the point with a piece of stone, and watch for the colours showing the tempers, as they are produced by the heat passing from that portion of the tool that is not slaked so thoroughly as the point, and which is working its way back towards that part of the tool. It is generally admitted that a turning tool is best when the temper is arrested with the extreme point thereof turning from a white to a straw, with the back of same blue; the point is then hard and the back tempered; of course, in special cases there are special rules drawn up from experience.

Note.—By plunging the point into water and holding it there perfectly still at one depth, unequal strains are set up, or started between the hot portion, and the part that is cooling in the water, and this invariably causes what are termed water cracks. If the reader will think a moment on this subject he will see that the portion of the tool that is hot is in full expansion, while the portion that is in the water is practically in full contraction; and if these two opposing forces are brought about in a harsh and hurried manner, and their efforts localised as stated above, viz. by holding the tool in water rigidly at a given depth, then there is nothing for it but that something must give way, hence the cracks referred to. We do not say that it will always crack, nor that it will always show itself at the time if it does; it is sometimes the next time the tool is forged that the flaw appears, or it will break off when the tool is put to work. Also note the remarks about having cold water in the troughs during the winter months, see p. 14.

Now suppose we have a milling cutter, say 3 inches diameter by 4 inches deep, with $1\frac{1}{4}$ inches diameter hole, made from steel of turning tool temper; if we are not careful with this tool we shall most surely crack it; the safest way is to heat the tool to a dull red, and cool in boiled oil, then the tool may be used in most cases without tempering. The effect of oil on steel is not nearly so sudden and so harsh as water; it does not make it so hard and brittle; but suppose there is no oil at hand, and the work must be done in water, then, in that case heat very gently and carefully to a dull red, and plunge the tool into lukewarm water, and let it remain immersed until it is well cooled; do not let it come in contact with an atmosphere that is much cooler than the water in which it has been immersed, or this may make it fly or crack. Clean the tool with stone or emery cloth and proceed to draw the temper; the best way to do this is to place the cutter on a hot round bar and hold it over a clear fire; when the required temper is reached, arrest or stop its progress right away by plunging again into the warm water, and there let it remain until cool.

Some firms that use these cutters prefer to have them made of a very mild cast steel, and simply harden the cutter in warm water, no tempering being necessary.

Again, some users prefer to make these tools in Swedish Bessemer steel, which is cheaper than the cast steel, and superior to the English Bessemer material, and then simply caseharden them, or treat them as in the last mentioned process; and needless to say, they each consider their way of hardening the cutters the best.

Drills.—When hardening drills, follow the instructions given regarding the hardening of turning tools, except when tempering let the point assume a purple or light blue colour before being arrested.

Shear Blades.—To harden small blades, such as are used in the smithy shears, heat the blade along the cutting edge to a bright red, plunge in water until cooled or slaked, and then in order to temper same, lay it over a clear red fire, and turn the blast very nearly off, and as the blade gets warm rub occasionally with a piece of hard fat or suet; when the grease from same lights with a bluish flame, the blade should be taken off the fire and slaked; the blade is then ready for grinding; no cleaning need be done between the hardening and tempering with the above process, because it is not the colours which serve as a guide to the temper in this instance.

Another way to temper shear blades is to clean the blade after hardening, then lay the same on a clear fire or on a large piece of hot material, and watch the colours showing the tempers as they appear; and if the right temper of steel has been used for making the shear blade, a medium blue will be about the right temper, and at this stage of the colouring the blade should be slaked off.

Tools that have been got up bright, such as taps, dies, cutters, etc., may be kept very clean during the hardening process by previously coating with one or other of the following articles, viz. common soft soap, grounds or settlings from a brewery vat, or barley meal mixed with water to a thin paste.

When soft soap is used, the tool may be covered with same and put straight into the fire, but when settlings or barley meal are substituted they should be allowed to dry on the tool in a warm place before putting the tool in the fire, or the moisture will collect the dust in the fire, which will adhere to the tool, and make it dirty instead of clean.

Now suppose we have a 1-inch tap to harden and temper. Begin by coating the tap with one or other of the above substances to prevent scaling during the heating process, and to protect the sharp edges from the fire; say that ordinary soft oap is selected for the purpose, then see that the spaces between the teeth of the tap are well filled with soap, and the tap heated slowly to a dull red colour, after which slake the tool off by lowering into the water in a vertical or perpendicular position.

Be very particular about this or the tap will come out of the water bent; now clean the tool, which will be easily done when a coating is used, then take an old collar or bush and raise the same to a white heat, and temper the tap by holding it inside the collar until a good medium blue is shown, at which point arrest the temper by slaking in water or oil.

Some smiths harden all taps in oil, but it is a matter to be decided more by the temper of the steel of which they are made than by anything else.

A large tap should be treated in the same way for hardening, but for tempering it is best to hold over the fire.

Flat cutters for use with boring and facing bars appear to be very simple acticles to harden and temper, but like other cast steel tools they can soon be spoiled by carelessness and thoughtlessness on the part of the operator; heat the tool uniformly throughout, then slake in water, clean the tool, and proceed to draw the temper by laying on a flat piece of hot material, in such a position as to leave the cutting edge slightly harder than the body of same.

Springs.—Heavy springs, such as those used for wagons, carts, and drays, should be heated to a dull red, and then plunged into water, from which they should be taken before they are quite cold, and placed on the fire; turn on the blast slightly and keep passing the spring to and fro, so that it may be heated evenly all over. To gauge the temper, pass a piece of dry ash or other hardwood along the spring with a light pressure, and when the spring is sufficiently tempered, it will cause the wood to throw off sparks of fire as it is passed along the spring; at this point take it off the fire, adjust the shape, and then lay it down on the floor in a dry place to cool. If the spring is examined in a dark place as soon as it is taken off the fire, the operator will see that it is just turning from a black to a red.

Light Springs.—These are invariably hardened in oil. Say we have some flat springs $\frac{3}{4}$ inch by $\frac{1}{16}$ inch by 5 inches to harden; heat and plunge into boiled oil, and to temper hold over the fire until the oil left on the spring gives a flare or blaze; the spring is then tempered and should be laid to cool, preferably on a wire sieve, so that it is sure to cool evenly all over. Some smiths recommend dipping these springs in oil, and holding them over the fire two or three times in succession, until the oil on them takes fire; by this means they make doubly sure that the temper of the spring is uniform throughout. A spring treated in this way is supposed to be always the same temper so long as the point at which the oil ignites has not been passed. Another way to temper the same spring is to clean and draw the temper to a deep blue over the fire or hot plate, and allow it to cool as before.

Small Coil Springs.—These require to be very carefully manipulated; for instance, it will not do to lay such springs on the bare fire, because as they get hot, their own weight will bend them; to overcome this difficulty, lay a piece of angle bar on the fire with the hollow side upwards, and the spring laid therein, or pass a round rod through the spring and heat over the fire. Another source of trouble is, if you take hold of the spring with tongs when hot, you are almost certain to alter the shape. The best and safest way to take the spring from the fire is to pass a light rod through the same, and plunge into the oil on the same. The temper should be drawn by holding over the fire on a bar or rod until the oil ignites, as we explained in the case of small flat springs.

Jumping.—The practice of jumping is performed with a view to enlarging the section, or in other words to increasing the width, thickness or diameter, and at the same time reducing the length.

Malleable.—The word malleable implies that the material is capable of being forged or worked into any shape by hammering, pressing, bending, twisting, and the like.

Portabar.—This is a name given to certain tools, used in the place of tongs on large pieces of work. Fig. 382 illustrates a portabar clamped to a forging. The tool in question very much resembles one half of a gigantic pair of tongs; the curve in the tool brings the handle part at or about in line with the centre of the forging, and this enables the operator to turn the forging as required, which would not be possible otherwise; when the work in hand is too heavy to turn about with the

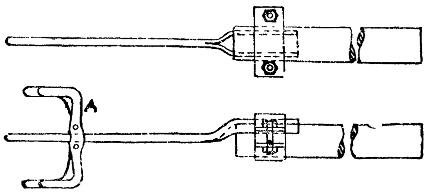


FIG. 382.

portabar alone, a couple of handles are bolted near the end of same to give leverage and facilitate the turning about of the forging. Sometimes a piece of material is reduced at one end to enable the portabar to be used; this is often done rather

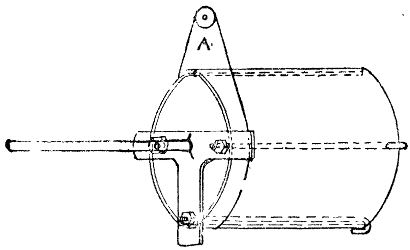


FIG. 383.

than keep altering one of the bars. Plain wrought-iron bars used to be often welded to a large piece of iron in order to work it, but this practice is not adopted in the case of steel. A pair of turning handles as used for heavy forge work are also illustrated in Fig. 382 at A, they are bent back, parallel, or in line with the bar.

Portabars are often designed specially for certain work, as is the case with this sort of tool when welding tubes; the bar is secured to the tube by three rods, hooked over the far end of the tube as shown in Fig. 383; the three rods are fastened to the end of the portabar with nuts.

Fig. 329 illustrates a bar for fastening to plates. It is a strong fork with a keyway running crossways. It is fastened to the plate by driving a key in the slot. When tubes are flanged by hand, which by-the-by, is very rarely the case nowadays, two of these bars are sometimes used to handle the same, with a long looped chain round the tube, see A, Fig. 383.

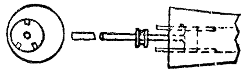


FIG. 384.

When one end of the tube is flanged, another pair of bars are used as shown in Fig. 326; these are also fastened with a drift or key.

Fig. 384 shows how a portabar can be fixed in the large end of a tuyere, or tube of similar size; the bar is driven into the tuyere, and then fastened there by means of three keys, as illustrated, which are driven into the notches prepared for them.

Fig. 385 shows how the small end of a tuyere is held while

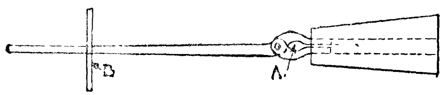


FIG. 385.

the large end is being welded. This arrangement is very much like a pair of stiff tongs, with only one rein or handle; the two bits are placed in the hole of the tuyere, and a drift is forced between the two bits at A, in the illustration before us, causing the two bits to expand, and press against the sides of the hole in the tuyere. The turning handle B is a piece of $\frac{5}{8}$ inch diameter iron fastened in place simply and solely by contracting the larger bar on to the same.

Punching is the act of making holes right through a piece of material or partly so, as in the case of bob-punching. The difference between drilling and punching is, that in the former, the material is scraped out of the hole by a revolving tool, whereas in the latter case, it is punched out in one piece, except where the punching is done partly from one side, and completed by turning the forging over, when only a part is forced out, the remaining portion being displaced, and forced sideways into the forging.

Rolling.—Implies the act of bending hoops or plates into shape at the rolls. It also means rolling to size when speaking of the manufacture of bars or plates.

Shutting.—When this word is used in connection with blacksmiths' work, it is understood to mean, the heating of two pieces of iron, each to a plastic state, and hammering or pressing them together, while hot, until they form one solid combined piece. Practice and experience only will show what is the correct welding heat, and this same teacher can alone give the ability to work the same smartly and properly before the heat has abated; and even the most qualified smith will need to exercise a deal of discretion when shutting the different tempers of steel and the different natures of steel and iron. The latter material is taken as the standard of what a welding material should be, and that steel which can be heated and worked in the same way as iron, without deteriorating in any way, is selected for welding purposes; and as a rule, steel, which contains the lowest percentage of carbon, is the best and easiest to weld; of course there are exceptions, but that only makes it all the more necessary that a man should be practical, and able to adapt his craft to varying circumstances.

A welding heat always causes more or less waste according to the experience of the workman. If two pieces of material were simply scarfed without upsetting and shut together in the form of a lap weld as illustrated in Fig. 387, they might be kept up to size, where the one has lapped over the other, but at each side of the shut, the bar would be found to be smaller in diameter, even though it had not been touched with a tool or hammer; this waste is due to the scaling which always takes place when iron and steel are heated. If a shut was made in this way by an experienced smith, this diminution that we speak of would be scarcely perceptible, but when any less experienced man has had the work in hand, the difference between the diameter of the bar before it has been heated, and the diameter on each side of the shut, where the effects of the fire have been felt, will be decidedly more pronounced. In anticipation therefore of this wastage, and also to provide a margin to work upon, a smith will always upset his bars before welding, either before or at the time of scarfing, except where the work has been previously forged with the knowledge that it had to be shut, in which case, the smith would no doubt

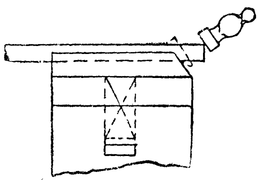


FIG. 386.

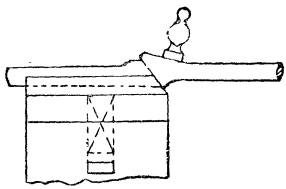


FIG. 387.

have left a lump or swell near the end, to save the labour of upsetting later on, and also perhaps with a view to avoid bruising the opposite end, which may have been machined.

There are many methods of shutting, besides those already mentioned, and in the next few pages, we propose to give a short description of those that are likely to be most useful.

First, to shut small rounds. In this case, place the two ends to be shut in the fire at the same time, and as soon as they are near a welding heat, upset and scarf in one process, by driving back the top edge to make the heel and taper, as shown in Fig. 386; five or six sharp blows on each will be quite sufficient, if done correctly. Then raise to a welding heat, lay one on the other, and hammer together.

Note particularly: when shutting, strike first over the thick portion of the top piece, and in such a manner as to drive the two together, see Fig. 387.

If the hammering is first directed on the thin end of the top scarf, it will tend to lengthen same, and probably draw the heel away from the bottom piece, making a very indifferent weld for want of sufficient hammering.

This process is suitable for all work up to about $2\frac{1}{2}$ inches round or square, and flats up to 3 inches wide.

No swage is required in the case of the two latter sections; they are usually shut together on the anvil. An ideal welding and scarfing swage is that illustrated in Fig. 386. It will be seen that one end is cut off at an angle for scarfing, and the corners of all the working parts are well rounded off, to avoid cutting the hot material being worked therein, when there is a little extra thickness of material to be dealt with, as in the case of lapped or upset ends.

Another way to shut this same class of work is to upset the bars a little way from the end, and in the case of small sizes, shut them together without any other scarfing. This is the strongest way of making the shut, and it is especially recommended in the case of steel, for by making the shut in this way it will bear a lot more work, and the more work there is on a shut, the stronger it will be—other things being right.

It is not often that a special upsetting tool is used, only perhaps in repetition work; but when such a tool is required for, say upsetting round bars, it is generally a block with holes drilled therein, varying in size and depth. For instance, take the hole for upsetting $\frac{3}{4}$-inch round bars; this would be drilled 1 inch deep, tapering to the bottom, and about halfway down the diameter would be $\frac{3}{4}$ inches, the diameter of the bar to be upset, and at the top it would be proportionately wide. Holes for other sized bars could be made in the same block, all varying in depth according to the thickness of the bar, which is usually about $1\frac{1}{3}$ times the diameter. From Fig. 388, which illustrates this special tool, it will be seen that when the bar has been heated and forced into any one of the holes, the end assumes the shape of the bottom of the hole, while the upper part is bulged out until it fills the top of same, as shown in the figure referred to. Practically speaking, square bars are never upset in a special tool; this work is usually done by heating the bar end, cooling the extreme point in water, and then upsetting, as it were, by dropping the end on the anvil or other block, and so bulging out the portion that had not been cooled; or instead of cooling the point in water as stated, lay the bar on the anvil and proceed to drive back the heel as indicated in Fig. 386. However, a combined scarfing and upsetting tool is easily made, see Fig. 389, and if the tool was only used now and again it would pay for itself. Fig. 389, while

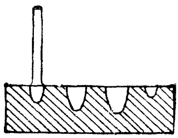


FIG. 388.

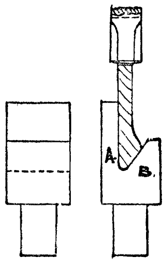


FIG. 389.

illustrating the tool in question, also indicates the method of using same. The long straight back marked A supports the bar and prevents bending; the bar will not bend the other way, that is towards B, because the scarf forces it in the opposite direction.

Another way of shutting is to butt the two ends at a welding heat, without any previous scarfing or preparation, and pressing the same well together, and then finishing the weld in swages or on the anvil.

Perhaps some of our readers may think this an indifferent way of doing this work, but such is not the case; there are some firms that adopt this method for their most important work, and it is very successful indeed. Of course, special appliances are necessary before a weld can be made in this way, and unless an employer had a lot of such work to do, he might not be agreeable to provide the appliances.

There are several of these special machines on the market for upsetting, welding and forging, some worked by hydraulic power, some with a screw, others are geared, some have an eccentric, and others a simple lever. They are designed by the makers to suit any class of work. In passing, we may say that some of these appliances are excellent, and others again are indifferent, and any firm contemplating buying one would do well to see a sample of their work done by the machine, before accepting delivery of same.

Another form of shut is known as the "clutch"; it is a very good and simple way of doing this work in the case of large rounds, squares, or rectangular bars, and in some cases it is the best method we can suggest, that is, when the power is

FIG. 390.

insufficient to work satisfactorily in other ways. It is particularly suitable for shafts, or any forging whose work has a twisting tendency. Say we have a $3\frac{1}{2}$-inch shaft to shut, without any steam or power hammer, manual labour alone being available.

Heat the end of the bar, and divide the same into quarters by cutting across the centre and then at right angles, and this time through the centre also; let the cut extend inwards about $1\frac{1}{2}$ inches from the end, as illustrated in Fig. 390. Cut out two opposite quarters, say the two that are shaded in the illustration, then treat the other piece in the same way, and the two will fit, the one into the other. The two ends may now be closed one into the other, and raised to a welding heat, and upset or driven together while lying across the fire with a tup or ram, as illustrated in Fig. 391; if the heat is right, this will unite and upset the two ends, giving sufficient material to weld, and clean up to size with sledge hammers and swages; and if the part has to be turned, sufficient material can be got in this way for that purpose. The amount of upsetting that is done should be guided and influenced by the attending circumstances; for instance, if the finishing has to be done by manual labour, then we need not have so much upsetting done as we would have had if there had been a steam or power hammer at hand for the purpose.

If preferred, the two pieces may be heated at the ends in different fires, and put together on the anvil, in which case the tup will be used as in the previous case.

This shut is a good method to use in conjunction with the forging machines, when the butt weld does not meet with the entire approval of the person in charge.

When using the tup, as in the case we have just been considering, it will be found to be a great help if a large weight

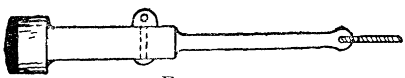


FIG. 391.

can be suspended against the end of the longest bar, while the tup is being used at the end of the other piece; this, of course, is not always possible, but when it can be done it will be a great assistance, and acts as a stop to the shaft being shut. If it is not possible to suspend the weight, then two men should hold the bar, giving it a push forward to meet the tup, as the blow is being delivered.

The tup is usually a piece of old shaft tapered to about $1\frac{1}{2}$ inches diameter for the handle, with a collar welded on to the striking end, to obtain a large striking surface. A hole is either punched or drilled for the suspending eye-bolt, which is firmly riveted into the ram or tup. In some cases an eye is made or shut on to the back end of the tup for fastening it to a rope so that any number of men may assist with the work, see Fig. 391. This is an advantage, too, for the man with the handle, as he can then devote himself solely to guiding the tup.

For suspending this useful tool there is nothing better than an open linked chain from beam to beam in a direct line with the work; a long rod may then be hooked into any of the links as required to suit any length of job; between the rod and the tup there should be a short piece of open linked chain, and a hook or shackle so that the height of the tup may be regulated by raising or lowering a link or more, one way or another, as the case may require.

A useful tool for this and similar class of work, is found in the adjustable horse, which consists of two sides, as shown in Fig. 392, one of which is notched as shown, while the opposite side is made with round holes to suit the notches. Two stretchers or distant pieces are fixed and riveted in each of the

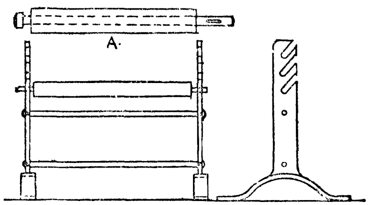


FIG. 392.

sides; the top bar is simply a piece of round bar, shouldered down to suit the holes and notches, an easy fit. Some may prefer the other top bar as shown at A, Fig. 392, which is a long cotter bolt with a piece of tube on the same; where this is used both sides of the horse have round holes only; this arrangement does not permit of such an instantaneous change as the previous one.

Fig. 393 illustrates an arrangement of handles for clipping a shaft and turning it about while being heated and worked. This form of handle is the best that can be had for moderately heavy work, and they will adopt themselves to squares as well as rounds; they can also be used for flat sections with two pieces of suitable hard wood packing. For turning handles for extra heavy work, see A in Fig. 382.

Another method of shutting is the V or splice. In this case each piece should be upset about the same distance from the end as the thickness of the bar, and one end should be drawn

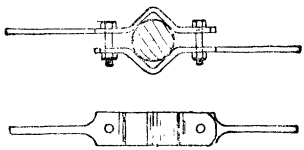


FIG. 393.

to a flat taper, as shown in Fig. 394, under the edge of the hammer pallets; the end of the other piece should also be drawn taper, but not nearly so thin; split up the centre with a

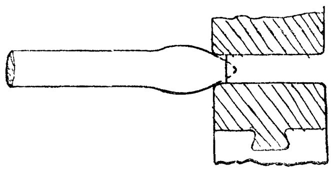


FIG. 394.

hot sate, and then throw the sides back wide enough to receive the first end, see Fig. 395; now raise both to a good welding heat, place one inside the other, and force together with hammers, tup or machine; but in making the scarfs do not have

FIG. 395.

them too thin, always remember that the fire will reduce them somewhat, and before heating the forgings, let each of the assistants clearly understand what he individually has to do when the heat comes out of the fire; lack of proper instructions beforehand is often the cause of heats being wasted, or the work badly done. Nothing can be more annoying to the smith than to see all his work and his efforts fail in their purpose through misunderstandings arising between himself and his assistants. A good plan to obviate this is to have a rehearsal of what is to take place, then it will be seen if each man really knows and understands what he has to do, and any little error can be explained and put right.

Large and heavy pieces of work are also shut by lap welding as follows: After upsetting, scarf with the edge of the hammer, as illustrated in Fig. 396, allowing the bar to come back a little at each blow, thus making a rough scarf. This can only be done when the bottom pallet is longer one way than the top one. When the two pallets are both of a size, the scarf will have to be

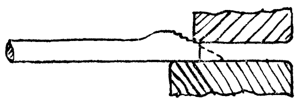


FIG. 396.

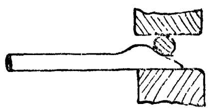


FIG. 397.

made with pieces of round bar or the fullers as in Fig. 397, commencing with a small one and using larger sizes as the work proceeds, moving the bar nearer to the end at the same time so as to form the taper as illustrated by dotted lines.

When shutting rounds under the steam hammer always use a V-block to lay the work in, unless you have top and bottom swages to fit the hammer that are suitable for the work.

If the hammer-driver is not used to this class of work, give him instructions to commence lightly, or he may perhaps strike the work too hard and cause one piece to slip off the other; you can call on him to increase the weight and speed when necessary.

Shutting Angles.—This is a more difficult job than an ordinary shut. There are two good methods to adopt which we recommend; one is to upset the ends and scarf one taper inside and one outside, then laying the one on the other, and welding both sides at the same time on a block as illustrated in Fig. 398, by one or two strikers at each side, commencing at the corner and welding as far down each side as possible at the first heat; then take a heat on each edge and finish them off. This part of the work is best done on the anvil, because the bar can then be more easily turned about, and it will lie more solidly. Some smiths, when preparing the piece that they intend

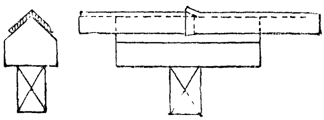


FIG. 398.

to lay on the top, set out the end slightly as shown in Fig. 398, and do not thin or scarf the end at all; this gives more material to work upon, and a better chance of a good job, and the bar is not so likely to slip back. The other method that we refer to is the best to adopt when there is no inverted V-block at hand to use. In this case, begin by scarfing one end as before, cut the flange of the other at the root, and turn back

FIG. 399.

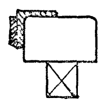


FIG. 400.

the whole flange, as illustrated in Fig. 399; this will allow the end B to pass outside C. Weld the two flanges A A in the same way as an ordinary bar, but on a block raised up higher than the depth of flange, see Fig. 400. This side should not be drawn any more than can be helped, as the other side has to be welded, and if the first side is drawn too much, there will not be enough lap on the second; now close down the flange B that was turned back, and heat and weld the same on to C.

Shutting T-Bars.—These shuts are made in much the same way as the last angle shut; one end is scarfed for a lap weld, and the other has the top flange separated from the shank and turned back, as in Fig. 399. The two shank parts are welded first, then the flange is closed down and welded on a block, with a groove through it to receive the shank, see Fig. 401.

Scarfing means preparing the ends of material preparatory to shutting one to another. The process is fully explained along with shutting.

Shrinkage.—See "Contraction."

Shearing is the act of clipping. This process is generally done at a shearing machine, or in the case of thin sheets with a pair of hand-shears as with a pair of large scissors

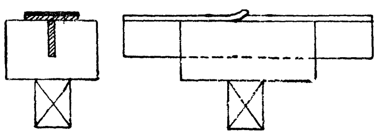


FIG. 401.

Swaging.—The word really means rounding up a piece of material in the swages, but the term is often used now when describing the process of working up a forging with a flattener or set hammer to make a smooth and good finish on the work.

Setting means adjusting or correcting the shape of a forging.

Slake means to subdue the heat in a forging suddenly by plunging it into water or oil.

Tempering.—By tempering is meant "toning down" or the act of reducing or modifying the excessive hardness set up in tools, springs, or other forgings after hardening, to enable them to do what is required of them without breaking, which would certainly take place if they were put to work without tempering. For further information see under "Hardening."

Testing.—By the word testing we understand the act of trying, verifying or proving the quality of material or workmanship.

Upsetting.—This process has already been explained, see "Shutting" and "Jumping."

Welding.—The words "Welding" and "Shutting" are synonymous, see "Shutting" for full explanation.

TABLES

FOR

SMITHS AND FORGERS

TABLES FOR SMITHS AND FORGERS

Forging Sizes for Bolts and Nuts. Whitworth Standard.*

Diam. of Bolt.	Width over Flat.		Diameter of Tapping Hole.		Diam. of Bolt.	Width over Flat.		Diameter of Tapping hole.	
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
$\frac{1}{4}$	$\frac{1}{2}$	and $\frac{1}{64}$	$\frac{3}{16}$		$1\frac{7}{8}$	$3\frac{1}{16}$		$1\frac{9}{16}$	and $\frac{1}{32}$
$\frac{5}{16}$	$\frac{9}{16}$	,, $\frac{3}{64}$	$\frac{1}{4}$		2	$3\frac{1}{8}$	and $\frac{1}{32}$	$1\frac{11}{16}$	,, $\frac{1}{32}$
$\frac{3}{8}$	$\frac{11}{16}$	,, $\frac{1}{64}$	$\frac{1}{4}$	and $\frac{3}{64}$	$2\frac{1}{4}$	$3\frac{1}{2}$	,, $\frac{3}{64}$	$1\frac{15}{16}$	
$\frac{7}{16}$	$\frac{13}{16}$	,, $\frac{1}{64}$	$\frac{5}{16}$	,, $\frac{3}{64}$	$2\frac{1}{2}$	$3\frac{7}{8}$	,, $\frac{1}{64}$	$2\frac{3}{16}$	
$\frac{1}{2}$	$\frac{7}{8}$	,, $\frac{1}{32}$	$\frac{3}{8}$	,, $\frac{1}{32}$	$2\frac{3}{4}$	$4\frac{3}{16}$		$2\frac{3}{8}$	,, $\frac{1}{32}$
$\frac{5}{8}$	1	,, $\frac{3}{32}$	$\frac{1}{2}$	,, $\frac{1}{64}$	3	$4\frac{1}{2}$	,, $\frac{1}{32}$	$2\frac{5}{8}$	,, $\frac{1}{64}$
$\frac{3}{4}$	$1\frac{1}{4}$	,, $\frac{3}{64}$	$\frac{5}{8}$		$3\frac{1}{4}$	$4\frac{13}{16}$	,, $\frac{3}{64}$	$2\frac{13}{16}$	,, $\frac{3}{64}$
$\frac{7}{8}$	$1\frac{7}{16}$	,, $\frac{3}{64}$	$\frac{11}{16}$	,, $\frac{3}{64}$	$3\frac{1}{2}$	$5\frac{1}{8}$	,, $\frac{3}{64}$	$3\frac{1}{8}$	
1	$1\frac{5}{8}$	,, $\frac{3}{64}$	$\frac{13}{16}$	,, $\frac{1}{32}$	$3\frac{3}{4}$	$5\frac{1}{2}$	,, $\frac{3}{64}$	$3\frac{5}{16}$	,, $\frac{1}{64}$
$1\frac{1}{8}$	$1\frac{13}{16}$	,, $\frac{3}{64}$	$\frac{15}{16}$	,, $\frac{1}{64}$	4	$5\frac{15}{16}$	,, $\frac{1}{64}$	$3\frac{9}{16}$	,, $\frac{1}{64}$
$1\frac{1}{4}$	2	,, $\frac{3}{64}$	$1\frac{1}{16}$		$4\frac{1}{4}$	$6\frac{3}{8}$		$3\frac{3}{4}$	,, $\frac{3}{64}$
$1\frac{3}{8}$	$2\frac{3}{16}$	,, $\frac{1}{32}$	$1\frac{1}{8}$	,, $\frac{3}{64}$	$4\frac{1}{2}$	$6\frac{13}{16}$	,, $\frac{1}{64}$	4	,, $\frac{3}{64}$
$1\frac{1}{2}$	$2\frac{3}{8}$	,, $\frac{1}{32}$	$1\frac{1}{4}$	,, $\frac{5}{64}$	5	$7\frac{3}{4}$	,, $\frac{3}{64}$	$4\frac{1}{2}$	,, $\frac{1}{32}$
$1\frac{5}{8}$	$2\frac{6}{16}$	,, $\frac{1}{64}$	$1\frac{3}{8}$		$5\frac{1}{2}$	$8\frac{13}{16}$	,, $\frac{1}{32}$	5	,, $\frac{1}{64}$
$1\frac{3}{4}$	$2\frac{3}{4}$		$1\frac{1}{2}$		6	10		$5\frac{7}{16}$	,, $\frac{3}{64}$

* Thickness of nut = diameter of bolt.
,, ,, head = $\frac{7}{8}$,, ,,

Fractions of an Inch with Decimal Equivalents.

$\frac{1}{16}$ .. ·0625	$\frac{1}{4}$ .. ·25	$\frac{7}{16}$ .. ·4375	$\frac{5}{8}$ .. ·625	$\frac{13}{16}$ .. ·8125
$\frac{1}{8}$ .. ·125	$\frac{5}{16}$ .. ·3125	$\frac{1}{2}$ .. ·5	$\frac{11}{16}$ .. ·6875	$\frac{7}{8}$ .. ·875
$\frac{3}{16}$ .. ·1875	$\frac{3}{8}$ .. ·375	$\frac{9}{16}$ .. ·5625	$\frac{3}{4}$ .. ·75	$\frac{15}{16}$ .. ·9375

Inches and Fractions Expressed as Decimals of 1 Foot.

Size. Inches.	0	1	2	3	4	5	6	7	8	9	10	11
0	..	·083	·167	·25	·333	·416	·5	·583	·666	·75	·833	·916
$\frac{1}{4}$	·021	·104	·187	·271	·354	·437	·521	·604	·687	·771	·854	·937
$\frac{1}{2}$	·042	·125	·208	·292	·375	·458	·542	·625	·708	·792	·875	·958
$\frac{3}{4}$	·062	·146	·229	·312	·396	·479	·562	·646	·729	·812	·896	·979

Safe Load for Chains.

Diam. of Link.	Tons.	Cwt.	Qr.	Diam. of Link.	Tons.	Cwt.	Qr.
in.				in.			
$\frac{1}{4}$	..	8	0	$\frac{5}{8}$	2	10	0
$\frac{5}{16}$	..	12	2	$\frac{11}{16}$	3	0	2
$\frac{3}{8}$	..	18	0	$\frac{3}{4}$	3	12	0
$\frac{7}{16}$	1	4	2	$\frac{13}{16}$	4	4	2
$\frac{1}{2}$	1	12	0	$\frac{7}{8}$	4	18	0
$\frac{9}{16}$	2	0	2	$\frac{15}{16}$	5	12	0

DIAMETERS AND CIRCUMFERENCES, TO THE NEAREST $\frac{1}{16}$ INCH.

Diam.	Circum.		Diam.	Circum.		Diam.		Circum.	
in.	ft.	in.	in.	ft.	in.	ft.	in.	ft.	in.
1 =	0	$3\frac{1}{8}$	5 =	1	$3\frac{11}{16}$	0	9 =	2	$4\frac{1}{4}$
$\frac{1}{8}$	0	$3\frac{1}{2}$	$\frac{1}{8}$	1	$4\frac{1}{16}$		$\frac{1}{8}$	2	$4\frac{11}{16}$
$\frac{1}{4}$	0	$3\frac{15}{16}$	$\frac{1}{4}$	1	$4\frac{1}{2}$		$\frac{1}{4}$	2	$5\frac{1}{16}$
$\frac{3}{8}$	0	$4\frac{5}{16}$	$\frac{3}{8}$	1	$4\frac{7}{8}$		$\frac{3}{8}$	2	$5\frac{1}{2}$
$\frac{1}{2}$	0	$4\frac{11}{16}$	$\frac{1}{2}$	1	$5\frac{1}{4}$		$\frac{1}{2}$	2	$5\frac{7}{8}$
$\frac{5}{8}$	0	$5\frac{1}{8}$	$\frac{5}{8}$	1	$5\frac{11}{16}$		$\frac{5}{8}$	2	$6\frac{1}{4}$
$\frac{3}{4}$	0	$5\frac{1}{2}$	$\frac{3}{4}$	1	$6\frac{1}{16}$		$\frac{3}{4}$	2	$6\frac{5}{8}$
$\frac{7}{8}$	0	$5\frac{7}{8}$	$\frac{7}{8}$	1	$6\frac{1}{2}$		$\frac{7}{8}$	2	7
2	0	$6\frac{1}{4}$	6	1	$6\frac{7}{8}$	0	10	2	$7\frac{7}{16}$
$\frac{1}{8}$	0	$6\frac{11}{16}$	$\frac{1}{8}$	1	$7\frac{1}{4}$		$\frac{1}{8}$	2	$7\frac{13}{16}$
$\frac{1}{4}$	0	$7\frac{1}{16}$	$\frac{1}{4}$	1	$7\frac{5}{8}$		$\frac{1}{4}$	2	$8\frac{3}{16}$
$\frac{3}{8}$	0	$7\frac{1}{2}$	$\frac{3}{8}$	1	8		$\frac{3}{8}$	2	$8\frac{9}{16}$
$\frac{1}{2}$	0	$7\frac{7}{8}$	$\frac{1}{2}$	1	$8\frac{7}{16}$		$\frac{1}{2}$	2	9
$\frac{5}{8}$	0	$8\frac{1}{4}$	$\frac{5}{8}$	1	$8\frac{13}{16}$		$\frac{5}{8}$	2	$9\frac{3}{8}$
$\frac{3}{4}$	0	$8\frac{5}{8}$	$\frac{3}{4}$	1	$9\frac{1}{4}$		$\frac{3}{4}$	2	$9\frac{3}{4}$
$\frac{7}{8}$	0	9	$\frac{7}{8}$	1	$9\frac{9}{16}$		$\frac{7}{8}$	2	$10\frac{3}{16}$
3	0	$9\frac{7}{16}$	7	1	10	0	11	2	$10\frac{9}{16}$
$\frac{1}{8}$	0	$9\frac{13}{16}$	$\frac{1}{8}$	1	$10\frac{3}{8}$		$\frac{1}{8}$	2	$10\frac{15}{16}$
$\frac{1}{4}$	0	$10\frac{1}{4}$	$\frac{1}{4}$	1	$10\frac{3}{4}$		$\frac{1}{4}$	2	$11\frac{5}{16}$
$\frac{3}{8}$	0	$10\frac{5}{8}$	$\frac{3}{8}$	1	$11\frac{3}{16}$		$\frac{3}{8}$	2	$11\frac{3}{4}$
$\frac{1}{2}$	0	11	$\frac{1}{2}$	1	$11\frac{9}{16}$		$\frac{1}{2}$	3	$0\frac{1}{8}$
$\frac{5}{8}$	0	$11\frac{3}{8}$	$\frac{5}{8}$	1	$11\frac{15}{16}$		$\frac{5}{8}$	3	$0\frac{1}{2}$
$\frac{3}{4}$	0	$11\frac{3}{4}$	$\frac{3}{4}$	2	$0\frac{3}{8}$		$\frac{3}{4}$	3	$0\frac{15}{16}$
$\frac{7}{8}$	1	$0\frac{3}{16}$	$\frac{7}{8}$	2	$0\frac{3}{4}$		$\frac{7}{8}$	3	$1\frac{5}{16}$
4	1	$0\frac{9}{16}$	8	2	$1\frac{1}{8}$	1	0	3	$1\frac{11}{16}$
$\frac{1}{8}$	1	$0\frac{15}{16}$	$\frac{1}{8}$	2	$1\frac{1}{2}$		$\frac{1}{8}$	3	$2\frac{1}{8}$
$\frac{1}{4}$	1	$1\frac{3}{8}$	$\frac{1}{4}$	2	$1\frac{15}{16}$		$\frac{1}{4}$	3	$2\frac{1}{2}$
$\frac{3}{8}$	1	$1\frac{3}{4}$	$\frac{3}{8}$	2	$2\frac{5}{16}$		$\frac{3}{8}$	3	$2\frac{7}{8}$
$\frac{1}{2}$	1	$2\frac{1}{8}$	$\frac{1}{2}$	2	$2\frac{3}{4}$		$\frac{1}{2}$	3	$3\frac{1}{4}$
$\frac{5}{8}$	1	$2\frac{1}{2}$	$\frac{5}{8}$	2	$3\frac{1}{8}$		$\frac{5}{8}$	3	$3\frac{11}{16}$
$\frac{3}{4}$	1	$2\frac{15}{16}$	$\frac{3}{4}$	2	$3\frac{1}{2}$		$\frac{3}{4}$	3	$4\frac{1}{16}$
$\frac{7}{8}$	1	$3\frac{5}{16}$	$\frac{7}{8}$	2	$3\frac{7}{8}$		$\frac{7}{8}$	3	$4\frac{7}{16}$

DIAMETERS AND CIRCUMFERENCES, TO THE NEAREST $\frac{1}{16}$ INCH—*con'd*

Diam. ft.	in.		Circum. ft.	in.	Diam. ft.	in.		Circum. ft.	in.	Diam. ft.	in.		Circum. ft.	in.
1	1	=	3	$4\frac{7}{8}$	1	5	=	4	$5\frac{7}{16}$	1	9	=	5	6
	$\frac{1}{8}$		3	$5\frac{1}{4}$		$\frac{1}{8}$		4	$5\frac{13}{16}$		$\frac{1}{8}$		5	$6\frac{3}{8}$
	$\frac{1}{4}$		3	$5\frac{5}{8}$		$\frac{1}{4}$		4	$6\frac{3}{16}$		$\frac{1}{4}$		5	$6\frac{3}{4}$
	$\frac{3}{8}$		3	6		$\frac{3}{8}$		4	$6\frac{9}{16}$		$\frac{3}{8}$		5	$7\frac{3}{16}$
	$\frac{1}{2}$		3	$6\frac{7}{16}$		$\frac{1}{2}$		4	7		$\frac{1}{2}$		5	$7\frac{9}{16}$
	$\frac{5}{8}$		3	$6\frac{13}{16}$		$\frac{5}{8}$		4	$7\frac{3}{8}$		$\frac{5}{8}$		5	$7\frac{15}{16}$
	$\frac{3}{4}$		3	$7\frac{3}{16}$		$\frac{3}{4}$		4	$7\frac{3}{4}$		$\frac{3}{4}$		5	$8\frac{5}{16}$
	$\frac{7}{8}$		3	$7\frac{9}{16}$		$\frac{7}{8}$		4	$8\frac{1}{8}$		$\frac{7}{8}$		5	$8\frac{3}{4}$
1	2		3	8	1	6		4	$8\frac{9}{16}$	1	10		5	$9\frac{1}{8}$
	$\frac{1}{8}$		3	$8\frac{3}{8}$		$\frac{1}{8}$		4	$8\frac{15}{16}$		$\frac{1}{8}$		5	$9\frac{1}{2}$
	$\frac{1}{4}$		3	$8\frac{3}{4}$		$\frac{1}{4}$		4	$9\frac{3}{8}$		$\frac{1}{4}$		5	$9\frac{7}{8}$
	$\frac{3}{8}$		3	$9\frac{3}{16}$		$\frac{3}{8}$		4	$9\frac{3}{4}$		$\frac{3}{8}$		5	$10\frac{5}{16}$
	$\frac{1}{2}$		3	$9\frac{9}{16}$		$\frac{1}{2}$		4	$10\frac{1}{8}$		$\frac{1}{2}$		5	$10\frac{11}{16}$
	$\frac{5}{8}$		3	$9\frac{15}{16}$		$\frac{5}{8}$		4	$10\frac{1}{2}$		$\frac{5}{8}$		5	$11\frac{1}{16}$
	$\frac{3}{4}$		3	$10\frac{5}{16}$		$\frac{3}{4}$		4	$10\frac{7}{8}$		$\frac{3}{4}$		5	$11\frac{7}{16}$
	$\frac{7}{8}$		3	$10\frac{3}{4}$		$\frac{7}{8}$		4	$11\frac{5}{16}$		$\frac{7}{8}$		5	$11\frac{7}{8}$
1	3		3	$11\frac{1}{8}$	1	7		4	$11\frac{11}{16}$	1	11		6	$0\frac{1}{4}$
	$\frac{1}{8}$		3	$11\frac{1}{2}$		$\frac{1}{8}$		5	$0\frac{1}{16}$		$\frac{1}{8}$		6	$0\frac{5}{8}$
	$\frac{1}{4}$		3	$11\frac{15}{16}$		$\frac{1}{4}$		5	$0\frac{1}{2}$		$\frac{1}{4}$		6	$1\frac{1}{16}$
	$\frac{3}{8}$		4	$0\frac{5}{16}$		$\frac{3}{8}$		5	$0\frac{7}{8}$		$\frac{3}{8}$		6	$1\frac{7}{16}$
	$\frac{1}{2}$		4	$0\frac{11}{16}$		$\frac{1}{2}$		5	$1\frac{1}{4}$		$\frac{1}{2}$		6	$1\frac{13}{16}$
	$\frac{5}{8}$		4	$1\frac{1}{16}$		$\frac{5}{8}$		5	$1\frac{5}{8}$		$\frac{5}{8}$		6	$2\frac{1}{4}$
	$\frac{3}{4}$		4	$1\frac{1}{2}$		$\frac{3}{4}$		5	$2\frac{1}{16}$		$\frac{3}{4}$		6	$2\frac{5}{8}$
	$\frac{7}{8}$		4	$1\frac{7}{8}$		$\frac{7}{8}$		5	$2\frac{7}{16}$		$\frac{7}{8}$		6	3
1	4		4	$2\frac{1}{4}$	1	8		5	$2\frac{13}{16}$	2	0		6	$3\frac{3}{8}$
	$\frac{1}{8}$		4	$2\frac{11}{16}$		$\frac{1}{8}$		5	$3\frac{1}{4}$		$\frac{1}{8}$		6	$3\frac{13}{16}$
	$\frac{1}{4}$		4	$3\frac{1}{16}$		$\frac{1}{4}$		5	$3\frac{5}{8}$		$\frac{1}{4}$		6	$4\frac{3}{16}$
	$\frac{3}{8}$		4	$3\frac{7}{16}$		$\frac{3}{8}$		5	4		$\frac{3}{8}$		6	$4\frac{9}{16}$
	$\frac{1}{2}$		4	$3\frac{13}{16}$		$\frac{1}{2}$		5	$4\frac{7}{16}$		$\frac{1}{2}$		6	$4\frac{15}{16}$
	$\frac{5}{8}$		4	$4\frac{1}{4}$		$\frac{5}{8}$		5	$4\frac{13}{16}$		$\frac{5}{8}$		6	$5\frac{3}{8}$
	$\frac{3}{4}$		4	$4\frac{5}{8}$		$\frac{3}{4}$		5	$5\frac{3}{16}$		$\frac{3}{4}$		6	$5\frac{3}{4}$
	$\frac{7}{8}$		4	5		$\frac{7}{8}$		5	$5\frac{9}{16}$		$\frac{7}{8}$		6	$6\frac{1}{8}$

DIAMETERS AND CIRCUMFERENCES, TO THE NEAREST 1/16 INCH—*contd.*

Diam. ft.	in.		Circum. ft.	in.	Diam. ft.	in.		Circum. ft.	in.	Diam. ft.	in.		Circum. ft.	in.
2	1	=	6	6 1/2	2	5	=	7	7 1/8	2	9	=	8	7 11/16
	1/8		6	6 15/16		1/8		7	7 1/2		1/8		8	8 1/16
	1/4		6	7 5/16		1/4		7	7 7/8		1/4		8	8 7/16
	3/8		6	7 11/16		3/8		7	8 5/16		3/8		8	8 7/8
	1/2		6	8 1/8		1/2		7	8 11/16		1/2		8	9 1/4
	5/8		6	8 1/2		5/8		7	9 1/16		5/8		8	9 5/8
	3/4		6	8 7/8		3/4		7	9 7/16		3/4		8	10
	7/8		6	9 1/4		7/8		7	9 7/8		7/8		8	10 7/16
2	2		6	9 11/16	2	6		7	10 1/4	2	10		8	10 13/16
	1/8		6	10 1/16		1/8		7	10 5/8		1/8		8	11 3/16
	1/4		6	10 7/16		1/4		7	11 1/16		1/4		8	11 5/8
	3/8		6	10 7/8		3/8		7	11 7/16		3/8		9	0
	1/2		6	11 1/4		1/2		7	11 13/16		1/2		9	0 3/8
	5/8		6	11 5/8		5/8		8	0 3/16		5/8		9	0 13/16
	3/4		7	0 1/16		3/4		8	0 5/8		3/4		9	1 3/16
	7/8		7	0 7/16		7/8		8	1		7/8		9	1 9/16
2	3		7	0 13/16	2	7		8	1 3/8	2	11		9	1 15/16
	1/8		7	1 3/16		1/8		8	1 13/16		1/8		9	2 5/16
	1/4		7	1 5/8		1/4		8	2 3/16		1/4		9	2 3/4
	3/8		7	2		3/8		8	2 9/16		3/8		9	3 1/8
	1/2		7	2 3/8		1/2		8	2 15/16		1/2		9	3 1/2
	5/8		7	2 13/16		5/8		8	3 3/8		5/8		9	3 15/16
	3/4		7	3 3/16		3/4		8	3 3/4		3/4		9	4 5/16
	7/8		7	3 9/16		7/8		8	4 1/8		7/8		9	4 11/16
2	4		7	3 15/16	2	8		8	4 1/2	3	0		9	5 1/16
	1/8		7	4 3/8		1/8		8	4 15/16		1/8		9	5 1/2
	1/4		7	4 3/4		1/4		8	5 5/16		1/4		9	5 7/8
	3/8		7	5 3/16		3/8		8	5 11/16		3/8		9	6 1/4
	1/2		7	5 9/16		1/2		8	6 1/8		1/2		9	6 11/16
	5/8		7	5 15/16		5/8		8	6 1/2		5/8		9	7 1/16
	3/4		7	6 5/16		3/4		8	6 7/8		3/4		9	7 7/16
	7/8		7	6 3/4		7/8		8	7 1/4		7/8		9	7 7/8

DIAMETERS AND CIRCUMFERENCES, TO THE NEAREST $\frac{1}{16}$ INCH—*contd.*

Diam. ft.	Diam. in.		Circum. ft.	Circum. in.	Diam. ft.	Diam. in.		Circum. ft.	Circum. in.	Diam. ft.	Diam. in.		Circum. ft.	Circum. in.
3	1	=	9	$8\frac{1}{4}$	3	5	=	10	$8\frac{13}{16}$	3	9	=	11	$9\frac{3}{8}$
	$\frac{1}{8}$		9	$8\frac{5}{8}$		$\frac{1}{8}$		10	$9\frac{3}{16}$		$\frac{1}{8}$		11	$9\frac{3}{4}$
	$\frac{1}{4}$		9	9		$\frac{1}{4}$		10	$9\frac{9}{16}$		$\frac{1}{4}$		11	$10\frac{3}{16}$
	$\frac{3}{8}$		9	$9\frac{7}{16}$		$\frac{3}{8}$		10	10		$\frac{3}{8}$		11	$10\frac{9}{16}$
	$\frac{1}{2}$		9	$9\frac{13}{16}$		$\frac{1}{2}$		10	$10\frac{3}{8}$		$\frac{1}{2}$		11	$10\frac{15}{16}$
	$\frac{5}{8}$		9	$10\frac{1}{4}$		$\frac{5}{8}$		10	$10\frac{3}{4}$		$\frac{5}{8}$		11	$11\frac{5}{16}$
	$\frac{3}{4}$		9	$10\frac{5}{8}$		$\frac{3}{4}$		10	$11\frac{5}{16}$		$\frac{3}{4}$		11	$11\frac{3}{4}$
	$\frac{7}{8}$		9	11		$\frac{7}{8}$		10	$11\frac{9}{16}$		$\frac{7}{8}$		12	$0\frac{1}{8}$
3	2		9	$11\frac{3}{8}$	3	6		10	$11\frac{15}{16}$	3	10		12	$0\frac{1}{2}$
	$\frac{1}{8}$		9	$11\frac{3}{4}$		$\frac{1}{8}$		11	$0\frac{5}{16}$		$\frac{1}{8}$		12	$0\frac{7}{8}$
	$\frac{1}{4}$		10	$0\frac{3}{16}$		$\frac{1}{4}$		11	$0\frac{3}{4}$		$\frac{1}{4}$		12	$1\frac{5}{16}$
	$\frac{3}{8}$		10	$0\frac{9}{16}$		$\frac{3}{8}$		11	$1\frac{1}{8}$		$\frac{3}{8}$		12	$1\frac{11}{16}$
	$\frac{1}{2}$		10	$0\frac{15}{16}$		$\frac{1}{2}$		11	$1\frac{1}{2}$		$\frac{1}{2}$		12	$2\frac{1}{16}$
	$\frac{5}{8}$		10	$1\frac{3}{8}$		$\frac{5}{8}$		11	$1\frac{15}{16}$		$\frac{5}{8}$		12	$2\frac{7}{16}$
	$\frac{3}{4}$		10	$1\frac{3}{4}$		$\frac{3}{4}$		11	$2\frac{5}{16}$		$\frac{3}{4}$		12	$2\frac{7}{8}$
	$\frac{7}{8}$		10	$2\frac{1}{8}$		$\frac{7}{8}$		11	$2\frac{11}{16}$		$\frac{7}{8}$		12	$3\frac{1}{4}$
3	3		10	$2\frac{1}{2}$	3	7		11	$3\frac{1}{16}$	3	11		12	$3\frac{5}{8}$
	$\frac{1}{8}$		10	$2\frac{15}{16}$		$\frac{1}{8}$		11	$3\frac{1}{2}$		$\frac{1}{8}$		12	$4\frac{1}{16}$
	$\frac{1}{4}$		10	$3\frac{5}{16}$		$\frac{1}{4}$		11	$3\frac{7}{8}$		$\frac{1}{4}$		12	$4\frac{7}{16}$
	$\frac{3}{8}$		10	$3\frac{11}{16}$		$\frac{3}{8}$		11	$4\frac{1}{4}$		$\frac{3}{8}$		12	$4\frac{13}{16}$
	$\frac{1}{2}$		10	$4\frac{1}{8}$		$\frac{1}{2}$		11	$4\frac{11}{16}$		$\frac{1}{2}$		12	$5\frac{1}{4}$
	$\frac{5}{8}$		10	$4\frac{1}{2}$		$\frac{5}{8}$		11	$5\frac{1}{16}$		$\frac{5}{8}$		12	$5\frac{5}{8}$
	$\frac{3}{4}$		10	$4\frac{7}{8}$		$\frac{3}{4}$		11	$5\frac{7}{16}$		$\frac{3}{4}$		12	6
	$\frac{7}{8}$		10	$5\frac{1}{4}$		$\frac{7}{8}$		11	$5\frac{13}{16}$		$\frac{7}{8}$		12	$6\frac{3}{8}$
3	4		10	$5\frac{11}{16}$	3	8		11	$6\frac{1}{4}$	4	0		12	$6\frac{13}{16}$
	$\frac{1}{8}$		10	$6\frac{1}{16}$		$\frac{1}{8}$		11	$6\frac{5}{8}$		$\frac{1}{8}$		12	$7\frac{3}{16}$
	$\frac{1}{4}$		10	$6\frac{7}{16}$		$\frac{1}{4}$		11	7		$\frac{1}{4}$		12	$7\frac{9}{16}$
	$\frac{3}{8}$		10	$6\frac{13}{16}$		$\frac{3}{8}$		11	$7\frac{7}{16}$		$\frac{3}{8}$		12	8
	$\frac{1}{2}$		10	$7\frac{1}{4}$		$\frac{1}{2}$		11	$7\frac{13}{16}$		$\frac{1}{2}$		12	$8\frac{3}{8}$
	$\frac{5}{8}$		10	$7\frac{5}{8}$		$\frac{5}{8}$		11	$8\frac{3}{16}$		$\frac{5}{8}$		12	$8\frac{3}{4}$
	$\frac{3}{4}$		10	8		$\frac{3}{4}$		11	$8\frac{9}{16}$		$\frac{3}{4}$		12	$9\frac{1}{8}$
	$\frac{7}{8}$		10	$8\frac{7}{16}$		$\frac{7}{8}$		11	9		$\frac{7}{8}$		12	$9\frac{9}{16}$

DIAMETERS AND CIRCUMFERENCES, TO THE NEAREST $\frac{1}{16}$ INCH—*contd.*

Diam. ft.	in.		Circum. ft.	in.	Diam. ft.	in.		Circum. ft.	in.	Diam. ft.	in.		Circum. ft.	in.
4	1	=	12	$9\frac{15}{16}$	4	5	=	13	$10\frac{1}{2}$	4	9	=	14	$11\frac{1}{16}$
	$\frac{1}{8}$		12	$10\frac{5}{16}$		$\frac{1}{8}$		13	$10\frac{7}{8}$		$\frac{1}{8}$		14	$11\frac{7}{16}$
	$\frac{1}{4}$		12	$10\frac{3}{4}$		$\frac{1}{4}$		13	$11\frac{5}{16}$		$\frac{1}{4}$		14	$11\frac{7}{8}$
	$\frac{3}{8}$		12	$11\frac{1}{8}$		$\frac{3}{8}$		13	$11\frac{11}{16}$		$\frac{3}{8}$		15	$0\frac{1}{4}$
	$\frac{1}{2}$		12	$11\frac{1}{2}$		$\frac{1}{2}$		14	$0\frac{1}{16}$		$\frac{1}{2}$		15	$0\frac{5}{8}$
	$\frac{5}{8}$		12	$11\frac{15}{16}$		$\frac{5}{8}$		14	$0\frac{1}{2}$		$\frac{5}{8}$		15	$1\frac{1}{16}$
	$\frac{3}{4}$		13	$0\frac{5}{16}$		$\frac{3}{4}$		14	$0\frac{7}{8}$		$\frac{3}{4}$		15	$1\frac{7}{16}$
	$\frac{7}{8}$		13	$0\frac{11}{16}$		$\frac{7}{8}$		14	$1\frac{1}{4}$		$\frac{7}{8}$		15	$1\frac{13}{16}$
4	2		13	$1\frac{1}{16}$	4	6		14	$1\frac{5}{8}$	4	10		15	$2\frac{3}{16}$
	$\frac{1}{8}$		13	$1\frac{1}{2}$		$\frac{1}{8}$		14	$2\frac{1}{16}$		$\frac{1}{8}$		15	$2\frac{5}{8}$
	$\frac{1}{4}$		13	$1\frac{7}{8}$		$\frac{1}{4}$		14	$2\frac{7}{16}$		$\frac{1}{4}$		15	3
	$\frac{3}{8}$		13	$2\frac{1}{4}$		$\frac{3}{8}$		14	$2\frac{13}{16}$		$\frac{3}{8}$		15	$3\frac{3}{8}$
	$\frac{1}{2}$		13	$2\frac{11}{16}$		$\frac{1}{2}$		14	$3\frac{3}{16}$		$\frac{1}{2}$		15	$3\frac{13}{16}$
	$\frac{5}{8}$		13	$3\frac{1}{16}$		$\frac{5}{8}$		14	$3\frac{5}{8}$		$\frac{5}{8}$		15	$4\frac{3}{16}$
	$\frac{3}{4}$		13	$3\frac{7}{16}$		$\frac{3}{4}$		14	4		$\frac{3}{4}$		15	$4\frac{9}{16}$
	$\frac{7}{8}$		13	$3\frac{13}{16}$		$\frac{7}{8}$		14	$4\frac{3}{8}$		$\frac{7}{8}$		15	$4\frac{15}{16}$
4	3		13	$4\frac{1}{4}$	4	7		14	$4\frac{13}{16}$	4	11		15	$5\frac{3}{8}$
	$\frac{1}{8}$		13	$4\frac{5}{8}$		$\frac{1}{8}$		14	$5\frac{3}{16}$		$\frac{1}{8}$		15	$5\frac{3}{4}$
	$\frac{1}{4}$		13	5		$\frac{1}{4}$		14	$5\frac{9}{16}$		$\frac{1}{4}$		15	$6\frac{1}{8}$
	$\frac{3}{8}$		13	$5\frac{3}{8}$		$\frac{3}{8}$		14	$5\frac{15}{16}$		$\frac{3}{8}$		15	$6\frac{9}{16}$
	$\frac{1}{2}$		13	$5\frac{13}{16}$		$\frac{1}{2}$		14	$6\frac{3}{8}$		$\frac{1}{2}$		15	$6\frac{15}{16}$
	$\frac{5}{8}$		13	$6\frac{3}{16}$		$\frac{5}{8}$		14	$6\frac{3}{4}$		$\frac{5}{8}$		15	$7\frac{5}{16}$
	$\frac{3}{4}$		13	$6\frac{9}{16}$		$\frac{3}{4}$		14	$7\frac{1}{8}$		$\frac{3}{4}$		15	$7\frac{11}{16}$
	$\frac{7}{8}$		13	7		$\frac{7}{8}$		14	$7\frac{9}{16}$		$\frac{7}{8}$		15	$8\frac{1}{8}$
4	4		13	$7\frac{3}{8}$	4	8		14	$7\frac{15}{16}$	5	0		15	$8\frac{1}{2}$
	$\frac{1}{8}$		13	$7\frac{3}{4}$		$\frac{1}{8}$		14	$8\frac{5}{16}$		$\frac{1}{8}$		15	$8\frac{7}{8}$
	$\frac{1}{4}$		13	$8\frac{1}{8}$		$\frac{1}{4}$		14	$8\frac{11}{16}$		$\frac{1}{4}$		15	$9\frac{5}{16}$
	$\frac{3}{8}$		13	$8\frac{9}{16}$		$\frac{3}{8}$		14	$9\frac{1}{8}$		$\frac{3}{8}$		15	$9\frac{11}{16}$
	$\frac{1}{2}$		13	$8\frac{15}{16}$		$\frac{1}{2}$		14	$9\frac{1}{2}$		$\frac{1}{2}$		15	$10\frac{1}{16}$
	$\frac{5}{8}$		13	$9\frac{5}{16}$		$\frac{5}{8}$		14	$9\frac{7}{8}$		$\frac{5}{8}$		15	$10\frac{7}{16}$
	$\frac{3}{4}$		13	$9\frac{3}{4}$		$\frac{3}{4}$		14	$10\frac{5}{16}$		$\frac{3}{4}$		15	$10\frac{7}{8}$
	$\frac{7}{8}$		13	$10\frac{1}{8}$		$\frac{7}{8}$		14	$10\frac{11}{16}$		$\frac{7}{8}$		15	$11\frac{1}{4}$

DIAMETERS AND CIRCUMFERENCES, TO THE NEAREST $\frac{1}{16}$ INCH—*contd.*

Diam.			Circum.		Diam.			Circum.		Diam.			Circum.	
ft.	in.		ft.	in.	ft.	in.		ft.	in.	ft.	in.		ft.	in.
5	1	=	15	11 5/8	5	5	=	17	0 3/16	5	9	=	18	0 3/4
	1/8		16	0		1/8		17	0 9/16		1/8		18	1 1/8
	1/4		16	0 7/16		1/4		17	1		1/4		18	1 9/16
	3/8		16	0 13/16		3/8		17	1 3/8		3/8		18	1 15/16
	1/2		16	1 3/16		1/2		17	1 3/4		1/2		18	2 5/16
	5/8		16	1 5/8		5/8		17	2 3/16		5/8		18	2 3/4
	3/4		16	2		3/4		17	2 9/16		3/4		18	3 1/8
	7/8		16	2 3/8		7/8		17	2 15/16		7/8		18	3 1/2
5	2		16	2 3/4	5	6		17	3 3/8	5	10		18	3 15/16
	1/8		16	3 3/16		1/8		17	3 3/4		1/8		18	4 5/16
	1/4		16	3 9/16		1/4		17	4 1/8		1/4		18	4 11/16
	3/8		16	3 15/16		3/8		17	4 1/2		3/8		18	5 1/16
	1/2		16	4 3/8		1/2		17	4 15/16		1/2		18	5 1/2
	5/8		16	4 3/4		5/8		17	5 5/16		5/8		18	5 7/8
	3/4		16	5 1/8		3/4		17	5 11/16		3/4		18	6 1/4
	7/8		16	5 1/2		7/8		17	6 1/8		7/8		18	6 11/16
5	3		16	5 15/16	5	7		17	6 1/2	5	11		18	7 1/16
	1/8		16	6 5/16		1/8		17	6 7/8		1/8		18	7 7/16
	1/4		16	6 11/16		1/4		17	7 1/4		1/4		18	7 13/16
	3/8		16	7 1/16		3/8		17	7 11/16		3/8		18	8 1/4
	1/2		16	7 1/2		1/2		17	8 1/16		1/2		18	8 5/8
	5/8		16	7 7/8		5/8		17	8 7/16		5/8		18	9
	3/4		16	8 1/4		3/4		17	8 7/8		3/4		18	9 7/16
	7/8		16	8 11/16		7/8		17	9 1/4		7/8		18	9 13/16
5	4		16	9 1/16	5	8		17	9 5/8	6	0		18	10 3/16
	1/8		16	9 7/16		1/8		17	10		1/8		18	10 9/16
	1/4		16	9 7/8		1/4		17	10 7/16		1/4		18	11
	3/8		16	10 1/4		3/8		17	10 13/16		3/8		18	11 3/8
	1/2		16	10 5/8		1/2		17	11 3/16		1/2		18	11 3/4
	5/8		16	11		5/8		17	11 9/16		5/8		19	0 3/16
	3/4		16	11 7/16		3/4		18	0		3/4		19	0 9/16
	7/8		16	11 13/16		7/8		18	0 3/8		7/8		19	0 15/16

AREAS AND WEIGHTS* OF ROUND AND SQUARE BARS.

Rounds.		Size.	Squares.	
Area of Section.	Weight of 1 foot.		Area of Section.	Weight of 1 foot.
sq. in.	lb.		sq. in.	lb.
·0123	·0418	⅛	·0156	·053
·049	·166	¼	·0625	·212
·1104	·375	⅜	·1406	·478
·1963	·667	½	·25	·850
·3068	1·04	⅝	·3906	1·33
·4418	1·5	¾	·5625	1·91
·6013	2·04	⅞	·7656	2·6
·7854	2·67	1	1·0	3·4
·99	3·37	⅛	1·26	4·28
1·22	4·15	¼	1·56	5·3
1·48	5·04	⅜	1·89	6·43
1·77	6·0	½	2·25	7·65
2·07	7·04	⅝	2·64	8·98
2·4	8·16	¾	3·06	10·4
2·76	9·38	⅞	3·51	11·93
3·14	10·68	2	4·0	13·6
3·55	12·07	⅛	4·51	15·33
3·98	13·53	¼	5·06	17·2
4·43	15·06	⅜	5·64	19·18
4·91	16·69	½	6·25	21·25
5·41	18·39	⅝	6·89	23·43
5·94	20·19	¾	7·56	25·7
6·49	22·06	⅞	8·26	28·08
7·06	24·0	3	9·0	30·6
7·67	26·07	⅛	9·76	33·18

* The weights in this and table of flats are for mild steel bars.

AREAS AND WEIGHTS * OF ROUND AND SQUARE BARS—*continued.*

Rounds.		Size.	Squares.	
Area of Section.	Weight of 1 foot.		Area of Section.	Weight of 1 foot.
sq. in.	lb.		sq. in.	lb.
8·29	28·19	3¼	10·56	35·9
8·94	30·4	⅜	11·39	38·73
9·62	32·71	½	12·25	41·65
10·32	35·09	⅝	13·14	44·68
11·04	37·54	¾	14·06	47·8
11·79	40·09	⅞	15·01	51·03
12·56	42·7	4	16·0	54·4
14·18	48·2	¼	18·06	61·4
15·90	54·1	½	20·25	68·8
17·72	60·2	¾	22·56	76·7
19·63	66·7	5	25·0	85·0
21·65	73·6	¼	27·56	93·7
23·76	80·8	½	30·25	102·8
25·97	88·3	¾	33·06	112·4
28·27	96·1	6	36·0	122·4
30·68	104·3	¼	39·06	132·8
33·18	112·8	½	42·25	143·6
35·78	121·6	¾	45·56	154·9
38·48	130·9	7	49·0	166·6
41·28	140·3	¼	52·56	178·7
44·18	150·2	½	56·25	191·2
47·17	160·4	¾	60·06	204·2
50·26	170·9	8	64·0	217·6
53·46	181·8	¼	68·06	231·4

* The weights in this and table of flats are for mild steel bars.

AREAS AND WEIGHTS * OF ROUND AND SQUARE BARS—*continued.*

Rounds.		Size.	Squares.	
Area of Section.	Weight of 1 foot.		Area of Section.	Weight of 1 foot.
sq. in.	lb.		sq. in.	lb.
56·74	192·9	$8\frac{1}{2}$	72·25	245·6
60·13	204·4	$\frac{3}{4}$	76·56	260·3
63·62	216·3	9	81·0	275·4
67·20	228·4	$\frac{1}{4}$	85·56	290·9
70·88	241·0	$\frac{1}{2}$	90·25	306·8
74·66	253·8	$\frac{3}{4}$	95·06	323·2
78·54	267·0	10	100·0	340·0
82·51	280·5	$\frac{1}{4}$	105·06	357·2
86·59	294·4	$\frac{1}{2}$	110·25	374·8
90·76	308·6	$\frac{3}{4}$	115·56	392·9
95·03	323·1	11	121·0	411·4
99·4	338·0	$\frac{1}{4}$	126·56	430·3
103·87	353·2	$\frac{1}{2}$	132·25	449·6
108·43	368·7	$\frac{3}{4}$	138·06	469·4
113·1	384·5	12	144·0	489·6

* The weights in this and table of flats are for mild steel bars.

Illustration for the practical use of above table:—

Suppose a forging has to be made off a bar $2\frac{1}{2}$ in. diam., with one end forged $1\frac{3}{4}$ in. square by 3 ft. long. The area for $1\frac{3}{4}$ in. section in the table is 3·06; multiply by 36, which is the length in inches, this gives 110·16, the cubic contents of the piece to be forged. Now take the area of the $2\frac{1}{2}$ in. section, 4·91 as divisor into the cubic contents 110·16, the quotient 22·4 is the number of inches off the $2\frac{1}{2}$-in. round required to make 3 ft. of $1\frac{3}{4}$ in. square

AREA OF RECTANGLES IN SQUARE INCHES.

Width and Thickness. Inches.	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
1/2	·125	·187																					
5/8	·156	·234	·312																				
3/4	·187	·281	·375	·47																			
7/8	·219	·328	·437	·55	·66																		
1	·25	·375	·5	·62	·75	·87																	
1/8	·28	·42	·56	·70	·84	·98	1·12																
1/4	·31	·47	·62	·78	·94	1·09	1·25	1·41															
3/8	·34	·51	·69	·86	1·03	1·20	1·37	1·55	1·72														
1/2	·37	·56	·75	·94	1·12	1·31	1·50	1·69	1·88	2·06													
5/8	·41	·61	·81	1·01	1·22	1·42	1·62	1·83	2·03	2·23	2·44												
3/4	·44	·66	·87	1·00	1·31	1·53	1·75	1·97	2·19	2·41	2·62	2·84											
7/8	·47	·70	·94	1·17	1·41	1·64	1·87	2·11	2·34	2·58	2·81	3·05	3·28										
2	·5	·75	1·0	1·25	1·50	1·75	2·0	2·25	2·5	2·75	3·0	3·25	3·5	3·75									
1/8	·53	·80	1·06	1·33	1·59	1·86	2·12	2·39	2·66	2·92	3·19	3·45	3·72	3·98	4·25								
1/4	·56	·84	1·12	1·41	1·68	1·97	2·25	2·53	2·81	3·09	3·37	3·66	3·93	4·22	4·5	4·78							
3/8	·59	·89	1·19	1·48	1·78	2·08	2·37	2·67	2·97	3·26	3·56	3·86	4·16	4·45	4·75	5·05	5·34						
1/2	·62	·93	1·25	1·56	1·87	2·19	2·50	2·81	3·12	3·44	3·75	4·06	4·37	4·69	5·0	5·31	5·62	5·94					
5/8	·66	·98	1·31	1·64	1·96	2·30	2·62	2·95	3·28	3·61	3·94	4·26	4·59	4·92	5·25	5·58	5·91	6·23	6·56				

AREA OF RECTANGLES

Thickness. Inches.	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝
Width.												
2¾	·69	1·03	1·37	1·72	2·06	2·41	2·75	3·09	3·44	3·78	4·12	4·47
⅞	·71	1·08	1·44	1·80	2·16	2·51	2·87	3·23	3·59	3·95	4·31	4·67
3	·75	1·12	1·5	1·87	2·25	2·62	3·0	3·37	3·75	4·12	4·5	4·87
⅛	·78	1·17	1·56	1·95	2·34	2·73	3·12	3·51	3·91	4·30	4·69	5·08
¼	·81	1·22	1·62	2·03	2·44	2·84	3·25	3·66	4·06	4·47	4·87	5·28
⅜	·84	1·26	1·69	2·11	2·53	2·95	3·37	3·80	4·22	4·64	5·06	5·48
½	·87	1·31	1·75	2·19	2·62	3·06	3·5	3·93	4·37	4·81	5·25	5·69
⅝	·90	1·36	1·81	2·26	2·72	3·17	3·62	4·08	4·53	4·98	5·44	5·89
¾	·94	1·41	1·87	2·34	2·81	3·28	3·75	4·22	4·69	5·16	5·62	6·09
⅞	·97	1·45	1·94	2·42	2·91	3·39	3·87	4·36	4·83	5·32	5·81	6·30
4	1·0	1·50	2·0	2·50	3·0	3·50	4·0	4·50	5·0	5·5	6·0	6·5
¼	1·06	1·59	2·12	2·66	3·19	3·72	4·25	4·78	5·31	5·84	6·37	6·9
½	1·12	1·69	2·25	2·81	3·37	3·94	4·50	5·06	5·62	6·19	6·75	7·31
¾	1·19	1·78	2·44	2·96	3·56	4·16	4·75	5·34	5·94	6·53	7·12	7·71
5	1·25	1·87	2·5	3·12	3·75	4·37	5·0	5·62	6·25	6·87	7·5	8·12
¼	1·31	1·97	2·62	3·28	3·94	4·59	5·25	5·90	6·56	7·22	7·87	8·53
½	1·37	2·06	2·75	3·44	4·12	4·81	5·5	6·19	6·87	7·56	8·25	8·94
¾	1·44	2·16	2·87	3·59	4·31	5·03	5·75	6·47	7·19	7·91	8·62	9·34
6	1·5	2·25	3·0	3·75	4·5	5·25	6·0	6·75	7·5	8·25	9·0	9·75

IN SQUARE INCHES.

1¾	1⅞	2	2⅛	2¼	2⅜	2½	2⅝	2¾	2⅞	3	Thickness. Inches.
											Width.
4·81	5·16	5·5	5·84	6·19	6·53	6·87	7·22	..	..	..	2¾
5·03	5·39	5·75	6·11	6·47	6·83	7·19	7·55	7·91	..	..	⅞
5·25	5·62	6·0	6·37	6·75	7·12	7·5	7·87	8·25	8·62	..	3
5·47	5·86	6·25	6·64	7·03	7·42	7·81	8·20	8·59	9·98	9·37	⅛
5·69	6·09	6·5	6·91	7·31	7·71	8·12	8·53	8·94	9·34	9·75	¼
5·91	6·33	6·75	7·17	7·59	8·01	8·44	8·86	9·28	9·70	10·12	⅜
6·12	6·56	7·0	7·44	7·87	8·31	8·75	9·19	9·62	10·06	10·5	½
6·34	6·80	7·25	7·70	8·16	8·61	9·06	9·51	9·97	10·42	10 87	⅝
6·56	7·03	7·5	7·97	8·43	8·91	9·37	9·84	10·31	10·78	11·25	¾
6·78	7·26	7·75	8·23	8·72	9·20	9·69	10·17	10·66	11·14	11·62	⅞
7·0	7·5	8·0	8·5	9·0	9·5	10·0	10·5	11·0	11·5	12·0	4
7·43	7·97	8·5	9·03	9·56	10·09	10·62	11·16	11·69	12·22	12·75	¼
7·87	8·44	9·0	9·56	10·12	10·69	11·25	11·81	12·37	12·93	13·5	½
8·31	8·91	9·5	10·09	10·69	11·28	11·87	12·47	13·06	13·66	14·25	¾
8·75	9·37	10·0	10·62	11·25	11·87	12·5	13·12	13·75	14·37	15·0	5
9·19	9·84	10·5	11·16	11·81	12·47	13·12	13·78	14·44	15·09	15·75	¼
9·62	10·31	11·0	11·69	12·37	13·06	13·75	14·44	15·12	15·81	16·5	½
10·06	10·78	11·5	12·22	12·94	13·65	14·37	15·09	15·81	16·53	17·25	¾
10·5	11·25	12·0	12·75	13·5	14·25	15·0	15·75	16·5	17·25	18·0	6

WEIGHT OF 1 FOOT OF FLAT OR

in.	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝
½	·42	·63	..	..	..	..	..	..	..	..	..	..
⅝	·53	·79	1·06	..	..	..	..	..	..	..	..	..
¾	·63	·95	1·26	1·59	..	..	..	..	..	..	..	..
⅞	·74	1 1	1·48	1·86	2·2	..	..	..	..	..	..	..
1	·85	1·3	1·7	2·12	2·5	2·9	..	..	..	..	..	..
⅛	·95	1·4	1·9	2·4	2·8	3·3	3·8	..	..	..	..	..
¼	1·05	1·6	2·1	2·6	3·1	3·7	4·2	4·8	..	..	..	..
⅜	1·15	1·7	2·3	2·9	3·4	4·0	4·6	5·3	5·8	..	..	..
½	1·26	1·9	2·5	3·1	3·8	4·4	5·1	5·7	6·4	7·0	..	..
⅝	1·39	2·1	2·7	3·4	4·1	4·8	5·5	6·2	6·9	7·6	8·3	..
¾	1·49	2·2	2·9	3·7	4·5	5·2	5·9	6·7	7·4	8·2	8·9	9·6
⅞	1·6	2·4	3·1	3·9	4·7	5·6	6·3	7·2	7·9	8·8	9·5	10·4
2	1·7	2·5	3·4	4·2	5·1	5·9	6·8	7·6	8·5	9·3	10·2	11·0
⅛	1·8	2·7	3·6	4·5	5·4	6·3	7·2	8·1	9·0	9·9	10·8	11·7
¼	1·9	2·8	3·8	4·7	5·7	6·7	7·6	8·6	9·5	10·5	11·3	12·4
⅜	2·0	3·0	4·0	5·0	6·0	7·1	8·0	9·1	10·1	11·1	12·1	13·1
½	2·1	3·2	4·2	5·3	6·3	7·4	8·5	9·5	10·6	11·7	12·7	13·8
⅝	2·2	3·3	4·4	5·6	6·7	7·8	8·9	10·0	11·1	12·3	13·4	14·5
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34·2	36·6	39·1	41·5	44·0	46·4	48·8	51·3	53·7	56·2	58·6	$\frac{3}{4}$
35·7	38·2	40·8	43·3	45·9	48·4	51·0	53·5	56·1	58·6	61·2	6

WEIGHT OF 1 SQUARE FOOT OF STEEL PLATE IN POUNDS.

Thickness.	lb.	Thickness.	lb.
$\frac{1}{16}$	2·5	$\frac{9}{16}$	22·9
$\frac{1}{8}$	5·1	$\frac{5}{8}$	25·5
$\frac{3}{16}$	7·6	$\frac{11}{16}$	28·0
$\frac{1}{4}$	10·2	$\frac{3}{4}$	30·6
$\frac{5}{16}$	12·7	$\frac{13}{16}$	33·1
$\frac{3}{8}$	15·3	$\frac{7}{8}$	35·6
$\frac{7}{16}$	17·8	$\frac{15}{16}$	38·2
$\frac{1}{2}$	20·4	1	40·7

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