Chapter XXXIII.—FORGING.

FORGING.—The operation of forging consists in beating or compressing metal into shape, and may be divided into five classes, viz., hand-forging, drop-forging, machine-forging, forging under trip or steam hammers, and hydraulic-forging. In purely hand forging much work is shaped entirely by hand tools, but in large shops much work is roughed out under trip or steam hammers, and finished by hand, while some work is finished under these hammers. In drop forging the work is pressed into shape by dead blows, which compress it into shape in dies or moulds. In machine forging the work is either formed by successive quick blows rather than by a few heavy ones, or in some machines it is compressed by rolling. In hydraulic forging the metal is treated as a plastic material, and is forced into shape by means of great and continuous pressure.

In all forging the nature or quality of the iron is of primary importance; hence the following (which is taken from *The English Mechanic*), upon testing iron, may not be out of place.

"The English Admiralty and Lloyds' surveyor's tests for iron and steel are as follows:—

"Two strips are to be taken from each thickness of plate used for the internal parts of a boiler. One-half of these strips are to be bent cold over a bar, the diameter of which is equal to twice the thickness of the plate. The other half of the strips are to be heated to a cherry-red and cooled in water, and, when cold, bent over a bar with a diameter equal to three times the thickness of the plate—the angle to which they bend without fracture to be noted by the surveyor. Lloyds' Circular on steel tests states that strips cut from the plate or beam are to be heated to a low cherry-red, and cooled in water at 82° Fahr. The pieces thus treated must stand bending double to a curve equal to not more than three times the thickness of the plate tested. This is severe treatment, and a plate containing a high enough percentage of carbon to cause any tempering is very unlikely to successfully stand the ordeal. Lloyds' test is a copy of the Admiralty test, and in the Admiralty Circular it is stated that the strips are to be one and a half inches wide, cut in a planing machine with the sharp edges taken off. One and a half inches will generally be found a convenient width for the samples, and the length may be from six to ten inches, according to the thickness of the plate. If possible, the strips, and indeed all specimens for any kind of experimenting, should be planed from the plates, instead of being sheared or punched off. When, however, it is necessary to shear or punch, the piece should be cut large and dressed down to the desired size, so as to remove the injured edges. Strips with rounded edges will bend further without breaking than similar strips with sharp edges, the round edges preventing the appearance of the small initial cracks which generally exhibit themselves when bars with sharp edges are bent cold through any considerable angle. In a homogeneous material like steel these initial cracks are apt to extend and cause sudden fracture, hence the advantage of slightly rounding the corners of bending specimens.

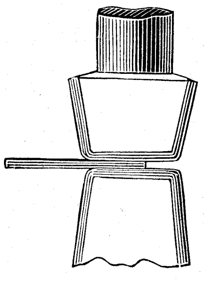

Fig. 2824.

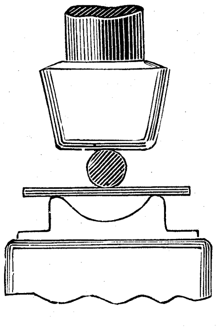

Fig. 2825.

"In heating the sample for tempering it is better to use a plate or bar furnace than a smith's fire, and care should be taken to prevent unequal heating or burning. Any number of pieces may be placed together in a suitable furnace, and when at a proper heat plunged into a vessel containing water at the required temperature. When quite cold the specimens may be bent at the steam-hammer, or otherwise, and the results noted. The operation of bending may be performed in many different ways; perhaps the best plan, in the absence of any special apparatus for the purpose, is to employ the ordinary smithy steam-hammer. About half the length of the specimen is placed upon the anvil and the hammer-head pressed firmly down upon it, as in Fig. 2824. The exposed half may then be bent down by repeated blows from a fore-hammer, and if this is done with an ordinary amount of care it is quite possible to avoid producing a sharp corner.

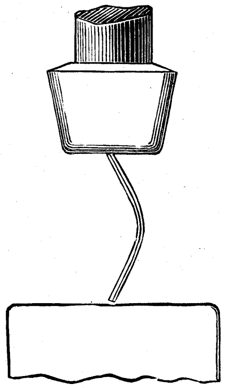

Fig. 2826.

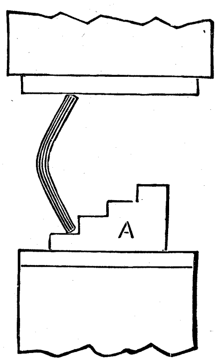

Fig. 2827.

"An improvement upon this is to place a cress on the anvil, as shown at Fig. 2825. The sample is laid upon the cress, and a round bar of a diameter to produce the required curve is pressed down upon it by the hammer-head.

"The further bending of the pieces thus treated is accomplished by placing them endwise upon the anvil-block, as shown in Fig. 2826. If the hammer is heavy enough to do it, the samples should be closed down by simple pressure, without any striking.

"Fig. 2827 is a sketch of a simple contrivance, by means of which a common punching machine may be converted temporarily into an efficient test-bending apparatus. The punch and bolster are removed, and the stepped cast-iron block A fixed in place of the bolster. When a sample is placed endwise upon one of the lower steps of the block A the descending stroke of the machine will bend the specimen sufficiently to allow of its being advanced to the next higher step, while the machine is at the top of its stroke. The next descent will effect still further bending, and so on till the desired curvature is attained. It would seem an easy matter, and well worth attention, to design some form of machine specially for making bending experiments; but with the exception of a small hydraulic machine, the use of which has, I believe, been abandoned on account of its slowness, nothing of the kind has come under the writer's notice.

"The shape of a sample after it has been bent to pass Lloyds' or the Admiralty test is that of a simple bend, the sides being brought parallel. While being bent the external surface becomes greatly elongated, especially at and about the point of the convex side, where the extension is as much even as fifty per cent. This extreme elongation corresponds to the breaking elongation of a tensile sample, and can only take place with a very ductile material. While the stretching is going on at the external surface, the interior surface of the bend is being compressed, and the two strains extend into pieces till they meet in a neutral line, which will be nearer to the concave than to the convex curve with a soft specimen. When a sample breaks, the difference between the portions of the fracture which have been subject to tensile and compressive strains can easily be seen.

"Fig. 2828 shows a piece of plate folded close together; and this can generally be done with mild steel plates, when the thickness does not exceed half an inch.

"Common iron plates will not, of course, stand anything like the foregoing treatment. Lloyds' test for iron mast-plates $\frac{1}{2}$ inch thick, requires the plates to bend cold through an angle of 30° with the grain, and 8° across the grain; the plates to be bent over a slab, the corner of which should be rounded with a radius of $\frac{1}{2}$ inch.

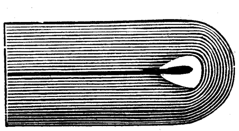
Fig. 2828.

"When the sample of metal to be tested is of considerable thickness, as in the case of bars, it is often turned down in a lathe to the shape shown in Fig. 2829, so as to reduce its strength within the capacity of the machine. The part to be tested has usually a length between the shoulders of 8, 10, or 12 inches, and must be made exactly parallel with a cross-sectional area apportioned to the power of the machine and the strength of the material to be tested. When it is desired to investigate the elastic properties of materials, it is desirable to have the specimens of as great a length as the testing apparatus will accommodate.

"Many of the early experiments on the tensile strength of wrought iron were made with very short specimens, such as in Fig. 2830, which is a sketch of that used formerly in the royal arsenal at Woolwich. This had no parallel length for extension at all, its smallest diameter occurring at one only point. Mr. Kirkaldy, to whom is due in a great measure the honour of having raised 'testing' to an exact science, discovered that this form of specimen gave incorrect results. He found that experiments with such specimens, more especially when the metals were ductile, gave higher breaking strains than were obtained with specimens of equal cross-sectional area having the smallest diameter parallel for some inches of length. This was due to the form of the specimen resisting to some extent the 'flow' or alteration of shape which occurs in soft ductile materials previous to fracture. He accordingly commenced to use a specimen of the form shown in Fig. 2831, with a parallel portion for extension of several inches in length, and specimens like that in Fig. 2830 became a thing of the past.

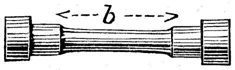

Fig. 2829.


Fig. 2830.

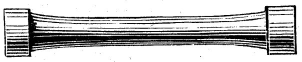
Fig. 2831.

"The specimens shown in the figures admit of being secured in the testing machine in many different ways. But whatever description of holder be employed, two absolute requirements must be kept in view. The holders must be stronger than the sample, and they must transmit the stress in a direction parallel to the axis of the sample without any bending or twisting tendency.

"Fig. 2832 gives two views of a very effective method of holding round specimens, used by Mr. Kirkaldy in his earlier experiments carried out for Messrs. Napier & Sons, of Glasgow. The enlarged ends of the samples are clasped in split sockets provided with eyeholes for attaching them to the shackles of the testing machine, the halves of the sockets being held together during the experiment by small bolts passing through the projecting lugs.

"Fig. 2833 explains the plan adopted for testing the strength of bolts and nuts in the same series of experiments.

"A good holder for lathe-turned samples is shown in Fig. 2834.

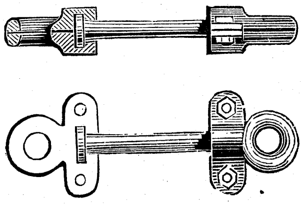
Fig 2832.

Close fitting socket-pieces *b b* embrace each end of the specimen, and also the turned collar at the extremity of the shackle *a*. The halves of the socket are held together by a collar *c*, the interior of which and exterior of the socket rings are turned to an equal taper, so that the socket-pieces are held quite firmly when the collar *c* is simply slipped over them by hand. When the experiment is over, a few taps with the hammer will remove the collar *c*.

"Samples of plates for tensile testing are usually shaped like Fig. 2835. The parallel portion B is generally 8, 10, or 12 inches long, as in the case of the turned specimens. Two minor points in the preparation of specimens may be here alluded to. In the first place the holes *a a* must be made large enough to obviate any danger of the pins which are placed in these holes to secure the specimen being sheared in two before the specimen breaks. In the second place, enough material must be left around these pin or bolt holes to prevent the probability of the metal tearing away between the hole and the edge of the plate. The pin holes must be placed exactly in a line with the axis of the specimen, and the part B must be quite parallel in width, so that the strength (and the elongation during the testing) may be, as nearly as possible, equal throughout the length of B. The shoulders, as *c*, should be easy curves, so that sharp corners may be avoided. When a number of such specimens are required at the same time, the strips of plate may be clamped together and planed or slotted to the desired width as one piece, but the tool marks should be afterwards removed by careful draw-filing.

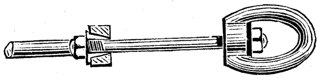
Fig. 2833.

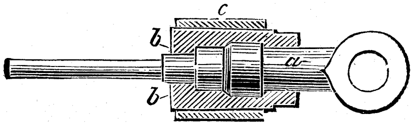

Fig. 2834.

"When the plates are thin, small side pieces are riveted on the sides of the ends to be clamped, as shown in Fig. 2836. These stiffen those ends and afford a larger bearing for the securing pins. The connection with the shackles is made by means of steel pins passing through the end holes, and when specimens like 2835 are properly prepared, the direction of the stress on them must be in a line with their axis. Fig. 2837 shows another form of plate specimen in which the holes are dispensed with, the ends being held in the

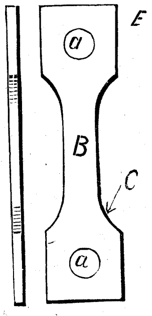

Fig. 2835.

machine by friction clips, as shown. These specimens are more easily prepared, and from the absence of holes may be made of a very narrow strip of plate.

"In Fig. 2837 the jaws or forked arms of the shackle are closed to form a rectangular ring, as shown in section in the figure. Two of the interior faces are tapered inwards to the same angle as the back of the wedges or clips *a a'*, which are perfectly smooth and free to slide upon the inclined or tapered surfaces of the shackles. The faces of the wedges, however, which come in contact with and grip the specimen to be tested, as *b*, are fluted or grooved, so that the friction of the edges against the specimen is much greater than against the inside surfaces of the shackles. The result of the arrangement is, that when the shackles are pulled, the wedges *a a'* are tightened against the specimen with a degree of force proportionate to the load on the specimen, which is prevented from slipping through the clips by the 'bite' of their fluted faces. The grooves on the faces of the clips need not be deep—a depth of a little more than $\frac{1}{16}$, with about the same distance apart, answering well for ordinary loads. With deep grooves and a wider pitch apart, the danger of the specimen breaking in the clips is increased. The inclination of the backs of the wedges *a a'* to the faces may be at an angle of 5 or 6 degrees. When the taper is too small, the removal of the halves of the specimen after breaking is sometimes difficult, while on the other hand, when too great, the specimen is apt to slip between the wedges while being tested. The wedges exert a very considerable outward pressure, and the jaws of the shackles must be made strong enough to resist any strain likely, under extreme conditions, to fall on them, otherwise they will speedily become unfit for use. In securing a specimen care must be taken that its axis is in the direct line of strain, and the opposite clips should be driven in equally so that the stress may act fairly upon it. Parallel planed strips of metal, without any enlargement at the ends, may be tested in these friction clips, though, of course, there is a chance of the specimen breaking within them. Turned specimens may also be held by such clips; as also may rough, unturned round and square bars, an advantage when it is desired to immediately ascertain approximately the strength of metal samples."

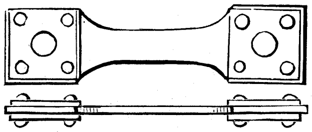
Fig. 2836.

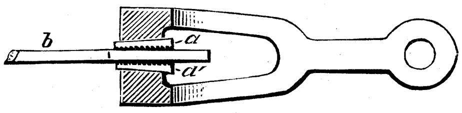
Fig. 2837.

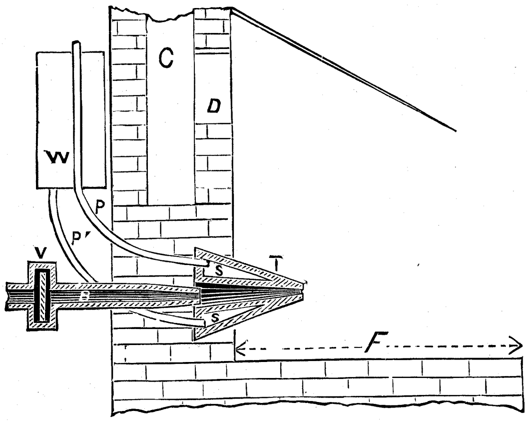
Fig. 2838.

Open fires for hand forging purposes are mainly of two classes, those having a side and those with a bottom or vertical blast.

Fig. 2838 represents a side draft forge. F is the fireplace, usually from 3 to 5 feet long, T is the tuyère through which the blast enters the fire, B being the blast pipe. To prevent T from being burned away it is hollow as at S, and two pipes P and P' connect to the water-tank W, thus maintaining a circulation of water through S; V is simply a valve or damper to shut off the supply of air from the tuyère; D is the opening to the chimney C.

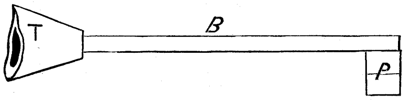
Fig. 2839.

The side blast, though not so much used as in former years, is still preferred by many skilful mechanics, on the ground that it will give a cleaner fire with less trouble. The method of accomplishing this is to dig out a hole in the fire bed and fill it in with coked coal, which will form a drain through which the slag or clinker may sink, instead of remaining in the active fire and obstructing the blast.

In cases where the fire requires to be built farther out from the chimney wall than the location of the tuyère permits, it may be built out as follows:—

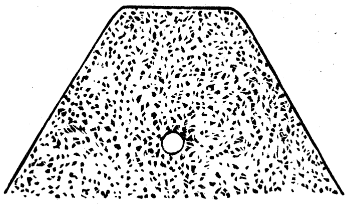
Fig. 2840.

A bar B, Fig. 2839, is placed in the tuyère hole and supported at the other end at P. The coal is well wetted and packed around and above the bar, which is then pulled out endwise, leaving a blast hole through the coal, as is shown in the end view Fig. 2840.

Fig. 2841 represents a patent tuyère of vertical or bottom draft, in which the blast passes through pipe A and circulates around B, finding egress at C into the fire. C is hollow and receives water from the tank F by the pipe D. The steam generated in the nozzle C is conveyed to the tanks by the pipe E.

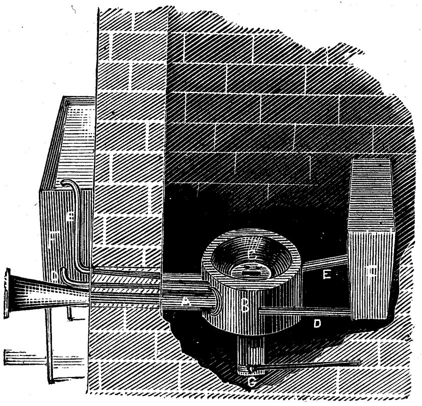
Fig. 2841.

Figs. 2842 and 2843 represent a blacksmith's forge, for work up to and about 4 inches in diameter. It consists of a wind-box A, supported on brickwork which forms an ash-pit G beneath it. To this box is bolted the wind-pipe B, and at its bottom is the slide E. In an orifice at the top of A is a triangular and oval breaker D, connected to a rod operated by the handle C. This rod is protected from the filling which is placed between the brickwork and the shell F of the forge by being encased in an iron pipe I. The blast passes up around the triangular oval piece D. The operation is as follows: when D is rotated, it breaks up the fire and the dirt falls down into the wind-box, cleaning the fire while the heat is on. At any time after a heat the slide E may be pulled out, letting the slag and dirt fall into the ash-pit beneath. It is a great advantage to be able to clean the fire while a heat is on without disturbing the heat.

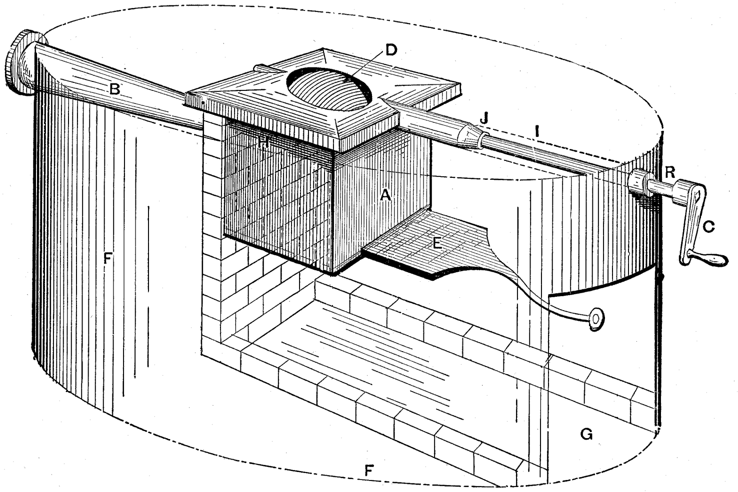

Fig. 2842.

Blacksmiths' anvils are either of wrought iron steel faced, or of cast iron steel faced, the faces being hardened. It is sometimes fastened to the block by spikes driven in around the edges. A better plan, however, is to make the block the same size as the anvil, and secure the latter by two bands of iron and straps, as shown in Fig. 2844, because in this way the block will not come in the way of arms or projecting pieces that hang below the anvil. The square hole is for receiving the stems of swages, fullers, &c., and for placing work over to punch holes through it, and the round is used for punching small holes.

The proper shape for blacksmiths' tongs depends upon whether they are to be used upon work of a uniform size and shape, or upon general work. In the first case, the tongs may be formed to exactly suit the special work. In the second case, they must be formed to suit as wide a range of work as convenient.

Suppose, for example, the tongs are for use on a special size and shape of metal only; then they should be formed so that the jaws will grip the work evenly all along, and therefore be straight along the gripping surface. It will be readily perceived, however, that if such tongs were put upon a piece of work of greater thickness, they would grip it at the inner end only, and it would be impossible to hold the work steady. The end of the work would act as a pivot, and the part on the anvil would move about. It is better, therefore, for general work to curve the jaws, putting the work sufficiently within the jaws to meet them at the back of the jaw, when the end will also grip the work. By putting the work more or less within the tongs, according to its thickness, contact at the end of the work and at the point of the tongs may be secured in one pair of tongs over a wider range of thickness of work than would otherwise be the case. This applies to tongs for round or other work equally as well as to flat or square work.

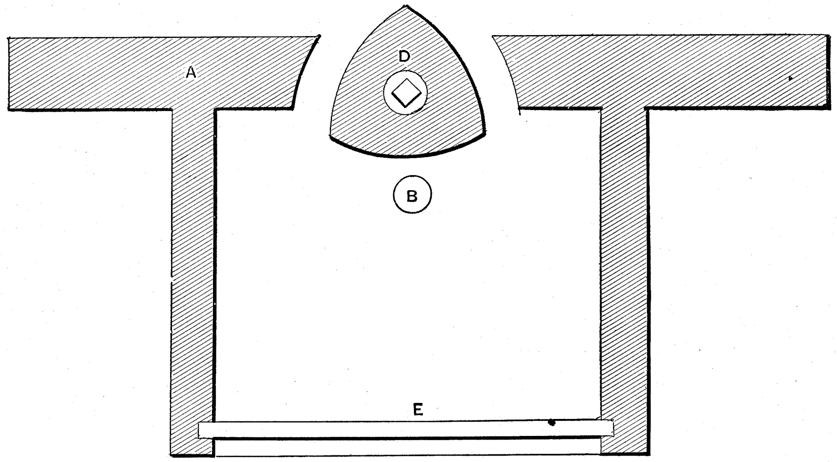

Fig. 2843.

To maintain the jaw pressure of the tongs upon the work, a ring is employed, the tong ends being curved to prevent the ring from slipping off.

After a piece of work has left the fire it should, if there are scales adhering upon it, have them cleaned off before being forged, for which purpose the hammer head or an old file is used, otherwise the forging will not be smooth, and the scale will be hammered into the surface. This will render the forging very hard to operate upon by steel cutting tools, and cause them to dull rapidly. For the same reason it is proper to heat a finished forging to a low red heat and pass a file over its surface, which will leave the forging soft as well as free from scale. A forging should not be finally finished by being swaged or forged after it has become black hot, because it produces a surface tension that throws the work out of true as the metal is cut away in finishing it.

Work to be drawn out is treated according to the amount of elongation and reduction of diameter required. Thus, suppose a piece of square work to require to be drawn out, then it is hammered on its respective sides, being turned upon the anvil so that each successive side shall receive the hammer blows. It is essential, however, that the piece be forged square, or in other words, that during the forging the sides be kept at a right angle one to the other, or else the work will hammer hollow, as it is termed; that is to say, the iron will split at the centre of the bar, which occurs from its being forged diamond-shaped instead of square. If a piece required to be forged diamond-shaped, it must be forged square until reduced to such dimensions as will leave sufficient to draw out while altering its form from the square to the diamond-shape.

In very small work, which is more apt to hammer hollow than large work, the end of the piece is left of enlarged size, as shown in the figure, the strength of the enlarged end serving to prevent the hammering hollow, which usually begins at the end of the piece; the end is in this case forged last. In the case of round work the same rule holds good, inasmuch as that a round bar may be forged smaller to some extent, either by hammer blows or by swaging, but if the forging by hammer blows be excessive, hammering hollow is liable to ensue.

The blacksmith's set of chisels consists of a hot chisel for cutting off hot iron, a cold chisel for cutting cold metal, a hardy, which sets in the square hole in the anvil, **C**-chisels, which are curved somewhat like the carpenter's gouge, and a cornering or **V**-chisel, in which the cutting edges are at a right angle one to the other.

The hot chisel has its edge well curved in its length, and is kept cool by lifting it from the work after each hammer blow, and by occasionally dipping it in water. Lifting it also prevents it from wedging in the work. The cold chisel is tempered to a blue, and answers virtually to the machinist's chisel. The hardy is used for small work, which is laid upon it and struck with the hammer. The **C**-chisel is used, not only in curved corners, but also to cut off deep cuts, answering, like the cape or cross-cut chisel of the machinist, to relieve the corners of the hot chisel. The cornering chisel is used for square corners, situated so that the hot chisel cannot be used. The blacksmith's punch is made well taper, so that it shall not wedge in the hole it produces.

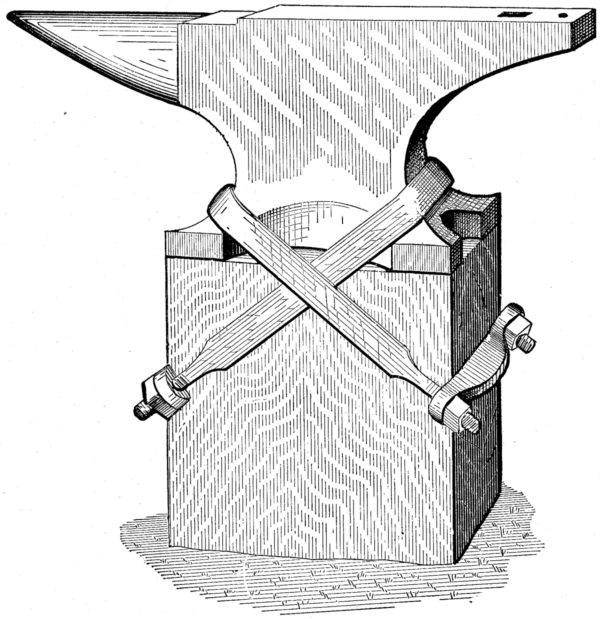

Fig. 2844.

For large holes a small punch is first used, and the hole enlarged in diameter by driving in punches of larger diameter. If this swells the work at the sides, it is forged down while the punch is in the hole.

The first blow given to the punch is a light one, so as to leave an indentation that will mark the location, and enable its easy correction if necessary. The blows delivered after the correct location is indented are quick and heavy; but a piece of soft coal is inserted and the punch placed on top of it, the gases formed by the combustion of the coal serving to prevent the punch from binding in the hole. Between the blows the blacksmith lifts the punch and moves the handle part of a lateral rotation, which prevents it from becoming fast in the hole. The punch should not be suffered to get red hot, but must be removed and cooled, a fresh piece of green soft coal being inserted in the hole just previous to the punch. If the punch is allowed to become as heated as the work, the end will "upset" or swell and become firmly locked. Should the punch lock in the hole a few blows will usually loosen it, but in extreme cases it is sometimes necessary to employ another punch from the opposite side of the work. Unless in very thin work, the hole is punched half way from each side, because by that means a short stout punch may be used.

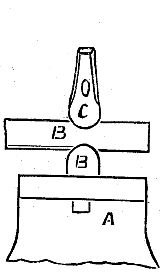

Fig. 2845

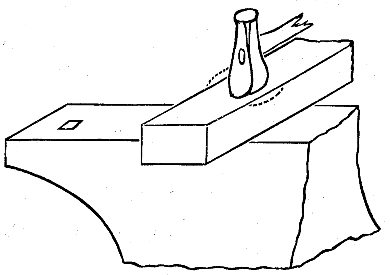

Fig. 2846.

It is obvious that when the hole requires to be bell-mouthed or of any other form, the punch must be made to correspond.

The tools employed by the blacksmith, other than tongs, hammers, chisels, and punches, are composed mainly of "fullers" and "swages" of various kinds. The fuller is essentially a spreading tool, while the swage may be termed essentially a shaping one.

In Fig. 2845, for example, let A represent an end view of an anvil, B the bottom, and C the top fuller, and the effects of blows upon C will be mainly to stretch the piece in the direction of its length without swelling it out sideways.

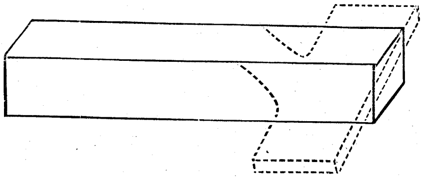

Fig. 2847.

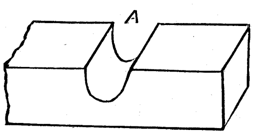

Fig. 2848.

If the work requires to be swelled sideways we turn the fuller the other way around, as in Fig. 2846, in which it is supposed that one side of the work is to be kept flat, hence no bottom fuller is employed. The action of a fuller may be increased in the required direction by leaning in the direction in which we desire to drive the iron; thus, suppose we require to spread the end of a rectangular bar from the full lines to the dotted ones in Fig. 2847 and the first fuller across the piece as at A, Fig. 2848, and then spread out the end by fullering, as in Fig. 2849, inclining the fuller in the direction in which we desire to forge the iron.

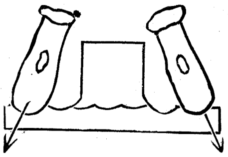

Fig. 2849.

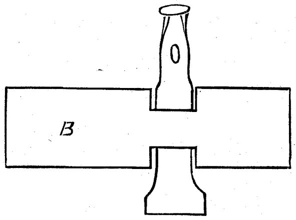

Fig. 2850.

It is the roundness of the face of the fuller that serves to control the direction in which it will drive the iron, since the curve acts somewhat on the principle of a wedge. Suppose, for example, that the faces were flat, as in Fig. 2850, and the iron would spread in both directions, the same as though the hammer were used direct, and if the work were intended to be kept parallel it would frequently require to be turned on edge to forge down the bulge that would form on the edge.

Fullers are, however, also used as finishing tools for curves or corners, an example being given in Fig. 2851, which represents a fuller applied to finish the round corner of a collar.

For finishing plane surfaces the flatter shown in Fig. 2852 is employed, W representing the work. For inside surfaces the flatter requires to be offset, as in Fig. 2853, in which L represents a link whose face A may be flattened by the flatter F. There is a tendency in this case for the flatter to tip or cant; and to avoid this and regulate the flatter upon the work, a side foot is sometimes added, as at A in Fig. 2854.

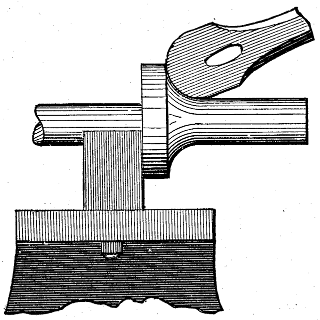
Fig. 2851.

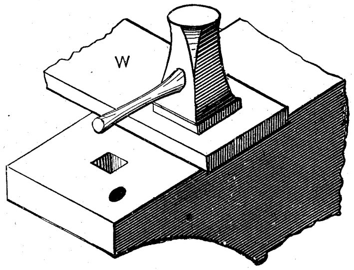

Fig. 2852.

Swages are shaped according to the kind of work they are to be used for.

Fig. 2855, for example, represents a top and bottom swage for rounding up iron. For general work the recesses or seats of such swages would be made considerably oval, as in Fig. 2856, the work being revolved slightly after each blow. This capacitates one swage for different sizes of iron. When, however, a swage is to be used for one particular size only, its cavity may be made more nearly a true half circle and may envelop one half the diameter of the work, so that when the top and bottom swages meet, the work will be known to be of the required diameter without measuring it. If the seat were made a true half circle it would lock upon the work, preventing the smith from revolving it and making it difficult to remove the swage.

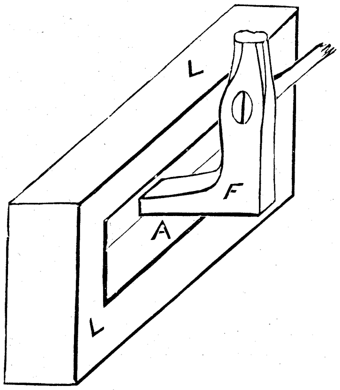

Fig. 2853.

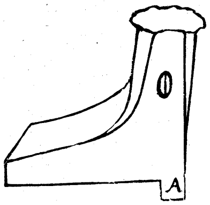

Fig. 2854.

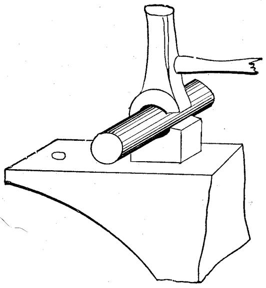
Fig. 2855.

If the conditions are such that a swage must be used to perform forging rather than finishing, its seat should be V-shaped and not curved. Suppose, for example, that a piece of iron, say, 6 inches in diameter, required a short section to be forged down to a diameter of 3 inches, then the swages should be formed as in Fig. 2857, because otherwise the effects of the blow will act to a certain extent to force the iron out sideways, for reasons which will be explained presently.

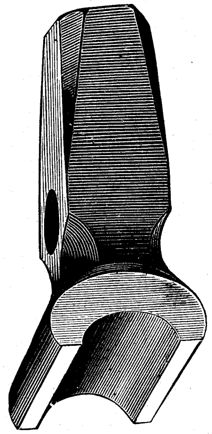
Fig. 2856.

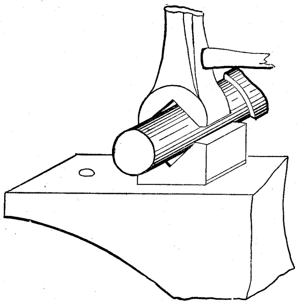
Fig. 2857.

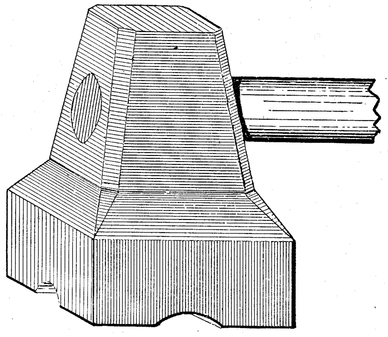
Fig. 2858.

In some cases, for small work, the upper swage is guided by the lower one: thus, in Fig. 2858 is a swage for a cross piece, and the outside of its base is squared and fits easily within the upper part of the lower one shown in Fig. 2859. For very

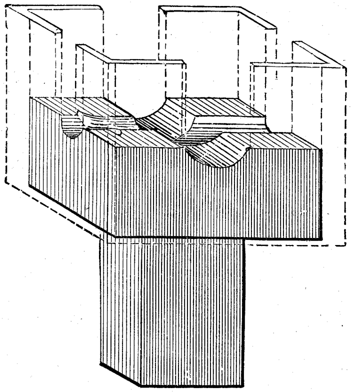
Fig. 2859.

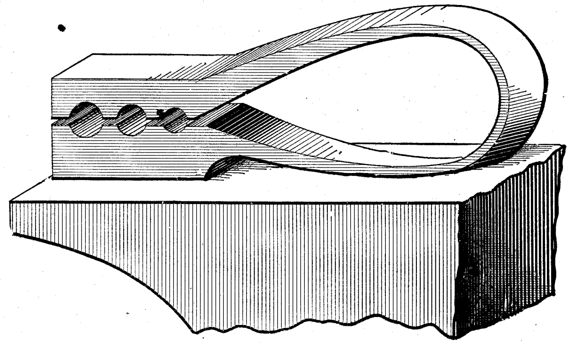
Fig. 2860.

small work, on which the hand hammer is sufficiently heavy to perform the swaging, a spring swage may be used: thus, in Fig 2860 is a swage for pieces of $\frac{3}{8}$, $\frac{5}{16}$, and $\frac{1}{4}$ inch in diameter, and having a square stem fitting into the square hole in the anvil. Fig. 2861 represents a spring swage for a pin having a collar, and it may be observed that the recess to form the collar must be tapered narrowest at the bottom, so that the top swage will readily release itself by the force of the spring, and so that the work may easily be revolved in the lower one. A similar tool is shown in Fig. 2862, designed for punching sheet metal cold, the die D being changeable for different sizes of punches P.

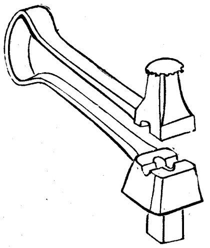
Fig. 2861.

For large hand-made forgings the swage block, such as in Fig. 2863, is employed, S representing a stand for the block, whose dimensions are larger than the block, so that the latter may be rested on its face in the stand when the holes are to be used.

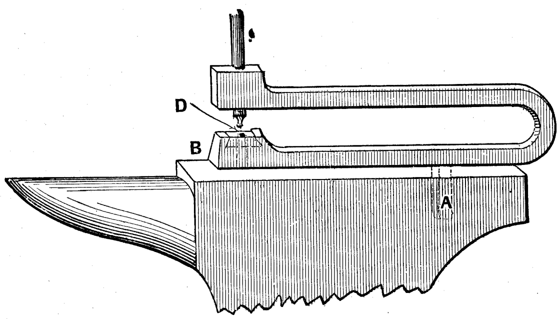

Fig. 2862.

Fig. 2864 represents a swage block mounted on bearers, so that it may be revolved to bring the necessary cavity uppermost.

Swages for trip hammers or for small steam hammers are for work not exceeding about 4 inches in diameter, made as in Fig. 2865, the weight of the top swage being sufficient to keep the two closed as in the figure; for larger sizes the bottom swage fits to the anvil, and the top one is provided with a handle, as in Fig. 2866, B representing the anvil block, S' the bottom, and S the top swage, having a handle H. The flange of the bottom swage is placed as in Fig. 2867, so as to prevent the swage from moving off the anvil block when the work is pushed through it endways. Obviously such swages are employed when the part to be swaged is less in length than the width of the hammer or of the anvil face.

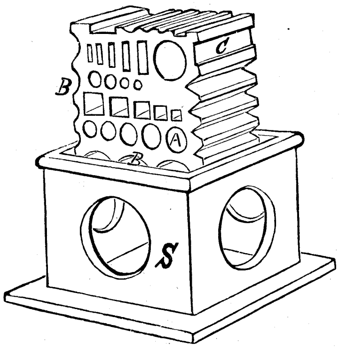

Fig. 2863.

If the hammer and anvil face is rounded as in Fig. 2868, or if dies thus shaped are placed in them, their action will be the same as that of the fuller, drawing the work out lengthways, with a minimum of effect in spreading it out sideways.

Detached fullers, such as shown in Figs. 2869 and 2870, are, however, used when the section to be acted upon is less in length than the hammer face.

In the case of trip hammers, steam hammers, &c., blocks fitted to the hammer and anvil block may take the place of detached swages and fullers. Thus, in Fig. 2871 is represented the hammer and anvil block for flat work, the corners being made rounded, because if left sharp they would leave marks on the work. The blocks or dies A and B are dovetailed into their places, and secured by keys K; hence they may be removed, and dies of other shapes substituted.

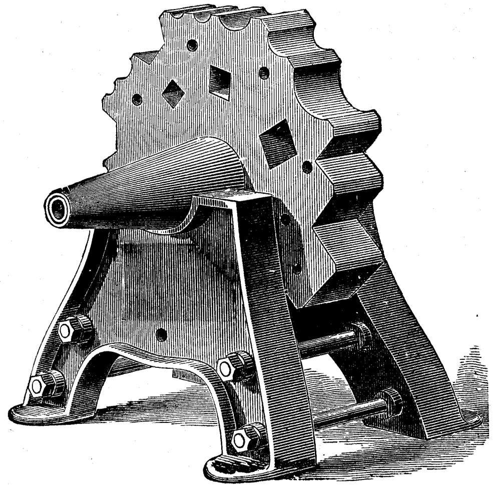
Fig. 2864.

When the work is parallel it may be forged to its finished dimensions by forming in the lower die recesses whose depth equals the required dimensions. Thus, in Fig. 2872 the recess A in the lower die equals in depth the depth A of the work, while the depth of the recess B in the die equals the thickness of the bar; hence by passing the work successively from A to B, and turning it over a quarter turn, it will be made to finished size, when the faces C D of the dies meet.

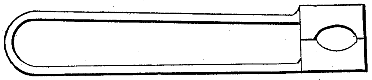
Fig. 2865.

For this class of work the recesses must obviously be made in the lower die, because it would be difficult to hold the work upon the lower die in the proper position to meet a recess cut in the upper one: and, furthermore, the recesses in the die should be wider than the work, to avoid the necessity of holding the work exactly straight in the recess, and keeping it against the shoulder or vertical face of the recess. If, however, the work is to be made taper, we may obviously make the recess taper, so as to produce smooth work, the die recess being made to be of the correct depth for the smallest end of the work.

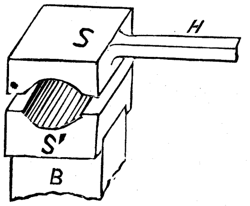

Fig. 2866.

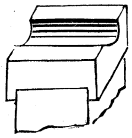
Fig. 2867.

When the shape of the work is such that it cannot be moved upon the die during the forging, the operation is termed stamping, or if the hammer or upper die falls of its own weight it is termed drop forging, and in this case the finishing dies are made the exact shape of the work, care being taken to let the work be

EXAMPLES IN STEAM HAMMER WORK.

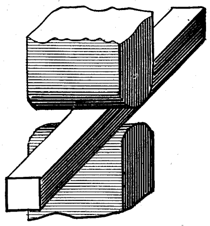

Fig. 2868.

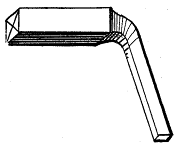

Fig. 2869.

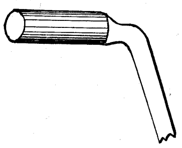

Fig. 2870.

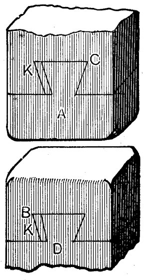

Fig. 2871.

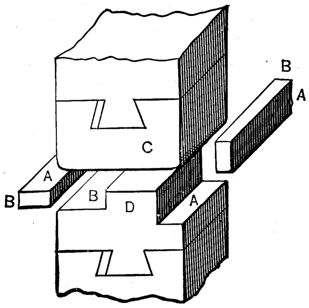

Fig. 2872.

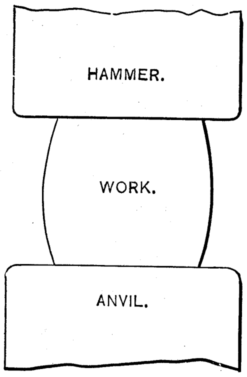

Fig. 2873.

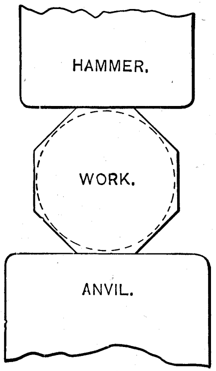

Fig. 2874.

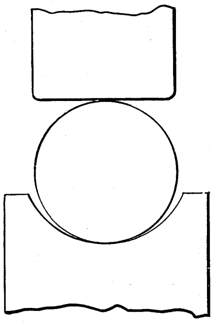

Fig. 2875.

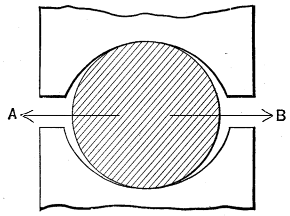

Fig. 2876.

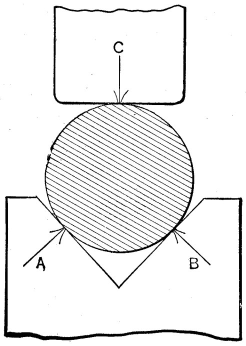

Fig. 2877.

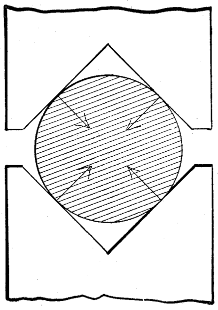

Fig. 2878.

enveloped as much as possible by the bottom die, so that the top one shall not lift it out on its up stroke.

In forging large pieces from square to round we have several important considerations. In order to keep the middle of the work sound, it must be drawn square to as near as possible the required diameter before the finishing is begun. During this drawing-down process the blows are heavy and the tendency of the work is to spread out at the sides, as in Fig. 2873.

When the work is ready to be rounded up it is first drawn to an octagon, as shown in Fig. 2874, so as to bring it nearer the work, nearer to cylindrical form. The corners are then again hammered down, giving the work sixteen sides, the work during this part of the process being moved endways, as each corner is hammered down. The blows are during this part of the forging lighter, but still the tendency is to spread the work out sideways. The final finishing to cylindrical form is done with light blows, the work being revolved upon the anvil without being moved endways, so that a length equal to the width of the anvil is finished before the work is moved endways to finish a further part of the length. The tendency to spread sideways is here unchecked, because the iron is squeezed top and bottom only. We may check it to some extent, however, by employing a bottom swage block, as in Fig. 2875, in which case the contact of the swage and the work will extend further around the work circumference than would be the case with a flat anvil. If we were to use a top and a bottom swage, as in Fig. 2876, the circumferential surface receiving the force of the blow will be still further increased, but there will still be a tendency to spread at the sides, as at A B, in Fig. 2876. A better plan, therefore, is to use a V-block with the hammer, as in Fig. 2877, in which case the effects of the blow are felt at A, B, and C, and the points A B of resistance being brought higher up on the work, its tendency to spread is obviously diminished. By using a top and bottom V-block, as shown in Fig. 2878, the effect will be to drive the metal towards the centre, and, therefore, to keep it sound at the centre, it being found that if the metal is swaged much without means being taken to prevent spreading, it "hammers hollow," as it is termed, or in other words, splits at its centre.

The points A B of resistance to the blow at C are higher and the tendency to spread sideways is better resisted. For cutting off under the steam hammer, the hack shown in Fig. 2879 is used, being simply a wedge with an iron handle.

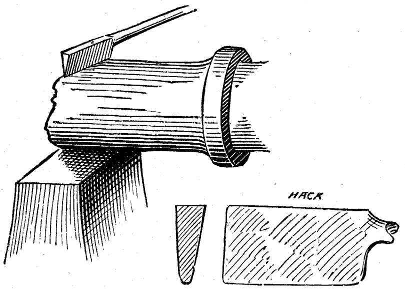

Fig. 2879.

WELDING.—In the welding operations of the blacksmith there are points demanding special attention: first, to raise the temperature of the metal to a proper heat; second, to let the temperature be as nearly equal as practicable all through the mass; third, to have the surfaces to be welded as clean and free from oxidation as possible; fourth, have the parts to be welded of sufficient diameter or dimensions to permit of the welded joint being well forged.

The following remarks on the theory of welding are from a paper read by Alexander L. Holley before the American Institute of Mining Engineers:—

"The generally received theory of welding is that it is merely pressing the molecules of metal into contact, or rather into such proximity as they have in the other parts of the bar. Up to this point there can hardly be any difference of opinion, but here uncertainty begins. What impairs or prevents welding? Is it merely the interposition of foreign substances between the molecules of iron, or of iron and any other substance which will enter into molecular relations or vibrations with iron? Is it merely the mechanical preventing of contact between molecules, by the interposition of substances? This theory is based on such facts as the following:

"1. Not only iron but steel has been so perfectly united that the seam could not be discovered, and that the strength was as great as it was at any point, by accurately planing and thoroughly smoothing and cleaning the surfaces, binding the two pieces together, subjecting them to a welding heat, and pressing them together by a very few hammer blows. But when a thin film of oxide of iron was placed between similar smooth surfaces, a weld could not be effected.

"2. Heterogeneous steel scrap, having a much larger variation in composition than these irons have, when placed in a box composed of wrought-iron side and end pieces laid together, is (on a commercial scale) heated to the high temperature which the wrought-iron will stand, and then rolled into bars which are more homogeneous than ordinary wrought iron. The wrought-iron box so settles together as the heat increases that it nearly excludes the oxidizing atmosphere of the furnace, and no film of oxide of iron is interposed between the surfaces. At the same time the enclosed and more fusible steel is partially melted, so that the impurities are partly forced out and partly diffused throughout the mass by the rolling.

"The other theory is that the molecular motions of the iron are changed by the presence of certain impurities, such as copper and carbon, in such a manner that welding cannot occur, or is greatly impaired. In favor of this theory it may be claimed that, say, 2 per cent. of copper will almost prevent a weld, while, if the interposition theory were true, this copper could only weaken the weld 2 per cent., as it could only cover 2 per cent. of the surfaces of the molecules to be united. It is also stated that 1 per cent. of carbon greatly impairs welding power, while the mere interposition of carbon should only reduce it 1 per cent. On the other hand, it may be claimed that in the perfect welding due to the fusion of cast iron, the interposition of 10 or even 20 per cent. of impurities, such as carbon, silicon, and copper, does not affect the strength of the mass as much as 1 or 2 per cent. of carbon or copper affects the strength of a weld made at a plastic instead of a fluid heat. It is also true that high tool steel, containing 1½ per cent. of carbon is much stronger throughout its mass, all of which has been welded by fusion, than it would be if it had less carbon. Hence copper and carbon cannot impair the welding power of iron in any greater degree than by their interposition, provided the welding has the benefit of that perfect mobility which is due to the fusion. The similar effect of partial fusion of steel in a wrought-iron box has already been mentioned. The inference is, that imperfect welding is not the result of a change in molecular motions due to impurities, but of imperfect mobility of the mass—of not giving the molecules a chance to get together.

"Should it be suggested that the temperature of fusion, as compared with that of plasticity, may so change chemical affinities as to account for the different degrees of welding power, it may be answered that the temperature of fusion in one kind of iron is lower than that of plasticity in another, and that as the welding and melting points of iron are largely due to the carbon they contain, such an impurity as copper, for instance, ought, on this theory, to impair welding in some cases and not to affect it in others.

"The obvious conclusions are: 1st. That any wrought iron, of whatever ordinary composition, may be welded to itself in an oxidizing atmosphere at a certain temperature, which may differ very largely from that one which is vaguely known as 'a welding heat.' 2nd. That in a non-oxidizing atmosphere heterogeneous irons, however impure, may be soundly welded at indefinitely high temperatures.

"The next inference would be that by increasing temperature we chiefly improve the quality of welding. If temperature is increased to fusion, welding is practically perfect; if to plasticity and mobility of surfaces, welding should be nearly perfect. Then how does it sometimes occur that the more irons are heated the worse they weld?

"1. Not by reason of mere temperature, for a heat almost to dissociation will fuse wrought iron into a homogeneous mass.

"2. Probably by reason of oxidation, which, in a smith's fire especially, necessarily increases as the temperature increases. Even in a gas furnace a very hot flame is usually an oxidizing flame. The oxide of iron forms a dividing film between the surfaces to be joined, while the slight interposition of the same oxide, when diffused throughout the mass by fusion or partial fusion, hardly affects welding. It is true that the contained slag, or the artificial flux, becomes more fluid as the temperature rises, and thus tends to wash away the oxide from the surfaces; but inasmuch as any iron with any welding flux can be oxidized till it scintillates, the value of a high heat in liquefying the slag is more than balanced by its damage in burning the iron.

"But it still remains to be explained why some irons weld at a higher temperature than others; notably, white irons high in carbon, or in some other impurities, can only be welded soundly by ordinary processes at low heats. It can only be said that these impurities, as far as we are aware, increase the fusibility of iron, and that in an oxidizing flame oxidation becomes more excessive as the point of fusion approaches. Welding demands a certain condition of plasticity of surface; if this condition is not reached, welding fails for want of contact due to mobility; if it is exceeded, welding fails for want of contact due to excessive oxidation. The temperature of this certain condition of plasticity varies with all the different compositions of irons. Hence, while it may be true that heterogeneous irons, which have different welding points, cannot be soundly welded to one another in an oxidizing flame, it is not yet proved, nor is it probable, that homogeneous irons cannot be welded together, whatever their composition, even in an oxidizing flame. A collateral proof of this is, that one smith can weld irons and steels which another smith cannot weld at all, by means of a skilful selection of fluxes and a nice variation of temperatures.

"To recapitulate. It is certain that perfect welds are made by means of perfect contact due to fusion, and that nearly perfect welds are made by means of such contact as may be got by partial fusion in a non-oxidizing atmosphere or by the mechanical fitting of surfaces, whatever the composition of the iron may be within all known limits. While high temperature is thus the first cause of that mobility which promotes welding, it is also the cause, in an oxidizing atmosphere, of that 'burning' which injures both the weld and the iron. Hence, welding in an oxidizing atmosphere must be done at a heat which gives a compromise between imperfect contact due to want of mobility on the one hand, and imperfect contact due to oxidation on the other hand. This heat varies with each different composition of irons. It varies because these compositions change the fusing points of irons, and hence their points of excessive oxidation. Hence, while ingredients such as carbon, phosphorus, copper, &c., positively do not prevent welding under fusion, or in a non-oxidizing atmosphere, it is probable that they impair it in an oxidizing atmosphere, not directly, but only by changing the susceptibility of the iron to oxidation."

In welding steel to iron both are heated to as high a temperature as possible without burning, and a welding compound or flux of some kind is used.

In welding steel to steel the greatest care is necessary to obtain as great a heat as possible without burning, and to keep the surfaces clean.

An excellent welding compound is composed as follows: Copperas 2 ozs., salt 4 ozs., white sand 4 lbs., the whole to be mixed and thrown upon the heat, as is done when using white sand as described for welding iron. An equally good compound is made up of equal quantities of borax and pulverized glass, well wetted with alcohol, and heated to a red heat in a crucible. Pulverize when cool, and apply as in the case of sand only.

A welding compound for cast steel given by Mr. Rust in the *Revue Industrielle* is made up as follows: 61 parts of borax, 20 parts of sal-ammoniac, 16¾ parts of ferrocyanide, and 5 parts of colophonium. He states that with the acid of this compound cast steel may be welded at a yellow red heat, or at a temperature between the yellow, red, and white heats. The borax and sal-ammoniac are powdered, mixed, and slowly heated until they melt. The heating is continued until the strong odor of ammonia ceases almost entirely, a small quantity of water being added to make up for that lost by evaporation. The powdered ferrocyanide is then added, together with the colophonium, and the heating is continued until a slight smell of cyanogen is noticed. The mixture is allowed to cool by spreading it out in a thin layer.

The lap weld is formed as follows: Suppose it is required to weld together the ends of two cylindrical pieces, and the first operation is to pump or upset the ends to enlarge them, as shown in Fig. 2880, so as to allow some metal to be hammered down in making the weld without reducing the bar below its proper diameter. The next operation is to scarf the ends forming them, as shown in Fig. 2881, and in doing this it is necessary to make the scarf face somewhat rounding, so that when put together as in the figure contact will occur at the middle, and the weld will begin there and proceed as the joint comes together under the blows towards the outside edges. This squeezes out scale or dirt, and excludes the air, it being obvious that if the scarf touched at the edges first, air would be enclosed that would have to find its escape before the interior surfaces could come together.

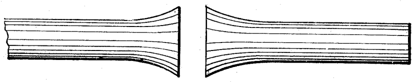
Fig. 2880.

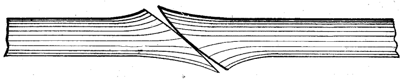
Fig. 2881.

It is obvious, that if the two pieces require to weld up to an exact length and be left parallel in diameter when finished an allowance for waste of iron must be made; and a good method of welding under these conditions is as follows:—

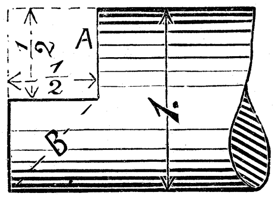

Fig. 2882.

Let the length of the two pieces be longer than the finished length to an amount equal to the diameter. Then cut out a piece as at A, in Fig. 2882, the step measuring half the diameter of the bar as shown. The shoulder A is then thrown back with the hammer, and the piece denoted by the dotted line B is cut off, leaving the shaft as shown in Fig. 2883.

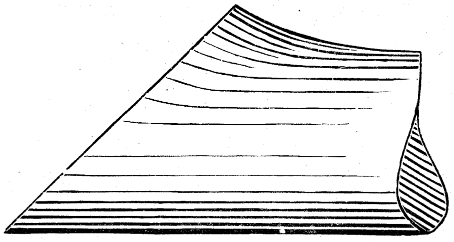
Fig. 2883.

The faces of the scarf should be somewhat rounding, so that when the weld is put together contact will take place in the centre of the lapping areas. Then, as the surfaces come together, the air and any foreign substances will be forced out, whereas, were the surfaces hollow the air and any cinder or other foreign substances would be closed in the weld, impairing its soundness.

The lap of the two pieces, when scarfed in this manner, is shown in Fig. 2884.

To take the welding heat the fire should be cleaned out and clear coked coal, and not gaseous coal, used. The main points in a welding heat are, to heat the iron equally all through, to obtain the proper degree of heat, and to keep the scarfed surfaces as free from oxidation, and at the same time as clean, as possible.

To accomplish these ends the iron must not be heated too quickly after it is at a good red heat, and the fire must be so made that the blast cannot meet it at any point until it has passed through the bed of the fire.

When the iron is getting near the welding heat it may be sprinkled with white sand, which will melt over it and form a flux that will prevent oxidation and cool the exterior, giving time to the interior to become equally heated. The sand should be thrown on the work while in the fire, as removing the work from the fire causes it to oxidize or scale rapidly. The work should be turned over and over in the fire, the scarf face being kept uppermost until the very last part of the heating, when the blast must be put on full, the bed of the fire kept full and clear so that there shall be sufficient bed to prevent the blast from meeting the heat until it has passed through the glowing coals.

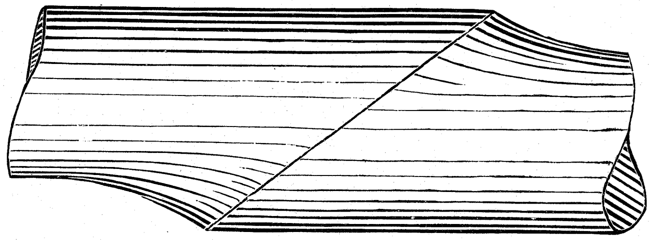

Fig. 2884.

When the heat is taken from the fire it should meet the anvil with a blow, the scarfed face being downwards, to jar off any dirt, cinder, &c., and the scarf should be cleaned by a stroke or two of a wire brush. But as every instant the iron is in the air it is both cooling and oxidizing, these operations must be performed as quickly as possible.

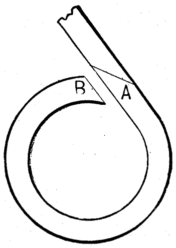

Fig. 2885.

The two scarfs being laid together as shown in Fig. 2884, the first blows must be delivered lightly, so as not to cause the upper piece to move, and as quickly as possible, the force of the blows being increased regularly and gradually until the weld is sufficiently firm to hold well together, when it may be turned on edge and the edges of the scarf hammered to close and weld the seam. If this turning is done too soon, however, it may cause the two halves to separate. When the weld is firmly and completely made the enlarged diameter due to the scarfing may be forged down, working the iron as thoroughly as possible.

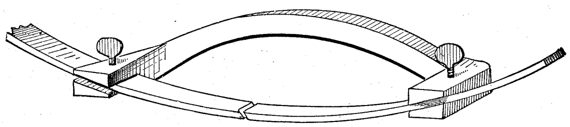

Fig. 2886.

To form the scarf of a ring or collar, one end is bevelled, as at B in Fig. 2885 and after the piece is bent to a circle it is cut off and bevelled as at A. When a slight band is to be welded, and it is difficult to steady the ends to bring them together, a clamp may be used to hold them as in Fig. 2886.

Fig. 2887 represents a tongue weld, and it is obvious that to insure soundness the wedge piece should fit in the bottom of the split, which may be well closed upon it by the hammer blows.

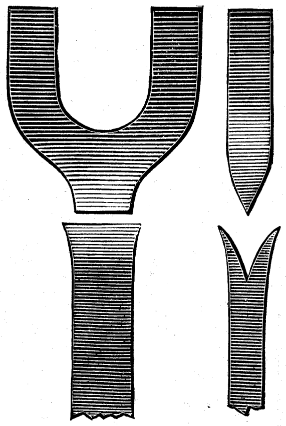

Fig. 2887.

Fig. 2888 represents an example of a **V**-weld applied to welding up a band that is to be square when finished, and as the lengths of the sides must be equal when finished, the side on which the weld is made should be made shorter, so that in stretching under the welding blows it will be brought to its proper length. The **V** form of weld is employed because it stretches less in welding than the lap weld. The **V**-piece to be welded in should bear at the bottom of the **V**, and the weld made by fullering.

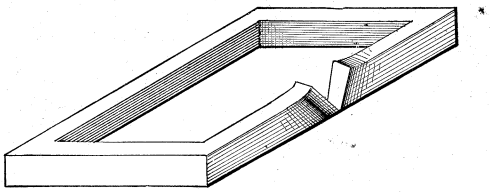

Fig. 2888.

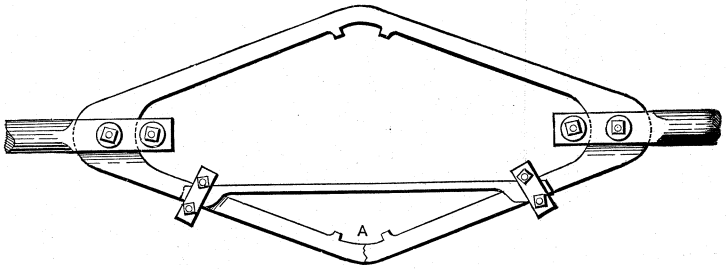

Fig. 2889.

Welds of this kind are obviously most suitable for cases in which the weld is required to influence the shape of the piece as little as possible. The figures above, which are taken from *Mechanics*, illustrate as an example the repairing of a broken strap for the beam of a river steamboat. The crack is at A, Fig. 2889, and is held together by a clamp as shown; a **V**-recess is cut out as in Fig. 2890, and this recess is fullered larger, as in Fig. 2891. A **V**-block is then welded in. The strap is then

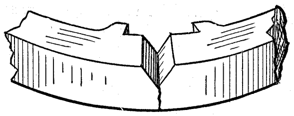

Fig. 2890.

turned over a second V-groove, cut out and fullered out, and a second V-piece welded in. By thus welding one side at a time the welding is taken in detail as it were, and the blows can be less heavy than if a larger weld were made at one heat, as would be the case if but one V block were used. A similar form of weld may be employed to form a square corner, as is shown in Fig. 2892, which is taken from "The Blacksmith and Wheelwright." In this example the inside corner is shown to have a fillet, which greatly increases the difficulty of the job. The weld is made by first fullering the V-piece on the sides and on the rounded corner and then laying the piece on the anvil to forge down, the fullering leaving the finished job as in Fig. 2893.

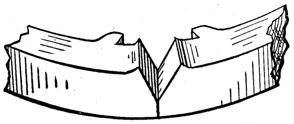

Fig. 2891.

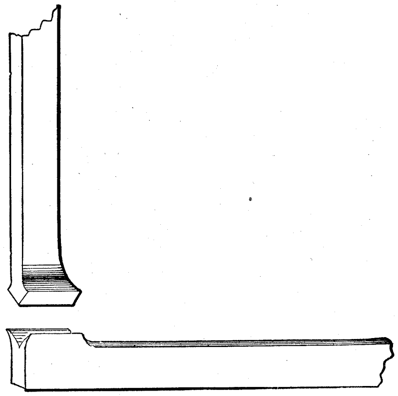

Fig. 2892.

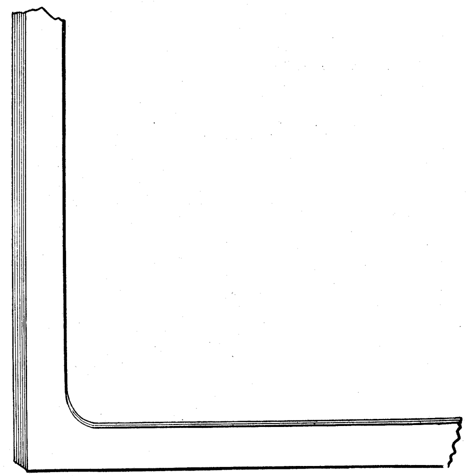

Fig. 2893.

When one piece has to be driven on to the other, the weld is called a pump-weld, for which the ends should be rounded as in Fig. 2894, so that they will meet at their centres, and will, when struck endways to make the weld, come to the shape shown in Fig. 2895.

Fig. 2894.

It is obvious that in this case the interior of the iron comes together and is welded, and that dirt, &c., is effectually excluded; hence if the iron is properly heated the weld may be as sound as a lap weld, and is preferred by many as the sounder weld of the two. When a stem requires to be welded to a large flat surface, the pump weld is the only one possible, being formed as in Fig. 2896, in which the stem is supposed to be welded to a frame. The plate is cupped as shown, and the metal being driven up on the sides as much as possible, the stem overlaps well at C B, so that it may be fullered there. The stem should first meet its seat at A, so that dirt, &c., may squeeze out as the welding proceeds.

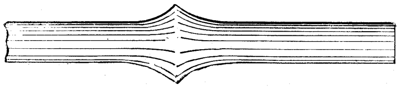

Fig. 2895.

Figs. 2897 and 2898 represent an example of welding a collar on round iron. The bar is upset so as to enlarge it at A, where the collar is to be. The collar is left open at the joint, and while it is cold it is placed on the red-hot bar and swaged until the ends are closed. The welding of the whole may then be done at one heat, swaging the outside of the collar first. Unless the bar is upset there would be a crack in the neck B of the collar on both sides.

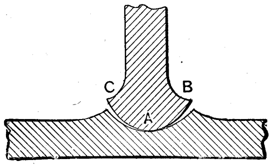

Fig. 2896.

WELDING ANGLE IRON.—Let it be required to form a piece of straight angle iron to a right angle.

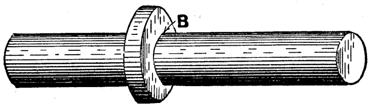

Fig. 2897.

The first operation is to cut out the frog, leaving the piece as shown in Fig. 2899; the width at the mouth A of the frog being $\frac{3}{4}$ inch to every inch of breadth measured inside the flange as at B.

The edges of the frog are then scarfed and the piece bent to an acute angle; but in this operation it is necessary to keep the scarfs quite clean and not to bend them into position to weld until they are ready for the welding heat; otherwise scale will form where the scarfs overlap and the weld will not be sound.

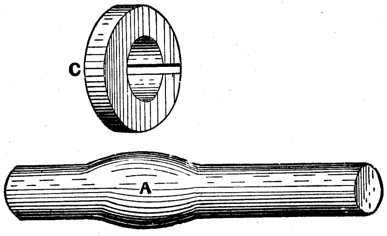

Fig. 2898.

The heat should be confined as closely as possible to the parts to be welded; otherwise the iron will scale and become reduced below its proper thickness.

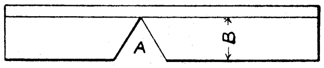

Fig. 2899.

The iron is then bent to the shape shown in Fig. 2900; and the angle to which it is bent is an important consideration. The object is to leave the overlapping scarf thicker than the rest of the metal, and then the stretching which accompanies the welding will bring the two arms or wings to a right angle.

It is obvious, then, that the thickness of the metal at the weld determines the angle to which the arms must be bent before welding. The thicker the iron the more acute the angle. If the angle be made too acute for the thickness of the iron at the weld there is no alternative but to swage the flange down and thin it enough to bring the arms to a right angle. Hence it is advisable to leave the scarf too thick rather than too thin, because while it is easy to cut away the extra metal, if necessary, it is not so easy to weld a piece in to give more metal. In very thin angle irons, in which the wastage in the heating is greater in proportion to the whole body of metal, the width of the frog at A in Fig. 2901 may be less, as, say, $\frac{9}{16}$ inch for every inch of angle-iron width measured as at B in the figure. For angles other than a right angle the process is the same, allowance being made in the scarf-joint and bend before welding for the stretching that will accompany the welding operation.

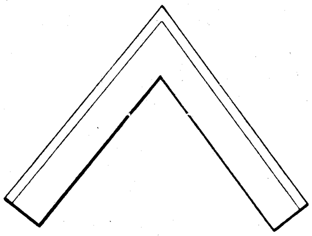
Fig. 2900.

The welding blows should be light and quick, while during the scarfing the scale should be cleaned off as soon as the heat leaves the fire, so that it will not drive into the metal and prevent proper welding. The outside corner should not receive any blows at its apex; and as it will stretch on the outside and compress on the inside, the forging to bring the corner up square should be done after the welding.

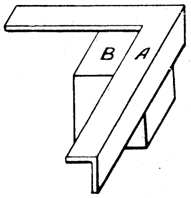

Fig. 2901.

The welding is done on the corner of an angle block, as in Fig. 2901, in which A is the angle iron and B the angle block.

To bend an angle iron into a circle, with the flange at the extreme diameter, the block and pins shown in Fig. 2902 are employed. The block is provided with the numerous holes shown for the reception of the pins. The pins marked 1 and 2 are first inserted and the iron bent by placing it between them and placed under strain in the necessary direction. Pins 3 and 4 are then added and the iron again bent, and so on; but when the holes do not fall in the right position, the length of the pin-heads vary in length to suit various curves.

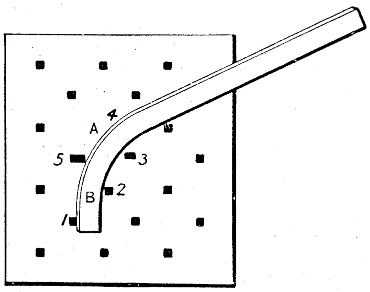

Fig. 2902.

To straighten the iron it is flattened on the surface A and swaged on the edge of the flange B, the bending and straightening being performed alternately.

When the flange of the angle iron is to be inside the circle, as in Fig. 2903, a special iron made thicker on the flange A is employed. The bending is accomplished, partly by the pins as before, and partly by forging thinner, and thus stretching the flange A while reducing it to its proper thickness.

To Forge a Bolt by Hand.—The blanks for bolts must be cut off sufficiently long to admit of one end being upset to form the head, the amount of this allowance, obviously, being determined by the size of the head.

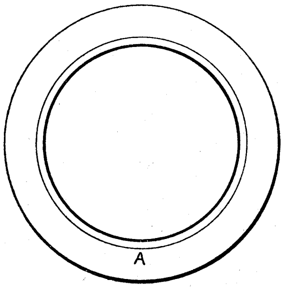

Fig. 2903.

Fig. 2904 is a side view, partly in section, and Fig. 2905 a top view of an anvil block for upsetting the ends of blanks to form the heads of bolts. The stem fits into the square hole of the anvil.

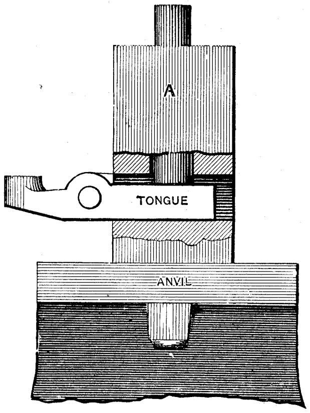

Fig. 2904.

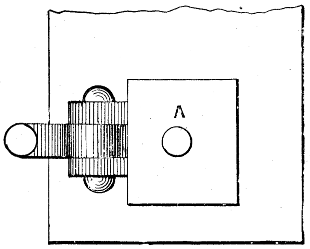

Fig. 2905.

The tongue is pivoted as shown in the top view to two lugs provided on the block; upon the tongue rests a steel pin whose length determines the height to which the blank will project above the top of the block, and, therefore, the amount or length of blank that will be upset to form the head, this amount being three times the diameter of the bolt for *black heads*.

The hole for the blank is made about $\frac{1}{64}$ inch larger in diameter than the designated size of the bolt, to permit of the easy extraction of the blank after it is upset, this extraction being accomplished by striking the end of the tongue with the hammer. If the block is made of cast iron the upper end of the hole will become worn after forging five hundred or six hundred bolts, leaving the bolts with a rounded neck, as at C C in Fig. 2906; a steel block, however, will forge several thousand bolts without becoming enlarged.

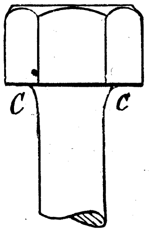

Fig. 2906.

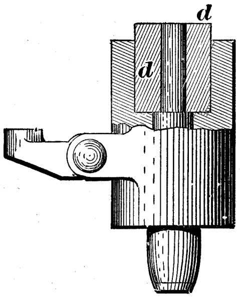

Fig. 2907.

An excellent plan is to provide the block with removable dies, such as at *d d* in Fig. 2907, which are easily renewed, a number of such dies having different diameters of bore fitted to the same block.

When the bolt end is sufficiently reset or enlarged to form the head it is laid in a bottom swage, containing three of the six sides of the hexagon, and a hammer blow on the uppermost part of the end forges a flat side. After each blow the work is revolved one-sixth of a revolution, and as the angles of the swage are true they obviously true the angles of the bolt head. After the head has been roughed down it is necessary to flatten it again under the head and on the end, for which purpose it may be placed in the heading block shown in Fig. 2904, after which the sides of the head may be finished and the cupping tool for chamfering the head applied.

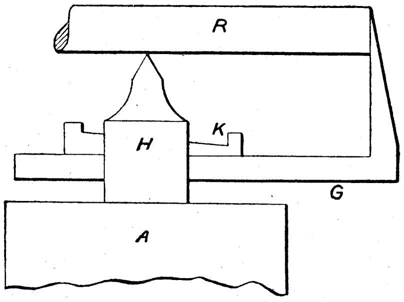

Fig. 2908.

The bolt may require passing from the heading tool to the swage several times, as forging it in one direction spreads it in another.

In shops where bolt-making is of frequent occurrence a special bolt-making device is usually employed. It consists of an oliver or foot hammer, having two hammers and an anvil; in the square hole at one end of the anvil fits a hardy or bottom chisel, such as shown in Fig. 2908, for cutting up the bar or rod iron into bolt blanks; A is the anvil, H the hardy, and G a gauge to determine the length cut off the rod R to form a blank. An upsetting or heading device corresponding to that in Fig. 2907 is provided, and at the other end of the anvil is the swage for forming the bolt head.

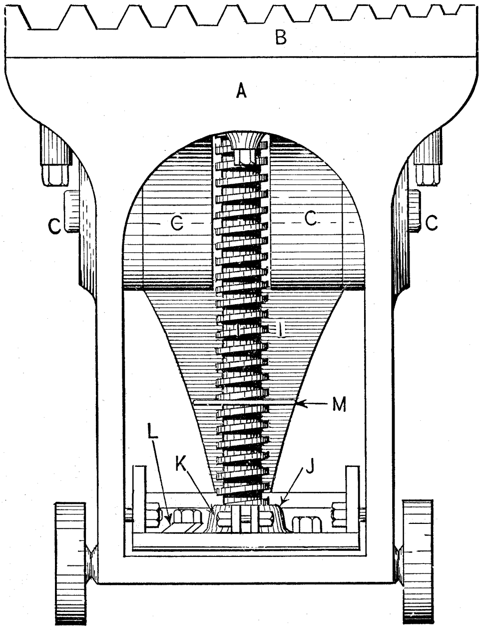

Fig. 2909.

The object of having two hammers is that one may be used for the upsetting of the blank and the other for the swage. The swaging hammer is provided with a hole and set-screw to receive top swages, and bolt hammers are adjustable for height so that they may be set so that their faces will meet the work fair.

Figs. 2909 to 2911 represent front, side, and top views of Pratt & Whitney's portable bolt-forging device. It is provided with an elevating screw that permits the employment of a single bolster-pin for all lengths of bolt for a given diameter, instead of requiring a separate pin for each different length of bolt. In the figures, A is a frame carried upon wheels, and to which is pivoted at C C the jaw D. The bolt-gripping dies are shown at E F. A treadle G is pivoted at H, and acts upon the lower end of D, causing the die F to grip or release the bolts, as may be required. The bolster-pin rests upon the end of the screw I, which enters at its foot a split nut J, which is caused to grip and lock the screw by operating the nut of the bolt K that passes through the split of the nut. L is a spring that lifts the treadle when it is relieved of the pressure of the operator's foot.

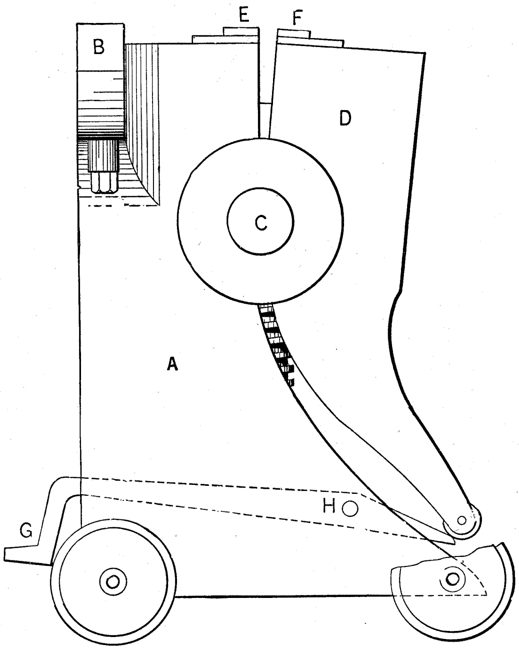

Fig. 2910.

At M is a leather washer to protect the nut J from the scale that falls from the forging. The operation is as follows :—

The nut K is released and the screw I operated to suit the length of bolt required. Then J is caused to clamp the screw by operating the nut K. The blank for the bolt is placed in the dies resting on the bolster-pin, which in turn rests upon the end of the screw I The treadle G is depressed, and the bolt blank clamped between E and F. The helper then with the sledge upsets the blank end to form the bolt head, and the blacksmith forges it to shape in the former bar B, which is provided with impressions for the form of head required, these impressions being of varying sizes, as shown. The device is so strongly proportioned as to be very solid, and is found to be a most useful addition to the blacksmith's shop.

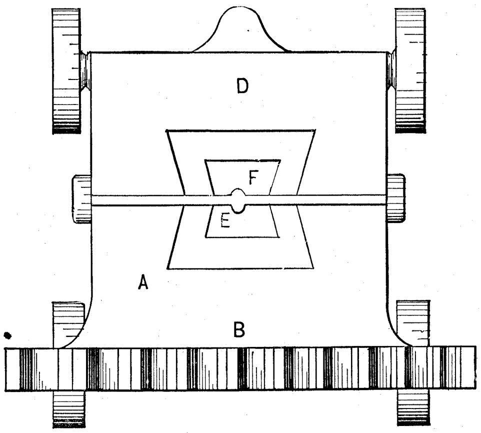

Fig. 2911.

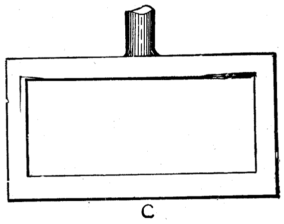

Fig. 2917.

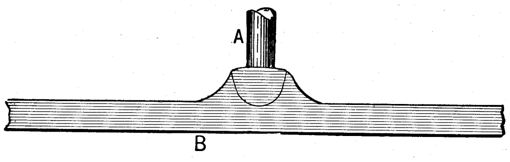

Fig. 2918.

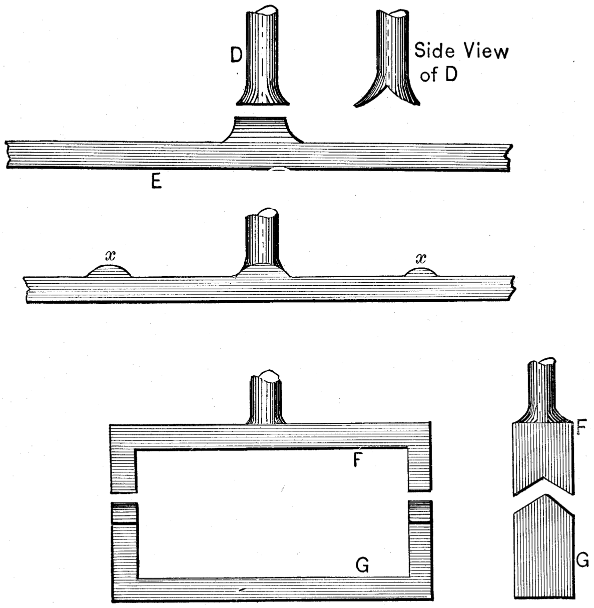

Fig. 2919.

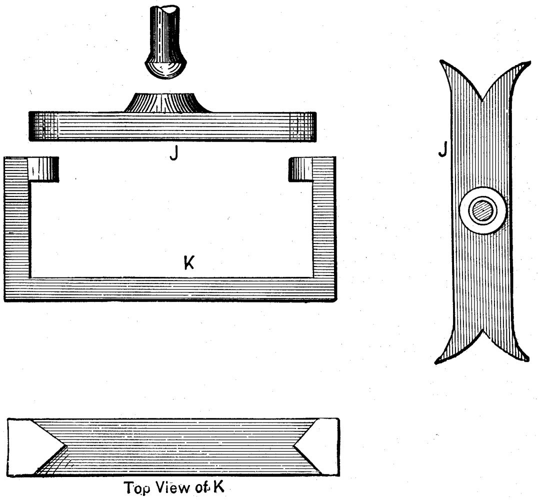

Fig. 2920.

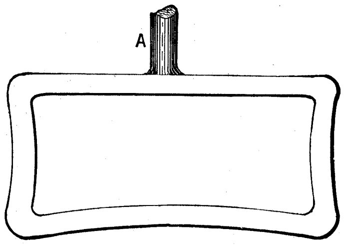

Fig. 2921.

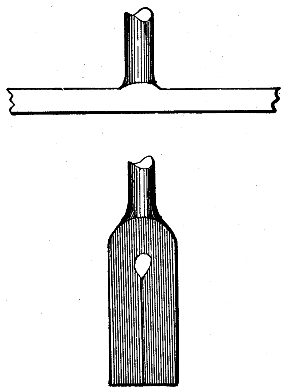

Fig. 2922.

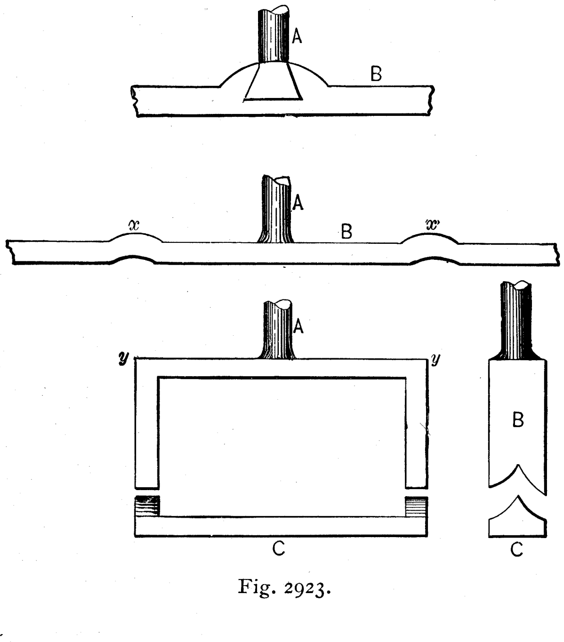

Fig. 2923.

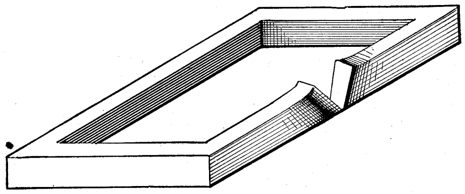

Fig. 2924.

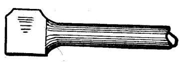

Fig. 2925.

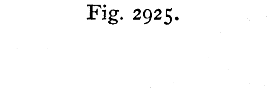

Fig. 2926.

To forge a turn buckle, such as in Fig. 2912, we bend two rings, such as in Fig. 2913, and weld into the open ends a piece as shown in Fig. 2914, on the opposite side a recess A, Fig. 2915, is cut out to receive a second piece, which being welded in the work appears as in Fig. 2916, and the end may be drawn taper. Two such pieces welded together obviously complete the job.

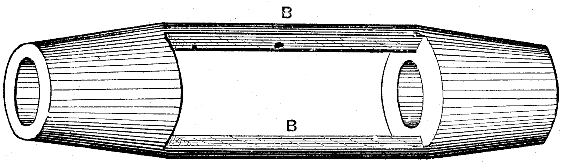

Fig. 2912.

Fig. 2917 represents a yoke for the slide valve of a steam engine or a locomotive, which may be forged by either of the following methods:

Fig. 2918 represents a stem A welded into the bar B, which may be bent to the required rectangle and welded at the ends.

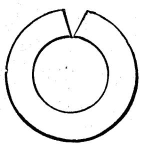

Fig. 2913.

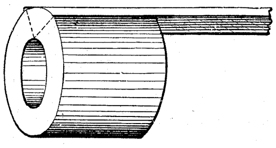

Fig. 2914.

A second method is to jump the stem D and split it open as in the side view in Fig. 2919. The bar E is forged with a projecting piece to go in the split of D, and after the weld is made, bar E is drawn to size as shown, leaving the two projections *x* where the corners are to come, which is necessary in order to have sufficient stock to bring the corners up square. The ends of E are split open as in the end view at F, and a piece G is then welded to F.

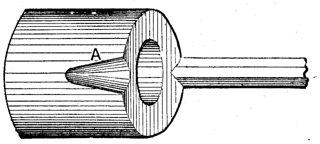

Fig. 2915.

In a third method the end of the stem is rounded for the weld, as shown in Fig. 2920. The ends of the bar J are then split open and piece K welded on.

It is to be observed with reference to the two last methods that in hammering to forge the weld the frame is closed, so that after welding the swaging to finish may be carried on until the frame is brought to square, and any superfluous metal may be cut away; whereas if the kind of weld is such as to stretch the sides, it may happen that to get a sound weld will stretch the side welded too long and throw the frame out of shape.

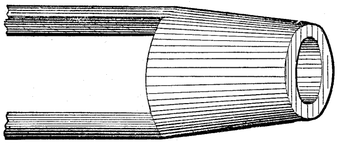

Fig. 2916.

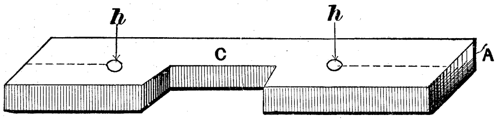

Fig. 2927.

Suppose, for example, that a scarf weld were made on the side of the yoke opposite to the stem, and if, in welding, the scarf is hammered too much, it would draw it out too much and throw the whole frame out of shape, as in Fig. 2921, so that the welded side would require to be jumped to bring it back to the proper length again.

A fourth method is to take a piece of iron and punch a hole in it, and then split it open up to the hole, as in Fig. 2922, and by opening out the split form the stem and part of the frame out of the solid, forging the remainder of the frame by the plan described for either the second or third methods.

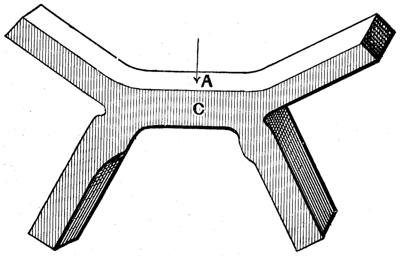

Fig. 2928.

A fifth method is to make the weld of the stem as in Fig. 2923, then forge out the bar B, leaving projections *x x* to bring the corners *y y* up square, and after bending to shape and squaring up to weld in a piece C.

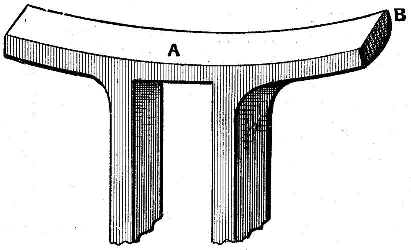

Fig. 2929.

A sixth method is to form the band first as in Fig. 2924, form the stem as in Fig. 2925, and weld as in Fig. 2926.

Figs. 2927, 2928, and 2929 represent a method of forging a fifth wheel for a vehicle. A rectangular piece of Norway iron is fullered to form the recess at C in Fig. 2927. Holes are then punched at *h* and splits are made to the dotted lines shown in the figure. The ends are then opened out, forming a piece such as in Fig. 2928. The letter A represents the same face of the work in all the figures, being the edge in Fig. 2927, and the top face after the ends are opened out. The four arms may then be dressed to shape, the two lower ones being drawn out and threaded before being finally closed to shape. A piece may then be welded on one end, as at B, to complete the circle.

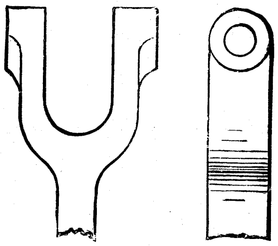

Fig. 2930.

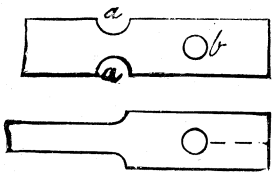

Fig. 2931.

To forge a double eye, such as in Fig. 2930, we may take a piece of sufficient size and fuller at *a a*, Fig. 2931; a hole is then punched at *b*, and it is then split through to the dotted line in Fig. 2931, and opened out as in Fig. 2932, and then forged to shape.

BENDING.—Fig. 2933 represents a tool for bending pieces of small diameter to a short curve, either when cold or heated. In bending hot iron it is advantageous to confine the heat as closely as possible to the part to be bent, as a more true bend may then be obtained.

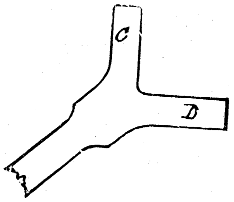

Fig. 2932.

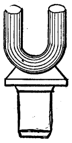

Fig. 2933.

As an example in bending, let it be required to bend a straight shaft into a crank shaft, and the following method (from "The Blacksmith and Wheelwright") is pursued. The shaft is first bent as in Fig. 2934. The piece is next bent as in Fig. 2935, and finally as in Fig. 2936, the corners A A and B B corresponding in all the figures.

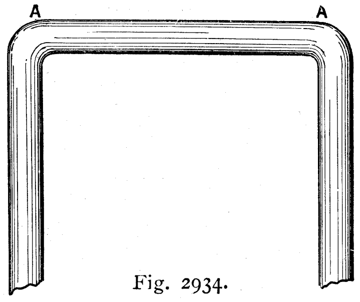

Fig. 2934.

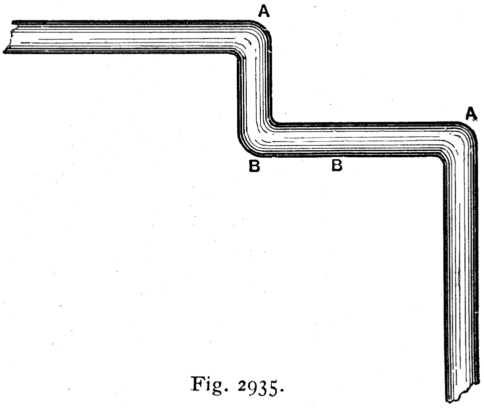

Fig. 2935.

BLACKSMITH'S BENDING BLOCKS.—In cases where a great number of pieces of the same size and shape are required to be bent during the forging process, a great deal of time may be saved and greater accuracy secured in the work by the employment of bending devices. Thus, in Fig. 2937 is shown at A a clip requiring to be bent to the shape at B. A pair of tongs is provided with a hole at C to receive the stem of the clip, and the jaw D is made of the necessary width to close the ends of the forging upon. It is obvious that the hole C being in the middle of the width of the tong jaw, the wings will be equidistant from the pin.

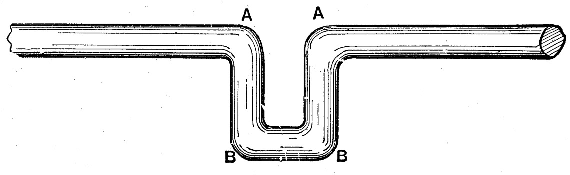

Fig. 2936.

Figs. from 2938 to 2943 represent bending devices.

Figs. 2938, 2939, and 2940, represent a "former" for a stake pocket for freight cars. A is a cast-iron plate having a projection B, around which the stake pocket C is bent. D is fast upon A, and affords a pivoted joint for the bending levers E F. The work is placed in the former as shown in Fig. 2939, and levers E F are swung around to the position shown in Fig. 2938. To enable the work to be put in and taken out rapidly and yet keep it firmly against the end of B, a hand-piece G is used as in Fig. 2940, its form being more clearly shown in the enlarged Fig. 2941. Sufficient room is allowed between B and D to admit the work, and the end of the piece G, which is pressed in the direction denoted by the arrow in Fig. 2940, forcing the work against B. A number of the pieces are piled on the fire so as to heat them sufficiently fast to keep the former at work, and the bottom piece is the one taken out,

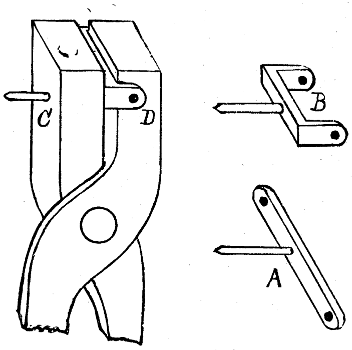

Fig. 2937.

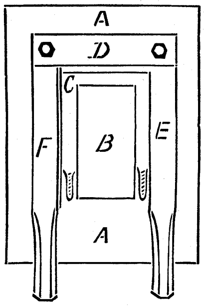

Fig. 2938.

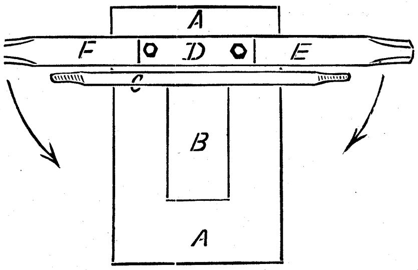

Fig. 2939.

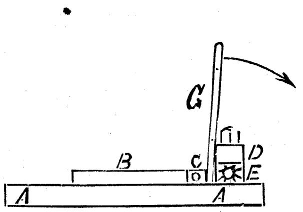

Fig. 2940.

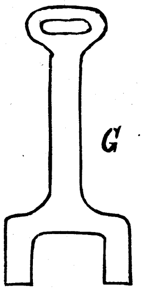

Fig. 2941.

The corners of the work are by this process brought up square and the faces are kept out of wind. The surface A forms a level bed. These advantages will be readily appreciated by all smiths who have had comparatively thin work to bend to a right angle in the ordinary way.

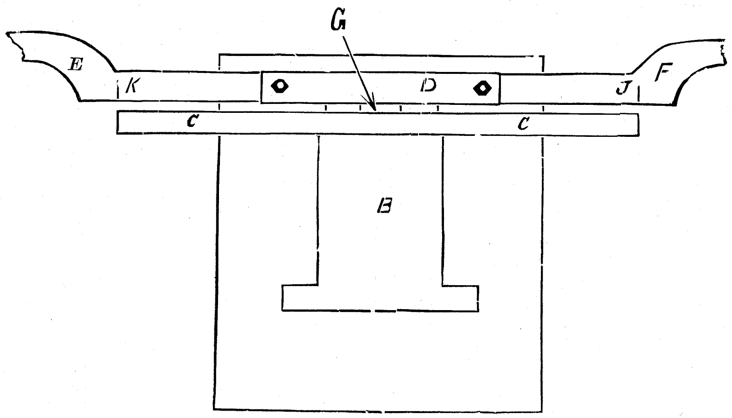

Fig. 2942.

Figs. 2942 and 2943 represent a similar former for the step irons of freight cars. In Fig 2942 the piece is thrown in place ready to be bent, its ends being fair with the lines J K on the bending levers E F. In Fig. 2943 the levers are shown closed and the work C therefore bent to shape The bed plates A are mounted on a suitable frame to raise them to a convenient height for the blacksmith.

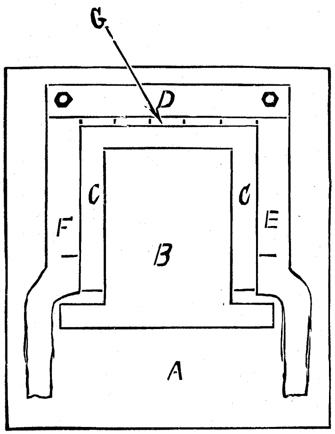

Fig. 2943.

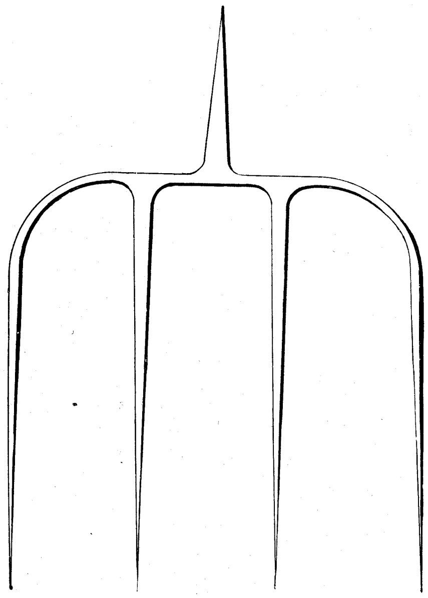

Fig. 2944.

FORGING A STABLE-FORK.—In the manufactories where stable and hay forks are made, the whole process of forging is done under the trip hammer, and is conducted as follows :—

To forge a four-tined fork, such as in Fig. 2944, a blank piece of steel is employed, its dimensions being $5\frac{3}{4}$ inches long, $7\frac{3}{4}$ inches wide, and $\frac{1}{2}$ inch thick. The first operation is to swage down one end, as at A in Fig. 2945. A split is then cut down as at B in Fig. 2946. The split is then opened out as in Fig. 2947, and is fullered and drawn out at C. Two more splits are then made at D D, and the ends are bent open as in Fig. 2948, when the four tines E E and F F are drawn out and shaped out. The stem, A, Fig. 2945, is then finished for the handle.

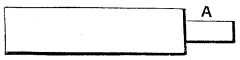

Fig. 2945.

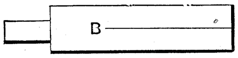

Fig. 2946.

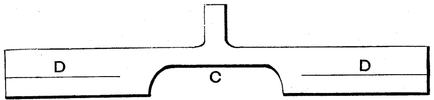

Fig. 2947.

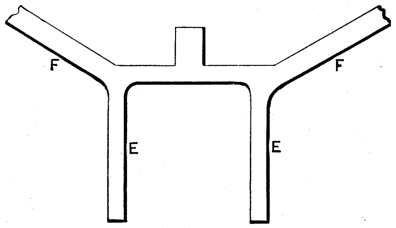

Fig. 2948.

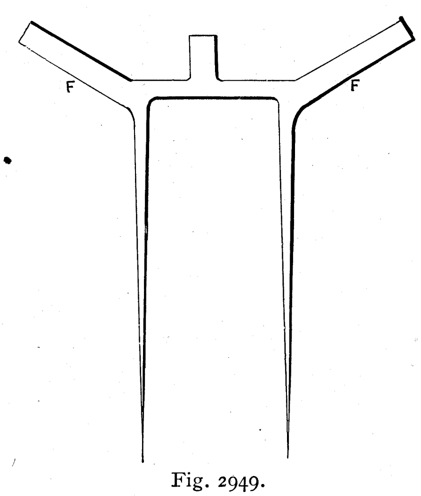

Fig. 2949.

The following example of forging under the hammer is derived from *The Engineer*, of London, England. Fig. 2950 shows the piece to be forged. A block of iron, Fig. 2951, is drawn out as in the figure, the dimensions of A and B being considerably above the finished ones. A forked tool T, Fig. 2952, may be used to nick the two grooves shown in Fig. 2953, which marks the locations for the hub and forms a starting guide for the two fullering tools shown in Fig. 2954, one of which is held by the blacksmith and the other by the helper. After this fullering the forging will appear as in Fig. 2955. The ends E, F may then be drawn out, having the shape as in Fig. 2956. To shape the curve between the side of the hub and the body of the stem, grooves are formed as in Figs. 2957 and 2958, Y and B being top and bottom half-round fullers, and these two grooves are subsequently made into one by means of larger half-round fullers, as in Fig. 2959. The object of making two small fullered grooves and then making them into one is to prevent the fullering from spreading the body of the stem by lessening the strain due to using a large fuller at once. The piece now appears as in Fig. 2960.

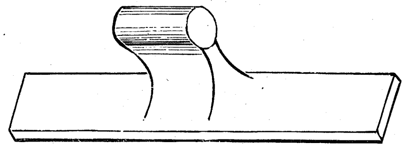
Fig. 2950.

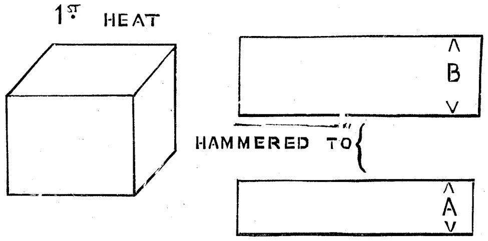

Fig. 2951.

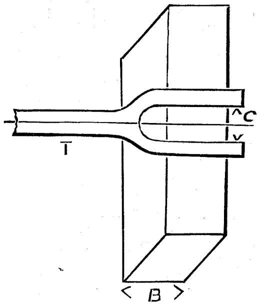

Fig. 2952.

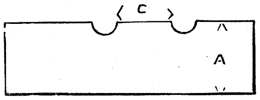

Fig. 2953.

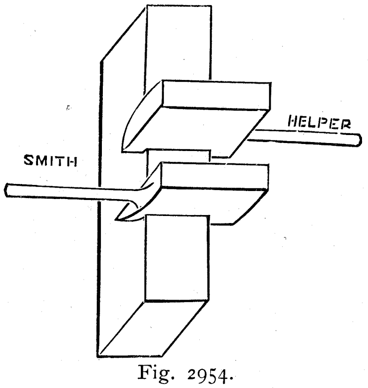

Fig. 2954.

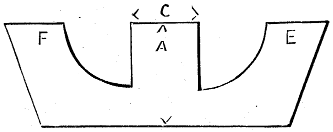

Fig. 2955

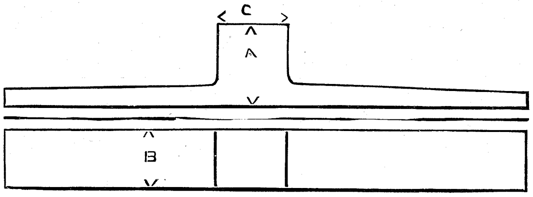

Fig. 2956.

The next operation is to cut or punch away the metal between the ends of the hub and the body of the piece, which is accomplished as follows:

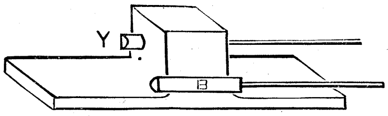

Fig. 2957.

A top and bottom die and block are made to contain the work, as in Fig. 2961, A and B being the work ends. Through these dies are two holes for two punches which are driven through together as marked; the dies are held fair, one with the other, by four holes in the lower and four pins in the upper one, a section and top view of the dies being shown in Fig. 2962.

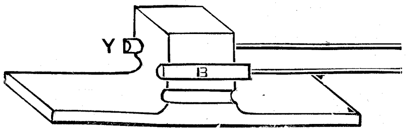

Fig. 2958.

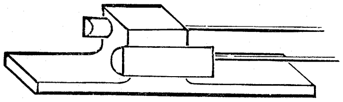
Fig. 2959.

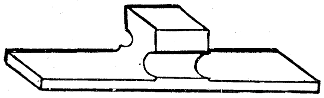
Fig. 2960.

The piece is at this stage roughed out to shape all over, and may be finished between the pair of finishing dies shown in Fig. 2963, which also represents a plan and sectional view, *a, b, c, d* being the holes to receive guide pins in the upper die.

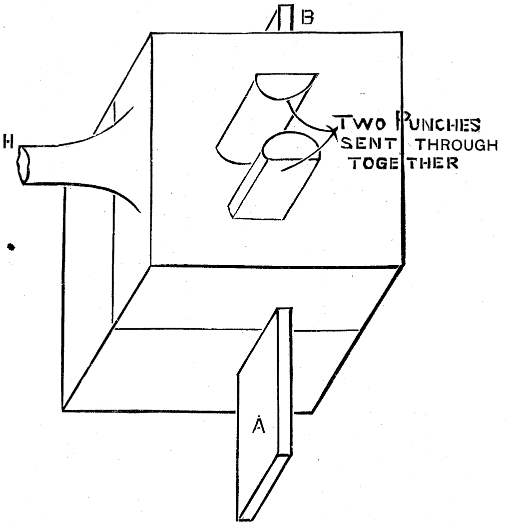

Fig. 2961.

An excellent example of forgings in Siemens Martin steel is given in the following figures, being the rope sockets for the Brooklyn Bridge.

Fig. 2964 represents two views of the forgings, and it will be readily perceived that they are very difficult to make on account of the taper hole, which is shown in dotted lines. The first operation was to take a bar of steel 6½ inches square and punch a hole, as at A Fig 2965.

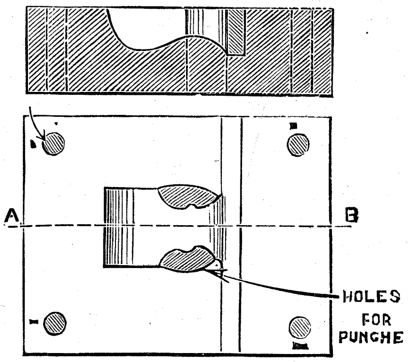

Fig. 2962.

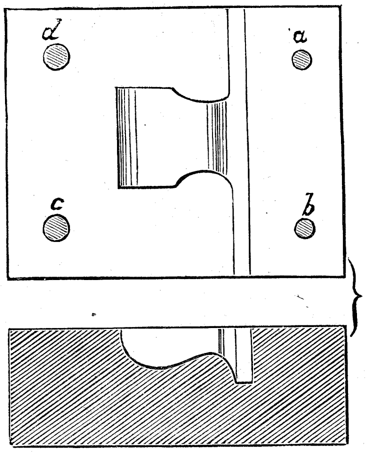

Fig. 2963.

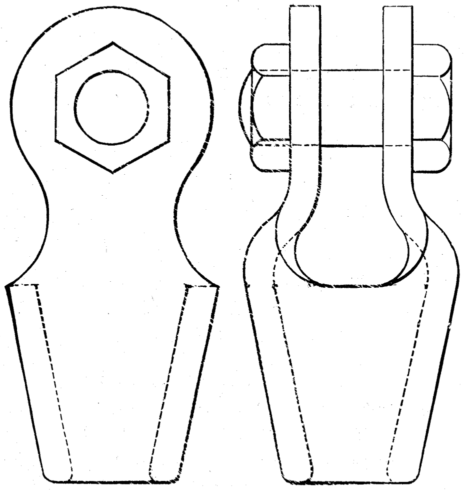

Fig. 2964.

Next the piece was fullered at B, C by the fuller A, Fig. 2966, and cut partly off as at D. The fullering at B was then extended by a spreading fuller, shaped as at B, and the end E was drawn out. Then the piece was cut off at D. Next the spreading fuller was applied to C, and the forging appeared as in Fig. 2967. The end F was then drawn out, and the appearance was as in Fig. 2968.

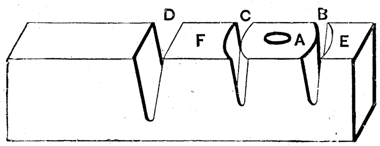

Fig. 2965.

The next operation was to enlarge the hole A, Fig. 2965, by drawing taper mandrels through it, the mandrels being about 7 in. long, having ½-in. tapes on them, and being successively larger. With the last of these mandrels in the hole the hub was drawn out to length and diameter, leaving the forging roughly shaped, but having the form shown in Fig. 2969.

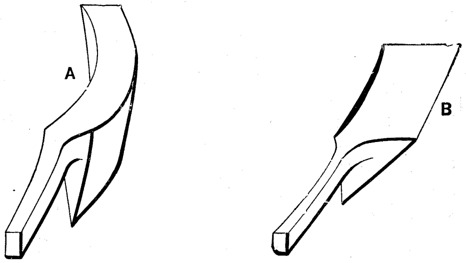

Fig. 2966.

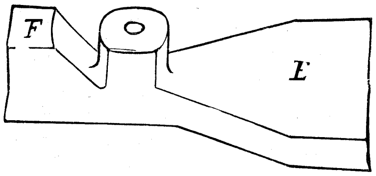

Fig. 2967.

To finish the hole the forging was then placed in a block such as shown at G, in Fig. 2970, a finishing punch being shown at H in the figure.

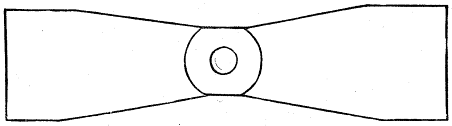

Fig. 2968.

The next operation was to let the steam hammer down upon the face of the punch and bring up the wings E F parallel, but not more than parallel, as then the mandrel could not be got out; the forging then appearing as in Fig. 2971.

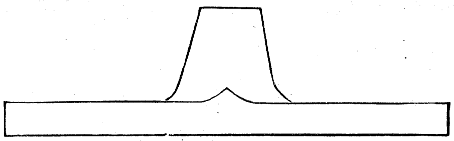

Fig. 2969.

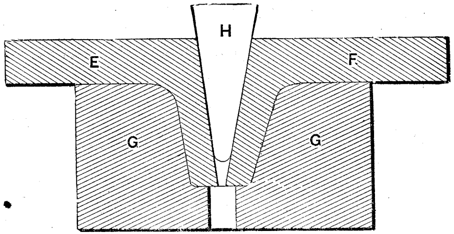

Fig. 2970.

The next process was to put in a bar mandrel such as shown in Fig. 2972 at I, the pieces J, K fitting on their sides to the mandrel and being curved outside to the circular and taper shape of the hole. The wings E F may then be closed on the mandrel to their proper width and the whole hub end being trimmed by hand, all the previous work having been done under the steam hammer. The

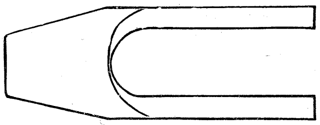

Fig 2971.

hub being finished the key M may be taken out and the washer L taken off, when I can be pulled out, leaving J K to be taken out separately. A pair of tongs are then put through the finished hub end, while the wings are punched and trimmed under the steam hammer, and subsequently finished by hand.

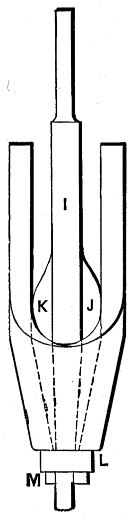

Fig. 2972.

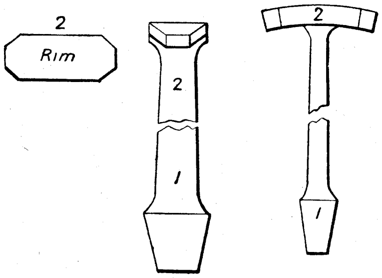

Fig. 2973.

The forging of wrought-iron wheels for locomotives is an excellent example. The spokes are first forged in two pieces, as 1 and 2 in Fig. 2973, and then welded to form the complete spoke. Piece 1 is first forged in dies under the steam hammer to the form shown in Fig. 2974, the dimensions being correct when the faces of the dies meet. The stud C D is then drawn out to the required length and dimensions.

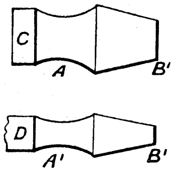

Fig. 2974.

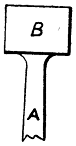

Fig. 2975.

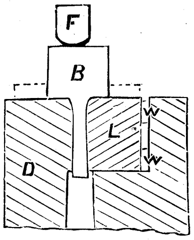

Fig. 2976.

The upper half of the spoke is first blocked out under dies to the shape shown in Fig. 2975, and the block B spread so as to form a section of the wheel rim, as shown in Fig. 2976, in which D is a die, L a movable piece wedged up by the wedges W W, and removable to enable the extraction of the forging, and F is an end view of the fuller, the use of which is necessary to cause the metal to spread sufficiently in the direction of the dotted lines. The corners of the rim are then cut off, as shown in Fig. 2973, and the rim is bent in a block having its top face of the necessary curve, as in Fig. 2977, A being the block, and B a piece movable, to allow the extraction of the work, and fastened in place by the key or keys C. The two pieces are then welded together, their lengths, &c., being gauged by a sheet-iron template, formed as in Fig. 2978. The welding is usually performed with sledge-hammers, but as soon as the pieces will hold well together, the drawing down is done under a steam hammer.

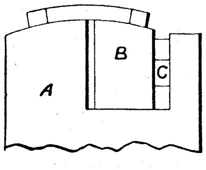

Fig. 2977.

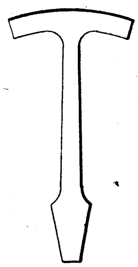

Fig. 2978.

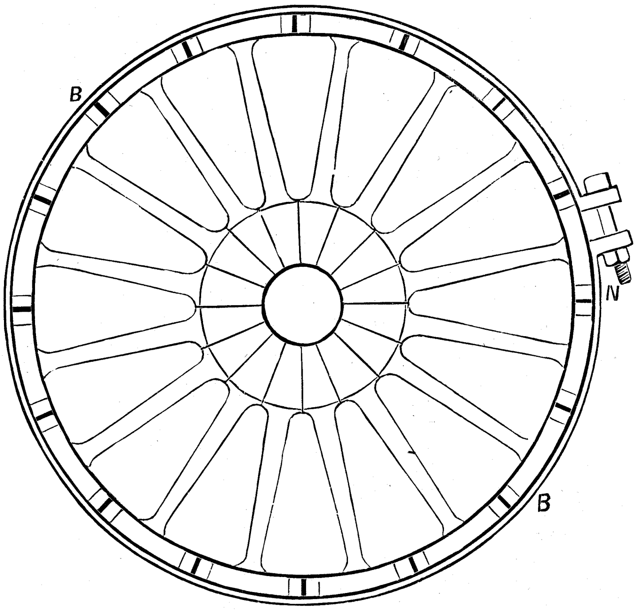

Fig. 2979.

The spokes thus forged are then put together, as in Fig. 2979, B representing a wrought-iron band, encircling the rim of the wheel and closed upon the same by the bolt and nut at N.

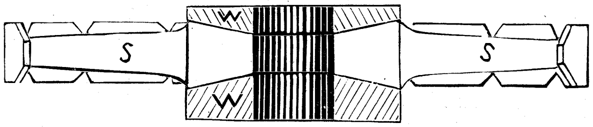

Fig. 2980.

Two washers are then forged, to be placed and welded in as at W W, in Fig. 2980.

The welding together of the spokes and of the washers to the spokes proceeds simultaneously. The washers are heated to come to a welding heat at the same time as the wheel hub is at a welding heat, and the two are welded together under a steam hammer. During the heating of the wheel hub, however, the band B, Fig. 2979, is tightened up with the screw to bring the spokes into closer contact when heated to the welding point.

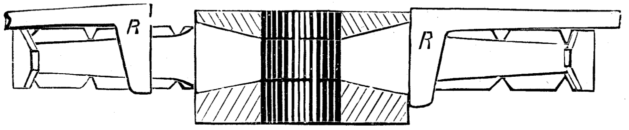

Fig. 2981.

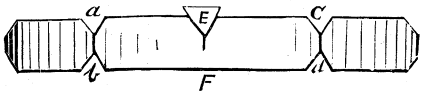

Fig. 2982.

The seams between the spokes at the circumference of the hub are welded with bars as shown in Fig. 2981, in which R R are two bars of iron which are operated by hand as rams. The wedge shape of the washers on their inside faces performs important duty in spreading the metal as well as simply compressing it, giving a much more sound weld than a flat washer or plain dish would.

The rim of the wheel is welded up as follows:

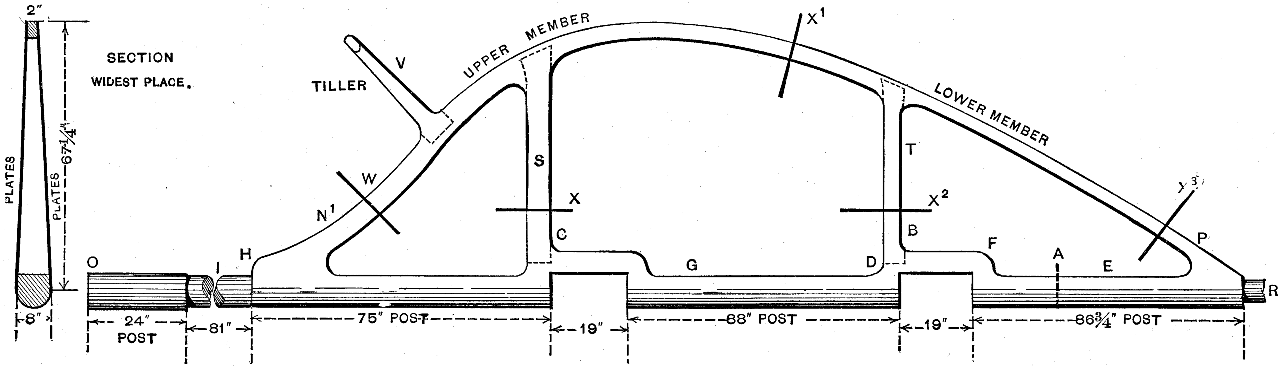

Fig. 2983.

In Fig. 2982 are shown four spokes of the rim as they appear after the hub is welded. Into the V spaces, as *a, b, c, d*; wedges of metal, of the form shown at E, are welded, after which the surplus metal of E is cut away, and the rim is solid as at F. In this process, however, it is necessary to weld all the pieces on one side of the wheel, as at *a b*, &c., except one, which must be left unwelded until all the pieces save one on the other side are welded, and the wheel must be allowed to become quite cool before these last two pieces are welded. Otherwise the strain induced by the contraction of the wheel rim while cooling will often cause the rim to break with a report as loud as that of a rifle. In those cases in which this breakage does not occur the wheel will be very apt to break at some part of the rim, when subjected to heavy shocks or jars.

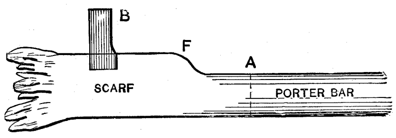

Fig. 2984.

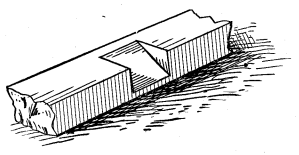

Fig. 2985.

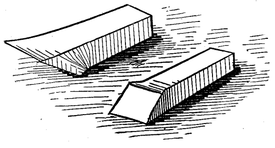

Fig. 2986.

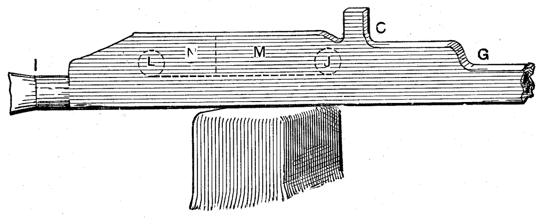

Fig. 2987.

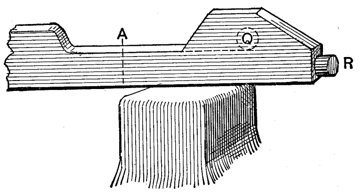

Fig. 2988.

The Figs. 2983 to 2999 (which are taken from *Mechanics*), illustrate the method employed to forge the rudder frame of the steamship *Pilgrim*.

A side elevation of the rudder frame is shown in Fig. 2983.

The forging is made in eight separate pieces, which are so united as to make three pieces. These three pieces are finally joined by five welds The whole length being 29 feet 11¾ inches, and the weight 6,500 pounds.

The work is commenced by piling and welding on the porter-bar at the point in the shaft marked A. The stubs B and C having been previously prepared, the pile on the porter-bar is heated and welded up and drawn, shown in Fig. 2984, and scarfed as shown in Fig. 2985; the piece, shown in Fig. 2986, is then laid in the scarf and welded; then the part from B to A is finished to size, the finished forging of the post being shown in Fig. 2984. The surplus stock to the right of B, Fig. 2984, is worked down into the post E, and the distance from B to F is thus made correct without loss of stock or time. The curve at D, Fig. 2983, was worked down somewhere near, and then another pile and weld carries the job to G. Here the same operations as at first are repeated, and the arm C is welded in. There is left a good lump of stock in front of C, and by another pile and weld enough is added to make the job to I, as shown in Fig. 2987. Holes are then punched at J and L, and the piece of stock M cut entirely out. A cut is made to L with a hack opening out the piece N from the shaft. A taper punch, with a 3-inch point and a 4-inch head, is then driven at L; to throw the piece N out into the position shown at N¹, Fig. 2983; N¹ is then finished, and the post from L to J brought to forging size; then, by the ordinary process of piling, welding and drawing, the shaft is finished from I to O. Next the porter-bar is cut off, so as to leave stock enough to make the lower part of the shaft, as shown in Fig. 2988. A hole was punched at Q, and the stubs drawn out, as shown in Fig. 2989, which gives the post complete.

The pieces S and T, and the tiller V, having been forged, as shown

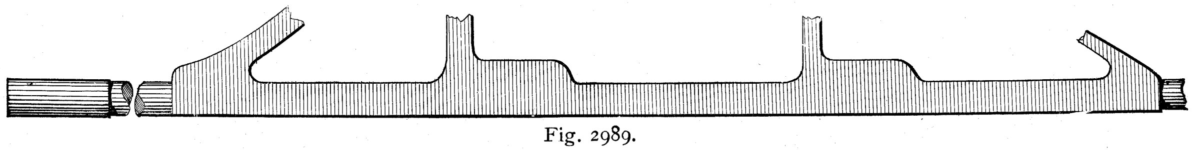

Fig. 2989.

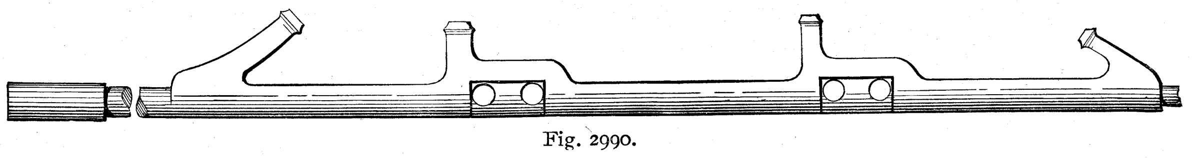

Fig. 2990.

in Fig. 2991, the upper member of the frame is started on the porter-bar at W, Fig. 2983, and filed, welded and drawn to make the job as far as X^1. Wooden templates, such as in Fig. 2992, are provided for the pieces of the frame, the first extending from W to X^1 and X, and the second including the part from X^1 to X^2 and X^3. After W, X^1 has been drawn out with lumps left where the tiller and the arm S are to be joined, the scarf is made for the tiller and that is welded in, and the job finished to piece S. The scarf for S is then made, and S welded in. This makes the upper member of the frame. The lower member is made in the same way, starting at X^3. These two members are shown complete in Fig. 2993. The post, Fig. 2989, was sent to the machine shop, and was turned, planed, bored, and slotted, as shown in Fig. 2990. The frame was now ready to be pieced up, by welds at W, X, X^1, X^2, and X^3, Fig. 2983.

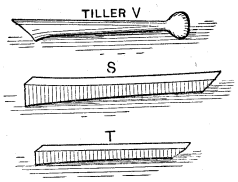

Fig. 2991.

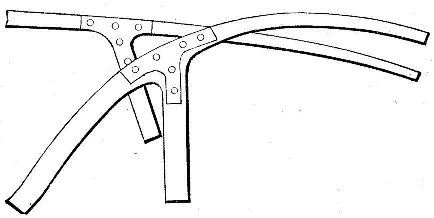

Fig. 2992.

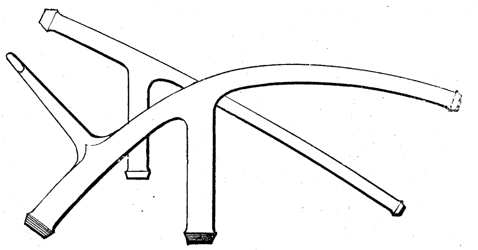

Fig. 2993.

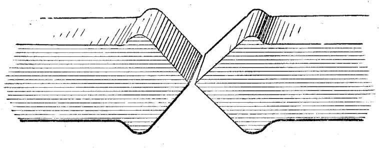

Fig. 2994.

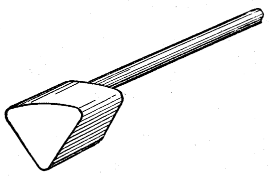

Fig. 2995.

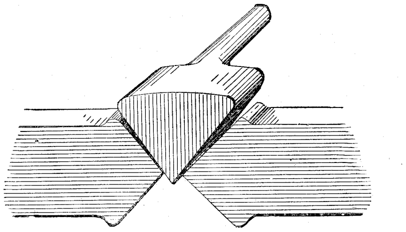

Fig. 2996.

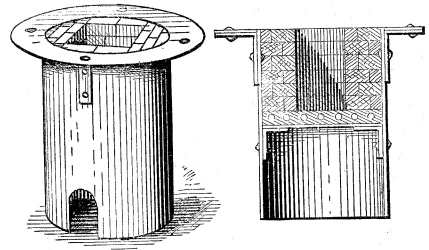

Fig. 2997.

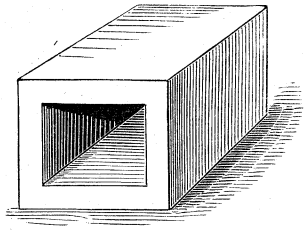

Fig. 2998.

The several sections are now ready to be welded together for the complete frame, these welds being made as follows: The ends are upset as in Fig. 2994 to receive on each side a **V**-piece, such as in Fig. 2995, which is heated on a porter-bar, and is of a more acute wedge than the ends to be welded, so that when laid in as in Fig. 2996 it will touch at the bottom first, and thus allow the air and whatever dirt there may be on the surfaces to squeeze out as the welding proceeds. The method of heating the frame for these welds is as follows: The **V**-block (which has the grain of the iron running in the same direction as that of the frame) being heated in the blacksmith's forge, the frame is clamped together and counterbalanced by means of weights, so that it may be laid over a fire pot, constructed as in Fig. 2997. This fire pot is lined with brick, and has its blast supplied through a piece of flexible tube. The anvil is of cast iron, shaped as in Fig. 2998, and placed on the other side of the frame and opposite to the fire pot or portable forge, as shown in Fig. 2997, so that the frame, when the heat is ready, may be turned over upon the blocks on which it rests, and the part to be welded will come upon the anvil. After one side is welded the anvil and the portable forge change places, and the second side of the weld is made.

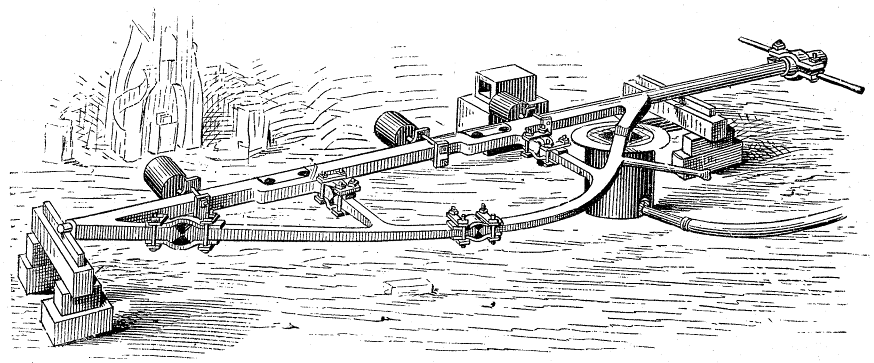

Fig. 2999.

In the following figures (which are taken from *Mechanics*) is illustrated the method employed to build up the shaft shown in Fig. 3001, which was for the steamer *Pilgrim*. Forgings of such large dimensions are built up of pieces or slabs, called blooms, which are themselves forged from scrap iron, which is piled as in Fig. 3000. For the forging in question this scrap iron consisted of old horseshoes, boiler-plate clippings, boiler rivets and old bolts, and the first step in the manufacture is to form this scrap into piles ready for the furnace.

These piles are made upon pieces of pine board ½ inch thick by 16 inches long by 10 inches wide. On these the scrap is piled about 14 inches high, each pile weighing about 270 pounds. After piling, the scrap goes into the furnace and is raised to a welding heat, the board retaining its form as a glowing coal almost to the last. The pile of scrap is heated so nearly to melting as to stick together enough so that it can be picked up in a long pair of tongs with peculiarly-shaped jaws, and, as these tongs are suspended by a chain from an overhead traveller running on an iron track, the bloom is easily transferred to the anvil of the steam hammer, where, after one or two blows, a small porter-bar with a crank end, such as shown in Fig. 3003, is welded on, and the pile is rapidly drawn out into a square bar. When completed the porter-bar is cut off, and the bar is laid aside to cool. The pile of scrap has now become a "bloom," such as shown in Fig. 3002, and has been reduced in weight from 270 lbs. to 240 lbs. The bloom is about 30 inches by 5 inches by 5 inches in dimensions, and has rounded, ragged ends, and a surface full of lines marking welding of the individual pieces, and at the ends looking as though the scrap had united by melting rather than by any welding process.

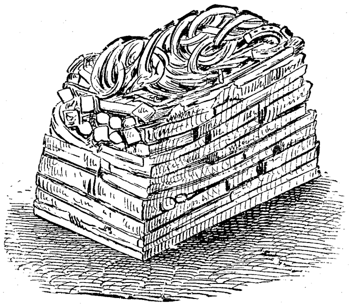

Fig. 3000.

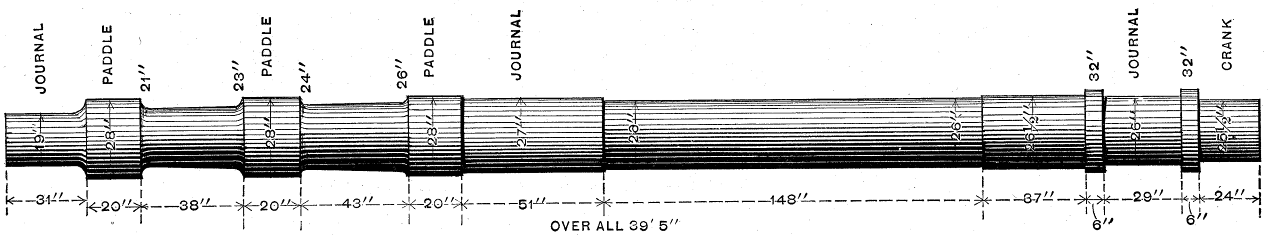

Fig. 3001.

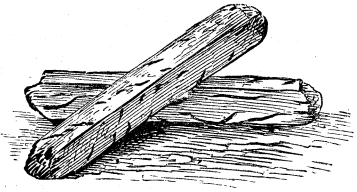

Fig. 3002.

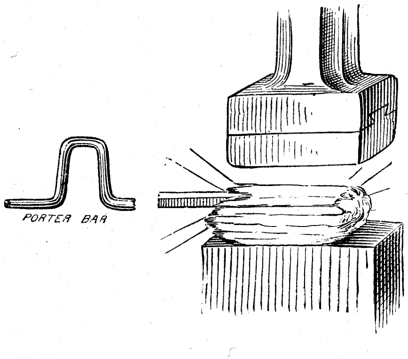

Fig. 3003.

These blooms are then taken to the large steam hammer and furnace by which the shaft is to be built up. The porter-bar, although merely a tool whereby to handle the mass, forms practically a base wherefrom to build up the shaft. The construction of the furnace is shown in Fig. 3004, the heat, after passing the work being used for the steam boiler that supplies steam to the steam hammer.

The porter-bar is held by a crane, the chain being placed in such position in the length of the porter-bar as to balance it. On the end of the porter-bar is a clamp, having arms by which the bar may be turned in the furnace and when under the hammer.

Fig. 3005 represents the bar in position in the furnace, the aperture through which it was admitted having been closed up by bricks luted with clay, one brick only being left loose, so that it may be removed to examine the heat of the bar. The end of the bar is flattened somewhat, and a slab is laid upon it as in Fig. 3006, the appearance after the first weld being shown in Fig. 3007. It is then turned upside down, and blooms are piled upon it as in Fig. 3008. After these are welded the end is shaped up round and to size. The extreme end is again flattened, or "broken down," as it is termed, and first a slab, and after reheating, blooms are added, as already explained; when these are welded and forged enough to consolidate the mass the mass is rounded up again, thus increasing the length of finished shaft. The end is again broken down and a slab added, and so on, the shaft thus being forged continuously from one end, and being composed of alternating slabs and blooms.

To forge this shaft 118,000 lbs. of blooms, 185 tons of coal, and 360 days of labor were required, the time occupied being 34 working days.

The slabs are simply forged pieces of larger dimensions than the blooms, and more thoroughly worked, the difference between slabs and blooms being that there is more waste with the blooms than with slabs, because the blooms heat quicker than the forged part of the crank.

Between both the slabs and the blooms there are placed rectangular pieces to hold them apart, and let the furnace heat pass between them, the arrangement of these pieces being shown in Figs. 3009 and 3010.

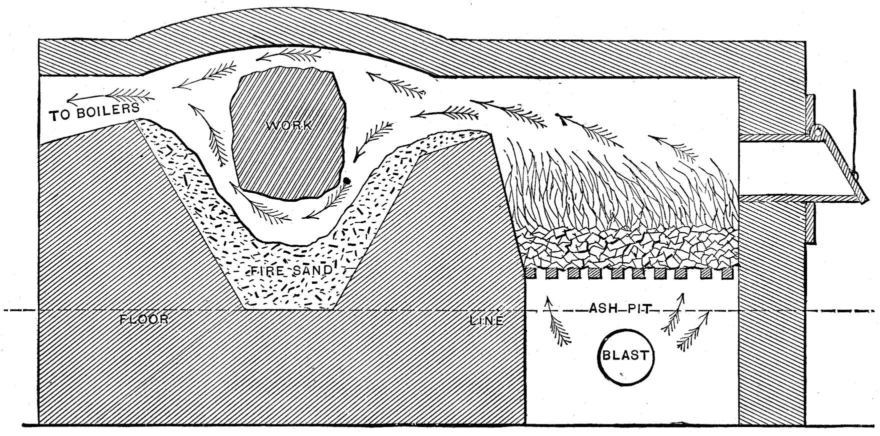

Fig. 3004.

Figs. 3011 to 3024 (which are taken from *Mechanics*), represent the method employed to forge the crank shaft of the United States steamship *Alert*.

Fig. 3011 represents the crank shaft, and Fig. 3012 an end

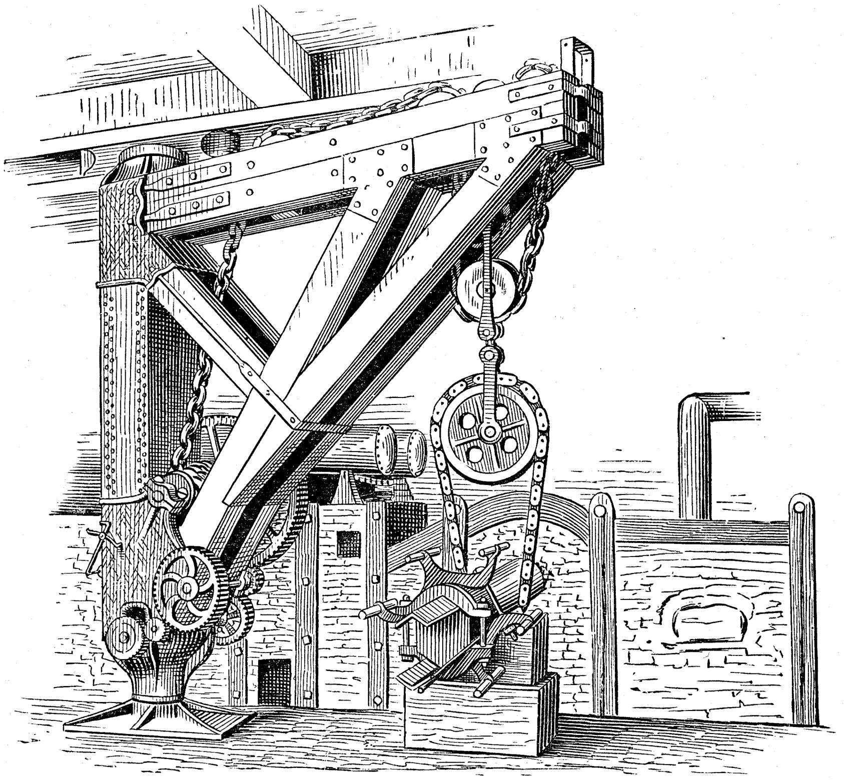

Fig. 3005.

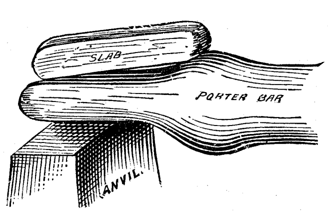

Fig. 3006.

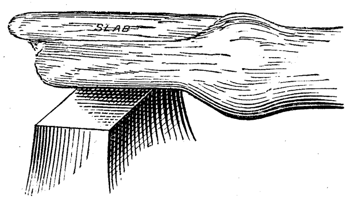

Fig. 3007.

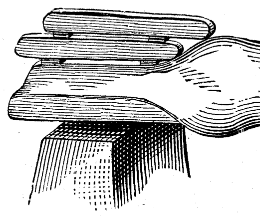

Fig. 3008.

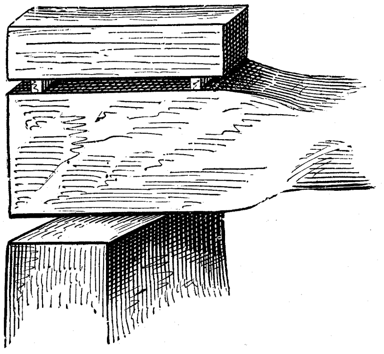

Fig. 3009.

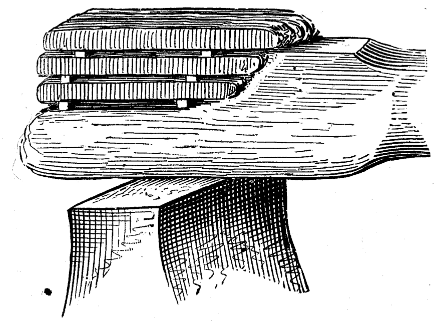

Fig. 3010.

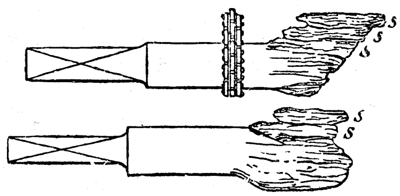

Fig. 3025.

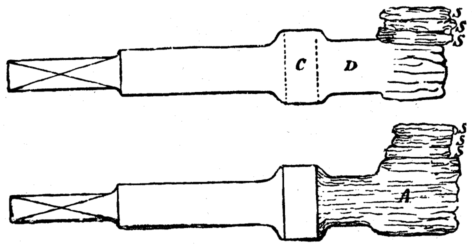

Fig. 3026

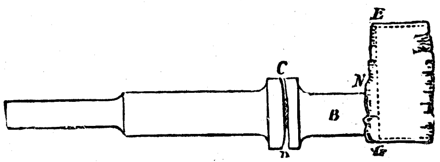

Fig. 3027.

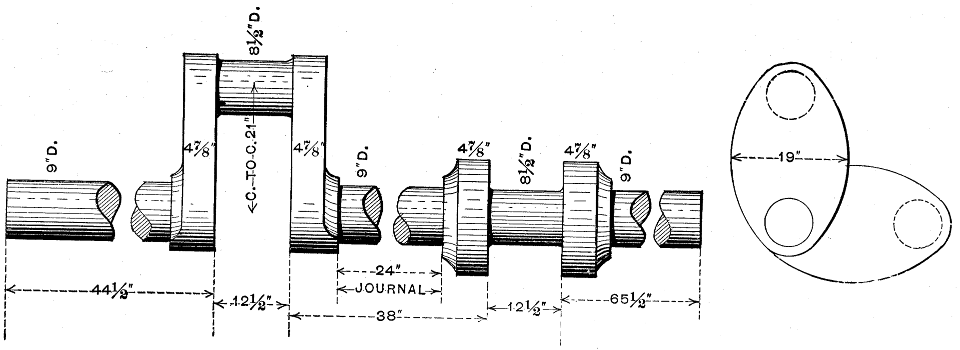

Fig. 3011.

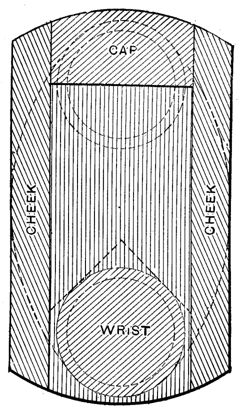

Fig. 3012.

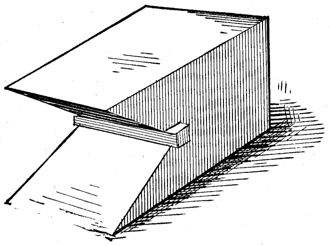

Fig. 3013.

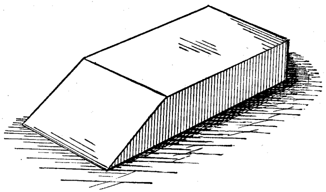

Fig. 3014.

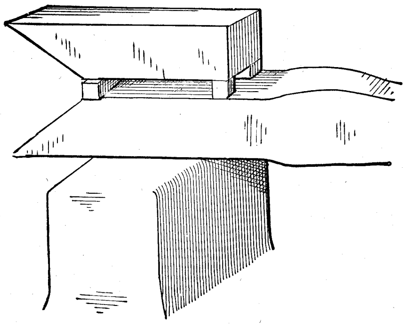

Fig. 3015.

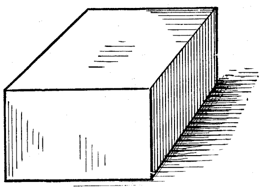

Fig. 3016.

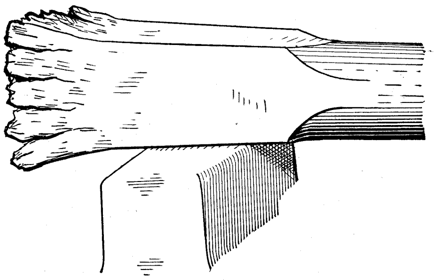

Fig. 3017

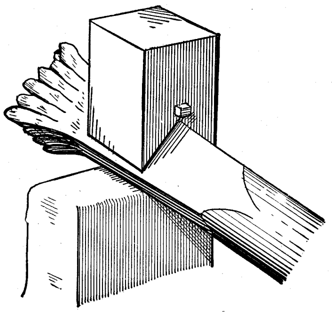

Fig. 3018.

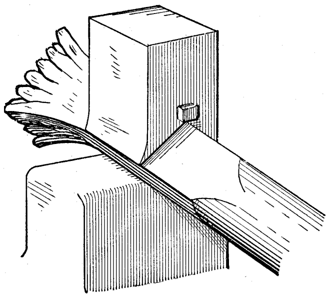

Fig. 3019.

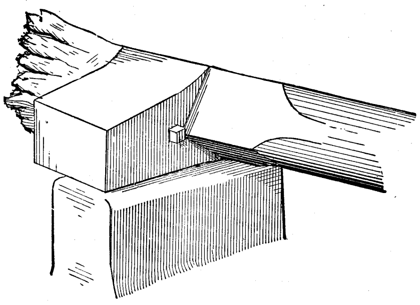

Fig. 3020.

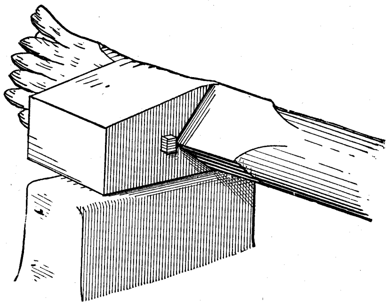

Fig 3021.

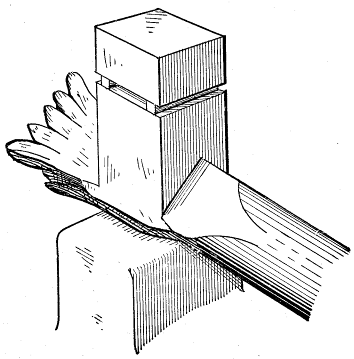

Fig. 3022.

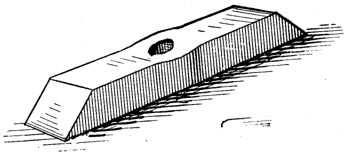

Fig. 3023.

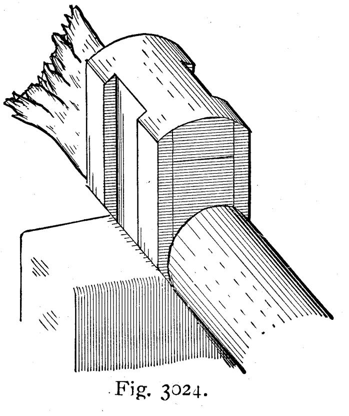

Fig. 3024.

sectional view, showing how the throws were built up. The first operation was to forge the saddles shown in Fig. 3013, these being the pieces that are shown between the *cap* and the *wrist*.

These saddles were made in halves, each half appearing as in Fig. 3014. From a pile and weld of blooms on the porter-bar, enough to make the two halves, one half was cut off. The other half was then drawn down on the porter-bar, and the first half was then piled on the latter, as shown in Fig. 3015. The square cross bar goes clear across and projects about an inch at each side. The back pieces were short bits. The square cross bar makes the saddle less liable to split in welding it on to the square shaft. Two "caps" were also made before the forging of the shaft itself began. These are shown in Fig. 3016, and their position in the finished work is shown in Fig. 3012.

The shaft itself was piled, welded, and drawn on the porter-bar in the usual manner, until the location of a crank was reached. Then a part of the work some distance from the new end was squared, as shown in Fig. 3017, and on this square the saddle was piled to heat and weld, as shown in Fig. 3018 As will be seen, the saddle rested upon the outer lines of the angle. The first blow was struck square on the top of the saddle, and after three or four blows the job presented the appearance shown in Fig. 3019. The piece was now turned so as to lie as shown in Fig. 3020, and worked with blows on the sides to the shape shown in Fig. 3021. This opened the top of the juncture of the saddle and squared the shaft down to the point where the weld was good. The piece was then turned back to the position shown in Fig. 3019, and worked with blows which again closed the angle on top, and made the weld good all through. The piece was then returned to the furnace, and at the next heat the saddle was squared up and finished, and the cap was piled on top of the saddle, as shown in Fig. 3022. The cap was welded on at the next heat, and two cheeks, like that shown in Fig. 3023, were laid upon one flat of the crank and pinned with $1\frac{5}{8}$-inch round pins. One of these pins is shown in the figure. Bits of iron were put under these cheek pieces in the usual manner. As the cheeks were very much smaller in section than the crank body, it was necessary to turn them over away from the fire, or else the cheeks would be burned before the crank body was hot enough to weld. To prevent the cheeks from falling off in the furnace the pins were put in as described before heating. After two cheek pieces had been welded on one side, two more were added on the opposite side, and then the crank was finished, as shown in Fig. 3024.

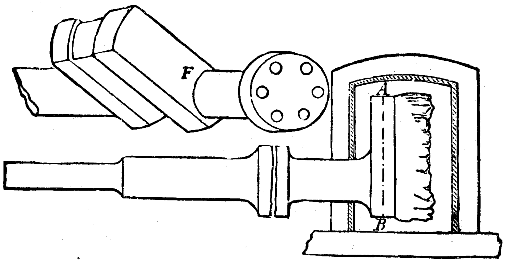

Fig. 3028.

As will be seen by inspection of Fig. 3012, the weld between the cap and the saddle comes about the middle of the wrist, and the cheek pieces support the cap sideways. By means of the piles and welds described, the grain of the iron was so disposed as to offer the most resistance to working strains. This method was devised by Mr. Farrell Dorrity, of the Morgan Iron Works.

FORGING LARGE CRANK SHAFTS.*—The following paper describes the method of forging marine crank shafts adopted at the Lancefield Forge, Glasgow. It will be better understood if a short account is first given of the ordinary methods in use for the same purpose.

"*First Method.*—The most common method is technically termed by the forgeman, 'finishing the piece before him.' He begins with a staff or stave, as shown in Fig. 3025, suspended by a chain from the crane, and made round for the convenience of manipulating under the steam hammer; this stave is used over and over again for many forgings, as it is merely the "porter" to carry the piece and enable it to be worked. The forging is begun by two or three slabs being placed on the stave as at S S S, and then inserted in the furnace. These slabs are flat blocks made up of pieces of scrap iron, which have been piled and heated, and then welded together. After being brought to a welding heat in the furnace, the slabs are withdrawn, placed under the steam hammer, and beaten down solid. The piece is then turned upside down, and two or three similar slabs placed on the opposite side, as shown at S S. When sufficient iron has been thus added to form the collar of the shaft (assuming it is to have a collar), it is rounded under the hammer, as at C, Fig. 3026, and the body of the shaft next to the collar is roughly formed, as at D. More slabs, S S S, are added to bring out the body, and afterwards the crank itself is proceeded with, on the same plan. The piece will begin to assume the appearance of A, Fig. 3026. Then more slabs are welded on the top, as at S S S, till the depth of the crank is obtained, after which the forgeman proceeds to finish the collar and body of the shaft, as shown. The collar on being finished is cut all round, as shown at C D, Fig. 3027, so that it may be more easily detached from the stave when the shaft is completed, leaving only sufficient connection to carry it till then. The forgeman then cuts the gable of the crank as at E G, and rounds up the body and neck as at B N, Fig. 3027.

"This, it will be observed, is a speedy process, and would invariably be adopted if it were not attended with a very serious drawback; it is very hazardous to the solidity of the forging. For it will be easily understood that not above a third of the crank itself can be thus formed, because the iron at the neck N would not carry a greater mass; if the whole mass of the crank, or even the half of it, was formed before the body and neck of the shaft were finished, a proper heat could not be taken on the body and neck for finishing, without the neck giving way or rupturing. Indeed, as it is, the undue proportion often causes the shaft to be strained at this part, where most strength should be, so that it is rendered weak, and a flaw is developed which by-and-by causes it to be removed from the steamer as dangerous and useless, if indeed it does not break outright; so that the forgeman, if he adopts this method, must be very careful to proportion the amount of iron he has massed in the furnace to the size of the body he is finishing, otherwise the weakening above mentioned will take place. All marine engineers will easily recognise this defect, which frequently occurs, but the cause of which is probably not well understood. Such a flaw will present a similar appearance to that shown at F, Fig. 3033, taken from an actual example.

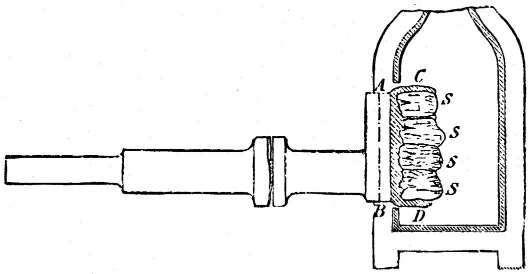

Fig. 3029.

"This difficulty of proportioning the part of the crank first forged to the size of the neck, will be still better understood by the appearance of it in the furnace, as shown in Fig. 3028. Having reached this stage, with one end of the shaft completed, as also that portion of the crank itself which of necessity was completed before the collar was cut, in order that the neck might be finished, no more iron can be added on the top edge, as it is up to the full depth already; it must therefore be added on the flat, as in Fig. 3029, where the piece is shown on its flat side in the furnace, the finished portion being outside the furnace door. A number of slabs S S S are then placed side by side to bring out the width of the crank further; these being welded down, the piece is turned upside down, and the process repeated on the other side. Afterwards other slabs are similarly placed on both sides, as shown in Fig. 3030, of which one is the flat, and the other is the edge view of the crank at this

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*From a paper read at the Glasgow meeting of the Institution of Mechanical Engineers, by W. L. E. MacLean.

stage; and this is continued until sufficient iron has been massed to allow of the other gable of the crank being cut down, as at A, Fig. 3031, and sufficient also to allow of the other part of the body B being rounded and prepared for further piecing out.

"Now it will be observed that the first gable finished has the slabs all welded on the edge of the crank, and the hammering has all been on the edge; hence the subsequent hammering on the flat has a tendency to open up the weldings, if they have not been thoroughly made. A section taken at A B, Figs. 3028 and 3029, will show as in Fig. 3032, on the left, the weldings being across the web of the crank; the circle indicates the section which the crank pin would present if cut through there. But when the slabs are placed on the flat afterwards, some of the joinings of the ends of the slabs, or "scarf ends," are certain to fall within the crank pin, as seen in Figs. 3028 and 3029; therefore the section through C D, Fig. 3030, will show somewhat like Fig. 3032 on the right, and the crank pin necessarily includes some of these flaws. The flaw thus produced, called 'a scarf end in the pin,' is readily recognizable by all marine engineers; at F, Fig. 3033, is a sketch from an actual occurrence.

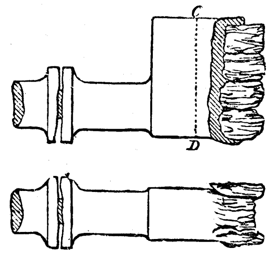


Fig. 3030.

"When the second gable is cut, and the other end is rounded, there is only the other collar to be put on (if a double-collared shaft), and the forging is completed.

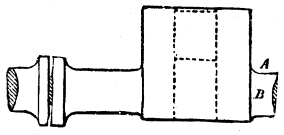


Fig. 3031.

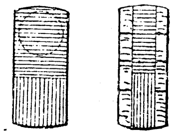


Fig. 3032.

This method is so speedy, compared with any other, that it is often resorted to even at the risk of making a bad forging; and too many broken shafts testify to the fact. Besides, it may be observed that in making a double crank shaft, while the one crank may be made in this way, the other must; for, the first crank, A, Fig. 3033, being completed, and the body, B, between the two cranks, also completed, the second crank, C, must of necessity be pieced off this body, even at the risk of the neck N being strained. This may account for the many instances in which one of the cranks of a double crank shaft gives way, rendering the shaft useless; and also for the plan, now almost universal, of making the two cranks separately and coupling them together; a further object being, no doubt, to have the means of replacing a defective half, if need be, without losing the whole shaft.

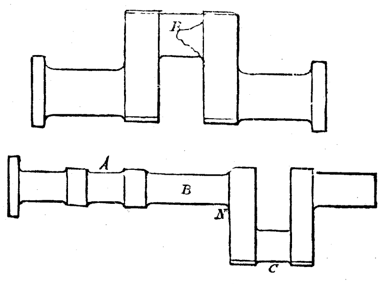


Fig. 3033.

"At Lancefield, when a double crank shaft is to be made, the after crank, A, is first made by the method afterwards described, so as to insure that this crank, through which, as being next the propeller, all the power of the engine passes, is perfectly sound; and in piecing the other crank off the body, it is worked with slabs on the flat instead of on the edge, as afterwards described.

"The writer's own opinion is that the crank is the most important part of the shaft, and, therefore, at all costs, should be made first. Others, no doubt, may take the same view, and, to avoid the risks just mentioned, may adopt the process described in the second method.

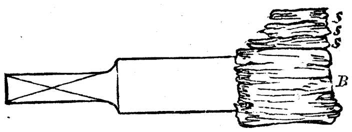


Fig. 3034.

"*Second Method.*—This method builds the middle first, and is called "turning the shaft end for end." The shaft is begun from a stave, by the addition of slabs, as shown in Figs. 3034 and 3035; Fig. 3034 shows it with iron added in slabs, till a butt is formed, as at B, to form the nucleus of the crank; slabs S S S are then piled on it to bring the crank up to the height.

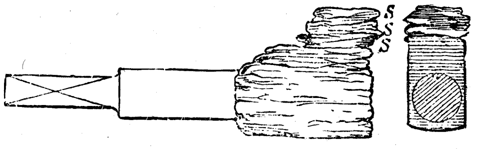


Fig. 3035.

"These are beaten down and welded, and more are added, as at S S S, Fig. 3035, till the full height of the crank is reached. Should the web (or edgeway of the crank) be thick, two slabs are frequently used to make up the breadth, placed edge to edge, as shown in Fig. 3035 on the right hand of the figure; the widths of these slabs are limited by that at which the shinglers can conveniently work and turn them under the steam hammer. The crank, however, is completed without any "side slabs," for the beating down of the slabs on the edge will broaden out the mass, and give sufficient material to forge out the crank to the proper height by hammering on the flat. The crank is afterwards cut at the off gable at G, Fig. 3036, the body B pieced out and rounded, the collar welded on, and then a small stave S is drawn upon the end, to enable the forgeman to handle the piece when he "turns it end for end" to complete the other end of the shaft.

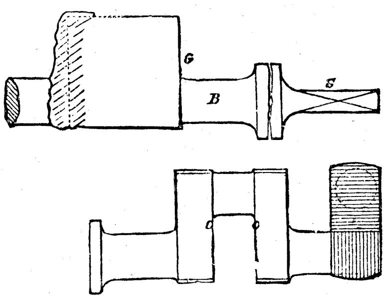


Fig. 3036.

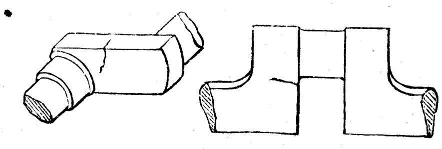
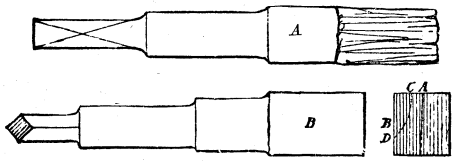


Fig. 3037.

"This method, though better than the last, is also objectionable; for though there is not equal risk of 'scarf ends' in the pin, yet the weldings are all on the edge, as in the lower view, in Fig. 3036, where the section of the crank pin is shown by the dotted circle; and the checks of the crank, O O, are thus liable to give way if a heavy strain comes on the crank when at work. The defects arising from this cause are shown in Fig. 3037, and will be readily recognised by all engineers.

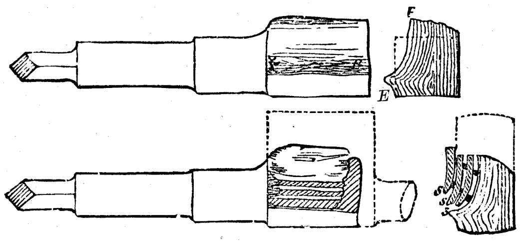
"*Third Method.*—Considerations such as these have led to the adoption of the third or Lancefield method.

Fig. 3038 shows the piece begun from the stave in the usual way, with the slabs all welded, however, on the flat, till a basis is formed for the building up of the crank. A portion A is roughly rounded to form the one end of the shaft, and the butt of the crank will present the appearance of a slightly elongated square, as shown at B, Fig. 3039. The workman then "scarfs" or hollows it down at one edge all along the side, as indicated in the end view by the dotted line from C to D; it will then present the appearance shown by the end view, Fig. 3040, being somewhat bulged outward at the points E and F. Three long thin slabs, Fig. 3042, shaped for the purpose, are then placed on the hollowed part, the piece lying flat in the furnace. These slabs are tapered a little the broad way, not on the length, and little pieces of iron are interposed between them, to keep the surfaces apart, and allow the flame free access between them. The object of making them thin is that they may be all equally heated, which is not so readily achieved when the slabs are thick; and the object of the tapering is to allow the slag to flow out freely when the uppermost slab is struck by the steam hammer. The surfaces thus get solidly welded.



Figs. 3038 and 3039.

"Fig. 3041 represents the slabs thus placed in elevation, and the figure on the right, in section. The slabs are forged long enough to go right across the whole width of the crank, excepting about 6 inches; this margin is necessary to allow of the lengthening out of the slabs to the whole width under the process of forging. After these slabs are perfectly welded, the piece is turned upside down, and the process is repeated on the other side, as shown in Fig. 3042. When welded down the mass has increased in depth as well. Another scarfing takes place on the first side, and then another on the second side, as shown in the figure, and so on, till the full size is obtained; and it will be seen, as in the right-hand view in Fig. 3042, that by this process of "scarfing" equally from both sides, the iron from the very middle of the body of the shaft is drawn up quite to the crank pin. The location of the pin is indicated by A A, and it will be seen that by no possibility can there be a "scarf end" in the crank pin, as the slabs in all cases go right across the crank, and also that the cheeks of the cranks have no edge weldings crossing them, as in the previous cases; for the tail of a slab may be at R, Fig. 3042, while the other end may be at S. The fibre is also developed by the continuous drawing up of the iron consequent upon the repeated flat scarfings across the whole width of the crank. When the crank has been thus massed sufficiently large, it is cut at the gable, with sufficient material left to piece out the other body of the shaft. This is now done, the coupling welded on, and a small stave drawn on the end to enable the forgeman to manipulate it, when it is turned end for end, to complete the other end.



Figs. 3040 and 3041.

"These proceedings occupy longer time than either of the other two methods, and consequently costs a little more; but the advantage is well worth all the difference, as greater confidence can be entertained that the forging is every way satisfactory. In brief, by making the crank first, is avoided the liability to weakness at the neck, characteristic of the forgeman's making the shaft before him, as in the first method; by the repeated 'side scarfing' is avoided the liability to fracture across the cheeks, consequent upon the edge weldings of both first and second methods; while by having the slabs the whole length of the width of the crank, any 'scarf end' in the length way of the crank pin is impossible (such as may occur in the first method); and the welding of the mass of the crank being wholly on the flat must tend to form a more solid forging than if hammered otherwise. Thus, if the forging is well heated and properly hammered, the system promises to insure that no weak part will be found in the shaft after it is finished and put to work. The writer believes, from the success which has already followed in every case the adoption of this method, that it will eventually be found that almost more depends on the mode in which a crank shaft forging is constructed than on the material of which it is made.

"This leads him to some observations regarding the material for such shafts. It is of course well known that in the early days of engineering, before the time when steam navigation had received a great impetus by the invention of the screw propeller, the connecting rods, cranks, shafts, &c., of land engines were all formed of cast iron; except, indeed, where the connecting rods were made of wood, strapped with plates of wrought iron, as frequently was the case with pumping, winding and blowing engines. In fact, all the parts that could be made of cast iron were so made, and the piston rods, bolts, keys, straps, and other smaller parts were alone made of malleable iron, the smaller pieces being made from rolled bars direct, as at present, and the larger made of similar bars, but placed side by side and bound together or 'fagoted,' as they were called, from their resemblance to a bundle of fagots. These bars, thus fagoted, were either brought to a welding heat in a smith's hearth and welded under the sledge-hammers of the men called 'strikers,' or hammermen; or else heated in a furnace, and welded under the tilt hammer worked by a steam engine. By-and-by it was found necessary to adopt the stronger material, wrought iron, for parts hitherto confined to cast iron, because the latter was found too deficient in cohesion to stand the strains due to the power of high-pressure steam, which was now almost universally superseding the use of low-pressure steam in the condensing engine. The system of fagoting, however, was still carried out, even far into the history of marine engineering; but when the rapid increase in the dimensions of engines, both stationary and marine, called forth the steam hammer, and so rendered the forging of heavy masses comparatively easy, the system of fagoting fell into disuse, for the following reason: In making up a fagot, say, of 18 inches or 20 inches square, it was found that in the furnace the outside bars would reach a welding heat much sooner than those in the middle; consequently on welding this fagot under the steam hammer, though the blow might reach to the centre, yet the interior would not be welded, while the surface was; hence the shaft or other forging would not be welded throughout, and it was no uncommon thing for a shaft to break and expose the internal bars quite loose and separate from each other.

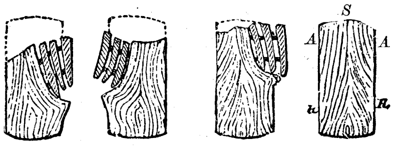


Fig. 3042.

"When it was seen that malleable was so much superior to cast iron, and that the system of fagoting was so imperfect, the adoption of 'scrap iron,' which was then composed principally of parings of boiler plates, pieces of cuttings from smiths' shops, old bolts, horseshoes, angle iron, &c., became general. These being piled together in suitable pieces, and in a pile of suitable size, for the convenience of working, were brought to a welding heat, and beaten out into a slab, or oblong-shaped piece, ready for the forgeman; who would build two or three together, adding more when required, and so bring out his piece to a sufficient size to enable him to shape his forging out of it. Then it was that engineers, seeing what an increase of strength they obtained by these means, invariably specified on their drawings (as many of them still do),. 'These forgings are to be made of carefully selected scrap iron, free from flaws and defects.'

"To meet the requirements of their customers, therefore, forge-masters had now nothing to do but to select and use the best available scrap iron; but the universal adoption of iron hulls in place of wooden ones, conjoined with the rapid and unprecedented increase in steam navigation, soon introduced a class of scrap iron which did not possess the qualifications of good scrap, and also called for a very much greater supply of forgings than could be obtained in superior scrap iron. The consequence was that shafts of scrap iron, when turned and finished, became liable to exhibit streaks and seams, not due alone to imperfect welding in the forging, but likewise to the laminations and imperfections of the original scrap iron, which the process of piling and shingling into the slab was not sufficient to obliterate. So constantly does this yet occur that it causes a strong temptation to make such forgings of new iron puddled direct from the pig and then shingled into slabs or blooms, under the idea that these streaks and seams will thus be avoided, and that the iron will be improved almost to the condition of scrap iron, while being forged under the steam hammer. This, however, is found not to be the case. The forging is certainly free from the streaks of the scrap iron, but this is obtained at the expense of strength; for the material is too raw; it wants cohesion, and has not had the proper kind or amount of working to bring it to the condition of superior wrought iron. This method is still further tempting, inasmuch as it is far cheaper than the other; the material costs less than scrap iron, and, as it welds at a lower temperature, a forging can be much more quickly and easily made. Still, for whatever class of machinery it may be fitted, it should certainly be renewed in every case for a crank shaft or propeller shaft.

"From these considerations it has been the custom at Lancefield, in the preparation of the iron for crank shafts, to improve upon the ordinary condition of the scrap iron in the following manner: The pile is made up of carefully cleaned and selected scrap; it is brought to a welding heat, and then hammered under the steam hammer. But instead of being beaten into a flat slab for the forgeman, it is beaten into a square billet, which is afterwards rolled in the rolling-mill into a flat bar, as if for 'best best' merchant iron. By this additional heating, hammering and rolling, all the different qualities of the scrap iron composing the pile are merged into one homogeneous material, having the fibre given to it that was lost in the separated portions of the scrap iron; and this, when cut up into proper lengths, and again piled and shingled into the slab, results in a material possessing somewhat the closeness and density of steel, while retaining all the toughness and tenacity of superior malleable iron. The improved method of constructing the forging, previously detailed, is worthy the use of this superior material; and both having been adopted at Lancefield with results which have commended themselves so unmistakably to many engineers, that they now not only specify the material, but stipulate for the mode of manufacture, it is thought the system has only to be more widely known in order to be universally adopted. It is certain to give greater confidence in the endurance of such important parts of the machinery, although this confidence may have to be obtained by a small increase in the cost, due to the extra workmanship both on the material and on the forging.

"When we take into consideration the vastly accelerated speed of the marine engine in late years, and the many disastrous effects which follow the breaking of a shaft at sea—also that the tendency of the age is still towards much higher pressures, and further lengthening of stroke it is not surprising that improvement in such an important part as the crank shaft should be eagerly sought after; but it has hitherto been sought in the direction of the material alone. Cast steel has been advocated, and brought to some extent into use; but its expense renders such shafts costly out of all proportion to the other parts of the engine; while, in the event of their heating when at work (a very frequent casualty), and having the water-hose directed upon the crank pin or journals, it cannot be expected that the material will behave any better, or even so well, as tough wrought iron. What is termed puddled steel is liable to the same objection, and probably, from its mode of manufacture, in a still greater degree. The so-called mild steel is no doubt proving itself a superior material, and yielding good results when rolled into ship or boiler plates. But thus prepared it is more costly than 'rolled scrap bar;' and if not rolled, but cast into an ingot, then it possesses some of the crystalline characteristics of steel, with all the disadvantages attending its manipulation into a forging.

"For extra large crank shafts, the fear of unsoundness, arising from the ordinary mode of forging, has led some engineers to consider the propriety of building the shafts and cranks in separate pieces. This, with engineers generally, has not hitherto been looked upon with favor; as the fewer the pieces the more rigid the shaft. Moreover, the increased weight necessitated by this separate building is viewed as a disadvantage, even although it were not attended with greater cost, as undoubtedly it is.

"The material and mode of manufacture advocated in this paper may tend to dissipate some of these apprehensions. They will not obviate defective construction in the engines themselves, or faulty proportion of their parts, or neglectful supervision of their working, but they will reduce to a minimum the risk of breakage in such untoward circumstances. If any objection be taken on the score of extra size, the enterprise which a quarter of a century ago engaged in the making of the unusually large shafts necessary for the 'Great Eastern' may still be trusted to meet the advancing requirements of the present day."

Fig. 3043 represents a foot-power hammer or Oliver. The hammer is upon a shaft in bearings, and is held in the position shown by an open coiled spring On the shaft is a chain pulley, the other end of the chain being connected through a leather strap to the treadle. Means are provided to adjust the height to which the hammer will lift to bring the hammer face fair with the work and to give the required degree of tension to the spring.

Fig. 3044 represents a Standish's foot-power hammer, in which the hammer and the anvil are provided with dovetail seats for receiving dies, swages, &c. The force of the blow is regulated by the height to which the hammer is raised, which may be adjusted by the nuts beneath the spiral springs. The handle on the hammer is for pulling the hammer down by hand when adjusting the lower die fair with the upper one.

What are known as power hammers are those driven by belt and pulley; while those known as trip hammers have their helve lifted through the medium of revolving lugs or cams. Steam hammers are those in which the hammer is lifted by a piston in a steam cylinder; while in hydraulic hammers, the hammer is moved by water pressure.

Fig. 3045 represents a Justice's power hammer, in which the hammer is guided in a slideway and is operated by leather straps attached to the ends of a spring, at the crown of which is attached a connecting rod driven by a crank disk. The stroke is altered by means of placing the crank pin in the required position in the slot in the crank disk. By means of gibs the hammer may be set to match the dies. The pulley is provided with a friction clutch operated by the treadle, shown.

Fig. 3046 represents a Bradley's Cushioned Hammer, in which motion is obtained by a belt passing over a pulley on a crank shaft, whose connecting rod R is capable of adjustment for length, so as to govern the distance to which the hammer shall fall, which obviously varies with different sizes of work. The hammer is lifted through the medium of a rubber cushion A, seated in a casting to one end of which is connected the rod R, while the other end is pivoted. The lever to which the hammer is affixed is raised against the compression of the rubber cushion B, and at the top of its stroke also meets the rubber cushion C; hence these two cushions accelerate its motion after the crank has passed its highest point of revolution. The cushion D prevents the rebound of the hammer after the blow is struck; hence as a result of these cushions, heavy or light blows may be struck with great rapidity and regularity. The weight W is on a lever that actuates a break upon the wheel shown at the side, so as to enable the stopping of the hammer quickly. The machine is put in motion by pressing the foot upon the treadle T, which

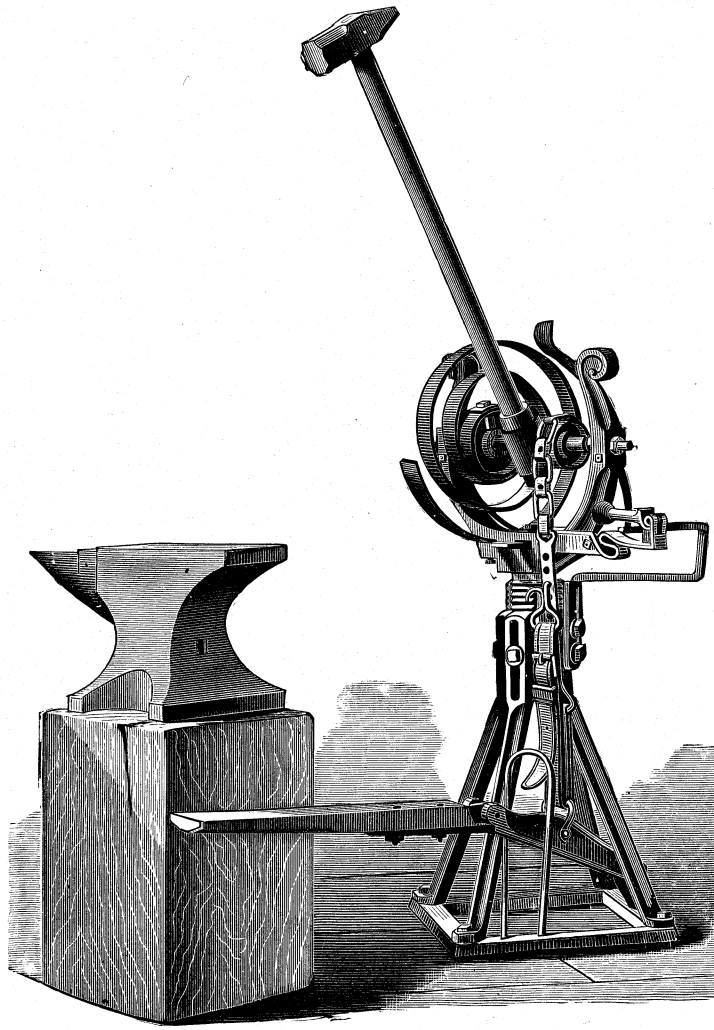


Fig. 3043.

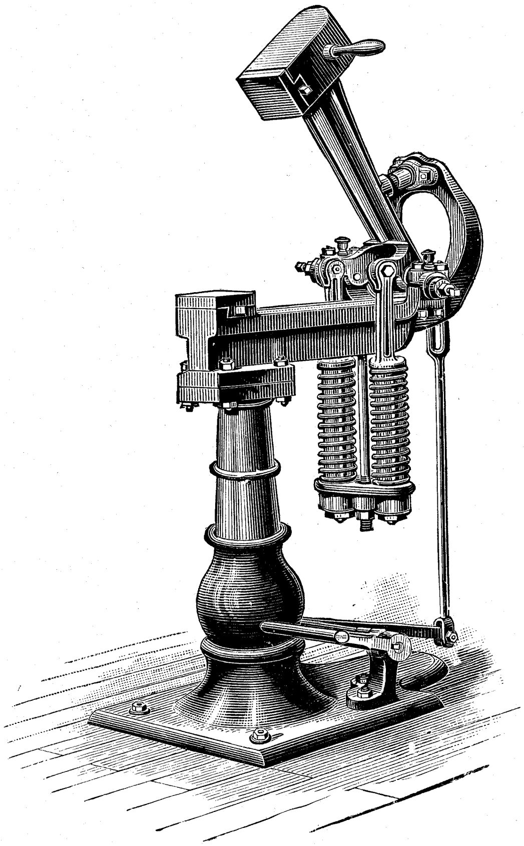


Fig. 3044.

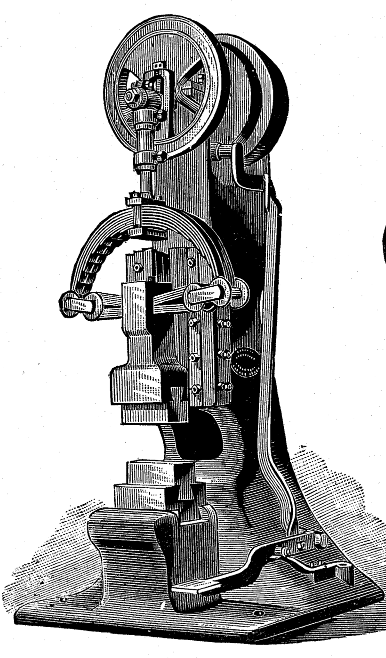


Fig. 3045.

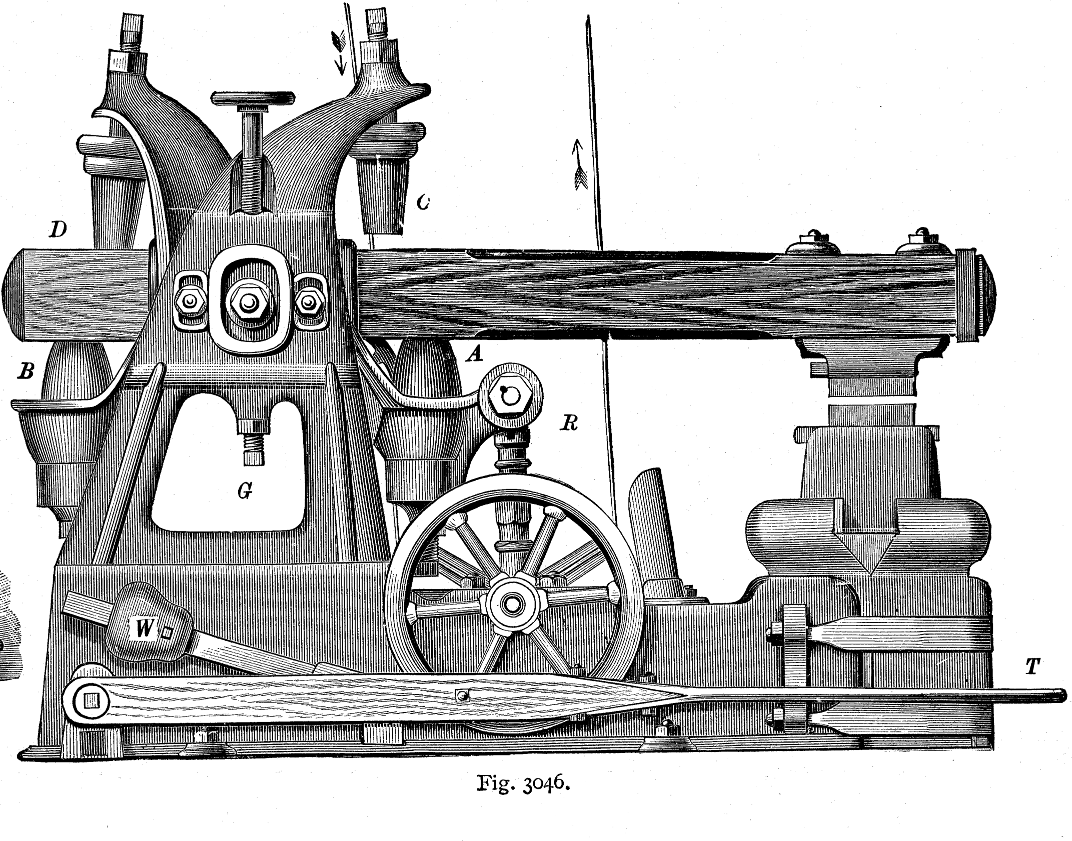


Fig. 3046.

operates a belt tightener, the belt running loose when the treadle is released.

The hammer lever or helve is adjustable for height by means of the screw G and hand-wheel H, which raise or lower the bearings in which the helve journals are carried. This is necessary, because as the helve moves in the arc of a circle the faces of the upper and lower die, or of the hammer and the anvil, as the case may be, can only come fair at one particular point in the path of the hammer; hence in proportion as the blow terminates (by meeting the work surface) farther from the anvil face, the pivot or journal of the helve must be raised, so that the journal will be horizontally level (or as nearly so as possible) with the hammer face at the moment the blow is delivered.

By giving motion to the helve through the medium of cushions, a direct mechanical connection, and the destructive concussion that would accompany the same, is avoided; hence a high speed may be obtained without the frequent breakage that would otherwise ensue.

Fig. 3047 represents Corr's power hammer, the construction being as follows: The semi-elliptic springs, shown on top and bottom of the beam, serve to balance the stroke, so that the hammer may run from 350 to 450 strokes per minute, with safety to the machinery. The hammer is adapted to almost any form or kind of forging. Large dies may be inserted for various kinds of forming and welding, such as making plough-shares and other articles, which require that the operation be commenced with a light tap, and increased to a heavy blow at the will of the operator.

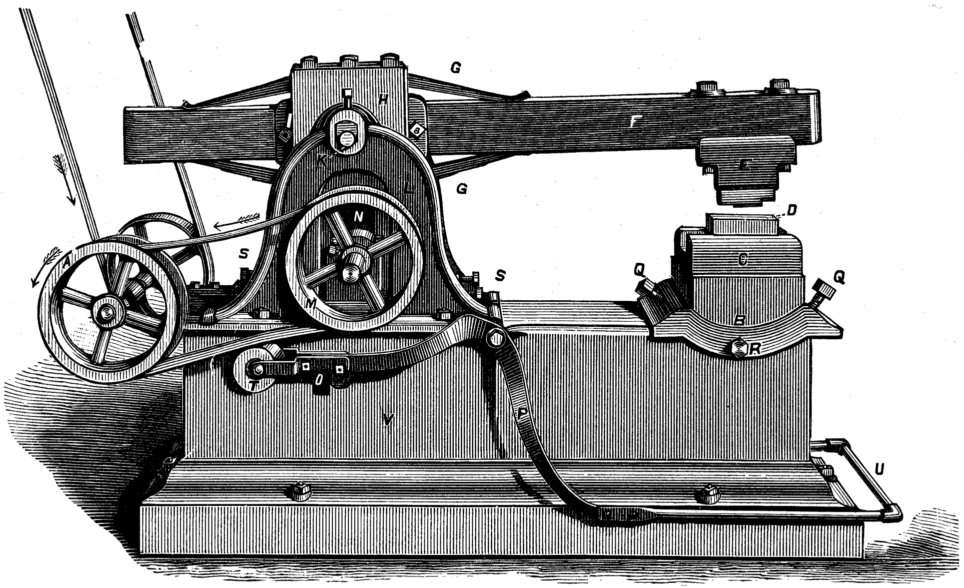


Fig. 3047.

The whole structure is mounted on a substantial iron bed V, 18 inches deep, 22 inches wide and $5\frac{1}{2}$ feet long. Attached to this bed V are two circular arms L; between them is pivoted near their top, at K, an oscillating frame H, having a longitudinal opening, in which is attached two semi-elliptic springs G G, and two plates I, with trunnions projecting laterally through the oscillating frame at K; the hammer beam F is inserted between the springs G G, and the trunnion plates I, which are bolted firmly to beam F at I; the ends of the trunnions and outsides of the oscillating frame H rest evenly against the inside of the circular arms L; at K a shaft is passed through the trunnions and beam F, and made rigid in them with its ends resting in boxing at K. Caps are provided to cover the ends of the boxing and shaft with set-screws projecting against the ends of the shaft, which secures it against end play.

By these mechanical arrangements the beam F and oscillator H are securely attached independently, vibrating on one common centre, allowing no side play of the hammer E, admitting F to the free action of the springs G G; in the lower end of the oscillating frame at N is a lateral opening 10 inches vertically by 6 inches longitudinally and 4 inches laterally, with flanges projecting longitudinally one inch into this opening from both sides. This makes the opening two inches smaller on the outside than the internal cavity; the rear and front internal walls are provided with steel plates, 4 by 10 inches, $\frac{1}{4}$ thick, resting against the inner ends of four set-screws, not shown, provided to adjust these plates to or from the sliding box at N, to compensate for wear and prevent lost motion. These plates and flanges form slides and guides between which a loose box and eccentric is provided with shaft projecting laterally through boxing at N, which project upwards from an adjustable frame immediately under the oscillator H; this permanently locates the eccentric and shaft in the lateral opening in the oscillator H, at N. The adjustable frame mentioned rests on suitable bearings on the inside of the circular arms L, and is fastened down by four bolts passing through suitable slots in the adjustable frame, entering the bearings on the arms L. This frame is adjusted back or forth by set-screws S S; this adjustment is for the purpose of giving a greater or less distance between the anvil and hammer at D, as may be desired for large or small work, long or short dies, &c.

The anvil B, weighing about 500 lbs., sits down in the bed at R and rests on circular bearings (between R and B), which radiate to the centre of the top of the anvil at D, and is held rigidly in any position longitudinally desired by set-screws Q Q, with their inner ends resting on shoulders on the sides of the anvil B, which projects down about ten inches; between this lower projection and the internal wall of the bed is sufficient space to admit of any adjustment desired. This lateral adjustment is accomplished by set-screws R, passing through the sides of the bed V, with their inner ends resting against the anvil which holds it rigid at any lateral adjustment. By this arrangement the anvil is accommodated to all and any class of work or shape of dies.

The anvil is constructed in two parts. Four inches of the top C may be taken off, leaving a suitable place to insert large dies for various purposes, such as dies for welding plough-shares and dies for forging journals on large shafts. A counter-shaft, provided with suitable pulleys, is attached on the rear end of the bed; this shaft is kept constantly in speed and power by the vertical belt in the direction indicated by the arrow; the other end of the shaft is provided with a flanged pulley, corresponding to a flanged pulley M, on the eccentric shaft; around these pulleys is placed a loose belt, as shown; in contact with this is a press pulley T, adjustably attached by two arms to the projecting end of the treadle P at O. If the foot be placed on the treadle at U and it be pressed down, the break on the opposite side breaks contact with the balance wheel (not shown); the press pulley will at the same time tighten the loose belt on the flanged pulleys. This gives motion to the pulley M, in the direction indicated by the arrow. Its motion is increased by a heavier pressure until it attains the same speed as the other flanged pulley; this would be the full speed, which may be diminished to any speed desired by lessening the pressure on the loose belt. By this means motion and power is given to the eccentric, which carries back and forth the lower end of the oscillating frame H; this gives vertical motion to the springs G G, and this imparts corresponding motion to the beam F. These springs accomplish a threefold object:

1st. They carry the hammer E up and down.

2nd. They cushion the hammer at the returning points and give off that power which was stored in them while cushioning.

3rd. By the power exerted in the machinery they follow up and impart still greater force to the blow.

It is found by this arrangement of eccentric loose box and oscillator that when the machinery is moved in the direction indicated by the arrow, that the downward stroke is one-sixth quicker than the up stroke; this is a natural result, for the down stroke is performed while the eccentric is revolving above the centre of its shaft and nearest the fulcrum of the operator H. With the present arrangement the downward stroke is performed with $\frac{5}{12}$ of the revolution and the up stroke is performed with $\frac{7}{12}$; the difference is $\frac{2}{12}$, which equals one-sixth. The up stroke is performed while the eccentric is revolving below the centre of its shaft and in that part farthest from the fulcrum of the oscillator H, so if the machinery were reversed the quick stroke would be up and the slow stroke would be down.

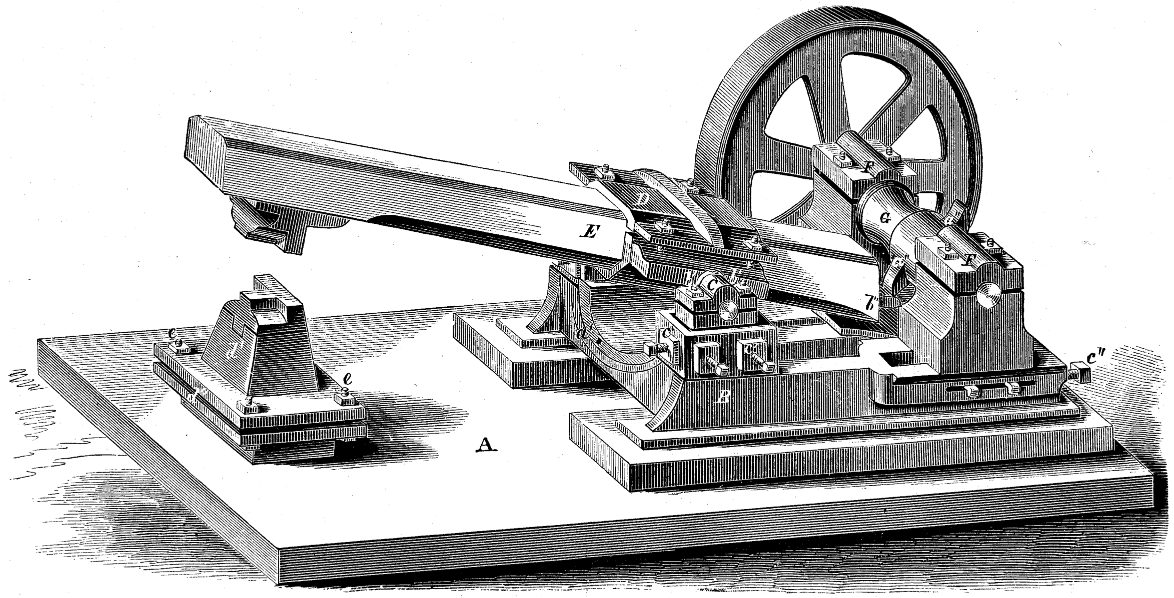


Fig. 3048.

In Fig. 3048 is shown a Kingsley's trip hammer. The main bed or foundation plate A carries the bed plate or frame B, at one end of which are the pillar blocks C, which afford journal bearing to the casting carrying the hammer shaft E, being fastened thereto by the clamp D. These journals are the centre of motion of the hammer helve E.

At the other end of the bed plate B, are the pillar blocks F, affording journal bearing to the cam and fly-wheel shaft. *a''* is the tripping cam, which is provided with two toes or cam arms, which meet the tripping piece *b''*, and this gives the hammer two strokes in a revolution of the fly-wheel shaft or cam shaft G. The stroke of the hammer may be altered by means of the set-screws *c''*, which move the pillar blocks F, so that the cam toes *a''* have contact with the tripping piece *b''* through more or less of the revolution of *a''*; the pillar blocks F being retained in their adjusted position by means of the set-screws shown below them in the bed piece B.

By the following means provision is made whereby the face of the hammer may be set out of parallel with that of the anvil block or lower die *d'*.

Fig. 3049 is a sectional view through the pillar blocks C, and casting and clamp D. The pillar blocks C C are carried in a semicircular frame *a'*, hence by unscrewing the bolts *b'* and screwing up the pillar block on the other side, the journals are thrown out of parallel, and the plane of motion of the hammer-shaft is altered so that the face of the upper die does not meet that of the anvil die fair to an amount which may be varied at will by operating the screws *b'*. The object of this is to enable the forging taper (as in sword blades) with common dies, and thus to save the making of special dies for each degree of taper required.

Similar provision is made in the anvil block which is easier to set, providing the degree of taper is within the limit of its range, of movement, otherwise the hammer also may be set.

Fig. 3050 represents a drop hammer, and Fig. 3051 is a sectional view of the lifting mechanism.

This machine consists of a base or anvil, a hammer which moves up and down between two uprights, and a lifting device, which is secured to the top of the uprights.

A board secured to the hammer passes up between two friction rolls, which revolve in opposite directions. When the two rolls are moved towards each other, the friction on the board causes the hammer to rise; and when again separated the hammer will fall. The *back* roll is keyed to a shaft, on each end of which is a driving-pulley; and thus by the use of two pulleys on the same shaft, equal wear comes on the bearings in which it revolves. The *front* roll turns freely on its shaft, and is driven by the back roll being geared to it. To secure to the gears both strength and durability, they are made with wide faces, are geared at both ends, and the teeth are of peculiar shape.

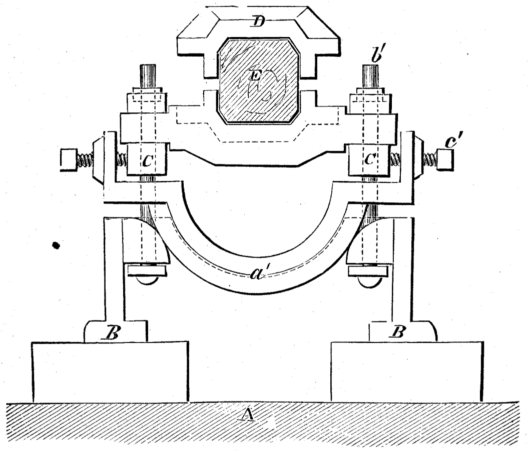


Fig. 3049.

The bearings to the shaft, on which the front roll revolves freely, are eccentric to the roll, and a partial revolution of the shaft moves the *front* towards the *back* roll, pinching the board. To an arm which is secured to the front shaft is fastened the upright rod, the *upward* movement of which *opens* the rolls, and whose downward movement closes the same; the weight of the rod being sufficient to cause the hammer to rise. This arrangement, simple and yet substantial, dispenses with the two eccentric-armed bushings, and the spreading of the upright rod at the top to reach both bushings, which caused so much trouble in the old way. In place of the dog which is usually used to hold up the hammer, (which is limited in adjustment to holes located at fixed distances in one of the uprights, necessitating not only the removal of the dog to another hole, and connecting and disconnecting the same to the treadle, but also the most accurate adjustment of the collar on the upright rod to the dog holding the hammer), we use a pair of clamps, located on the lifter, under the rolls. These clamps, holding the hammer centrally, prevent the side blow against the upright, the inevitable result of the contact of hammer and dog, when the former is only held on one side, as it must be, by the use of the dog. The opening of the clamps by the foot-treadle allows the hammer to fall; and the clamps are so made that the hammer will ascend freely, whether the foot is on the treadle or not, and if the foot is off the treadle, will hold up the hammer at any point where it may be arrested in its upward movement. It will be readily seen that the only adjustment required is that of the collar on the upright rod, to any height of blow desired.

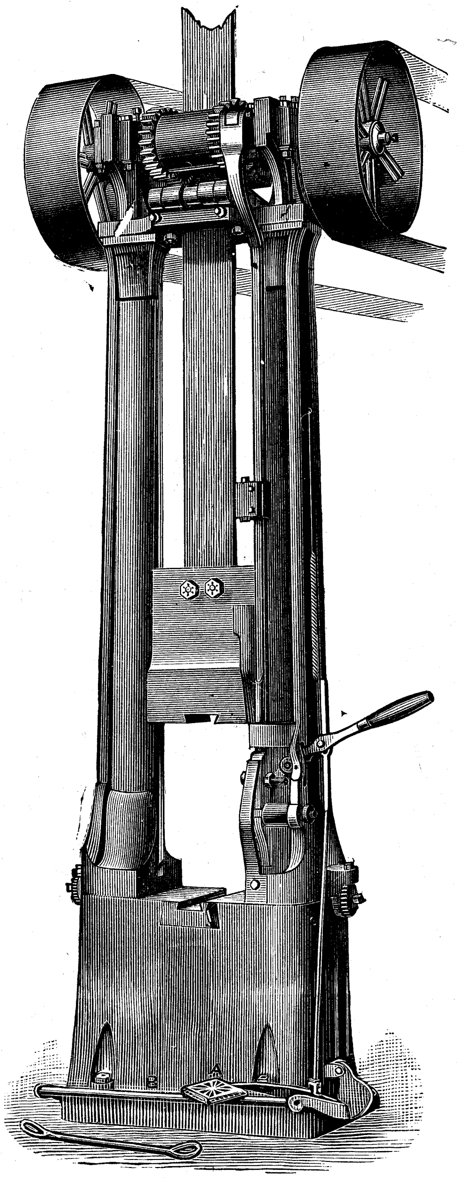


Fig. 3050.

This machine has two treadles, one connected to the clamps, and the other to a lever which operates the upright rod.

To obtain repeated blows with one motion of the foot, place the foot upon the treadle connected to the clamps. If variable blows are wanted, place the foot upon the *other* treadle, and the hammer will follow the motion of the foot. This extra treadle is a late improvement, and is not shown in the cut. The operation required to obtain automatically any number of blows of the same height is described as follows:—

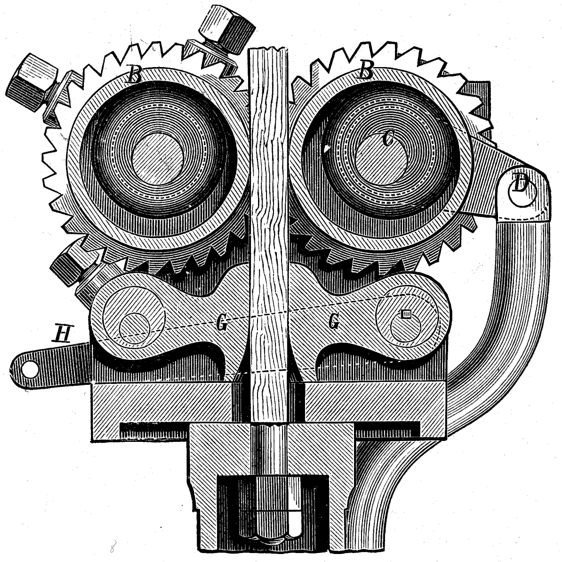


Fig. 3051.

Pressure upon the treadle opens the clamps and allows the hammer to fall; just before the dies come together, the trip at the bottom which holds up the upright rod is released, and allows the rod to drop; this closes the rolls, causing the hammer to ascend. The hammer continues to rise until it strikes the collar on the upright rod, and, lifting the rod, opens the rolls, removing the pressure upon the board, and allows the trip at the bottom to go under to hold the rod up, and the hammer remains suspended, provided the foot is off the treadle. So long as pressure is kept

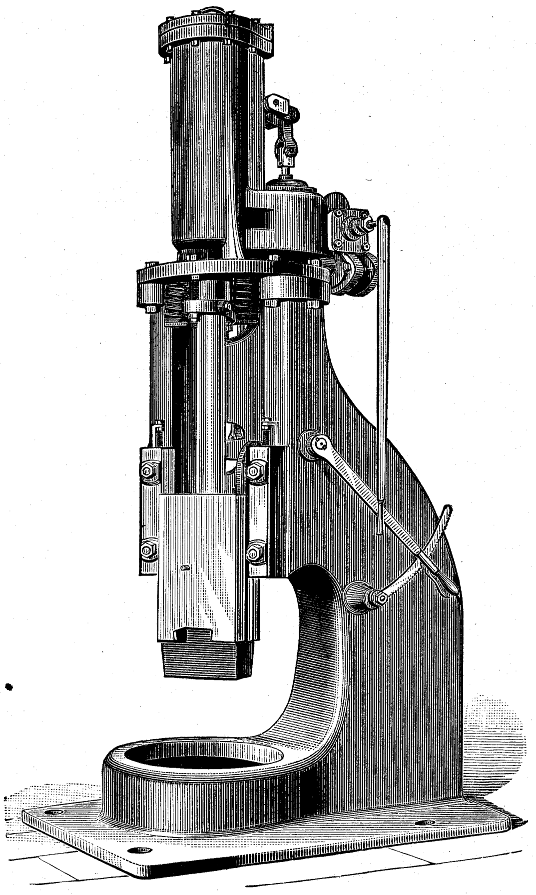


Fig. 3052.

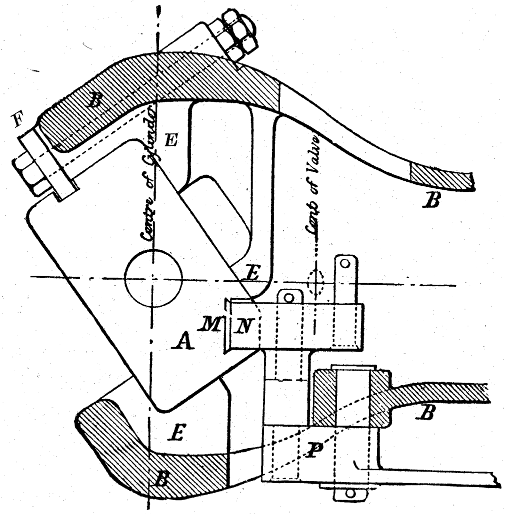


Fig. 3053.

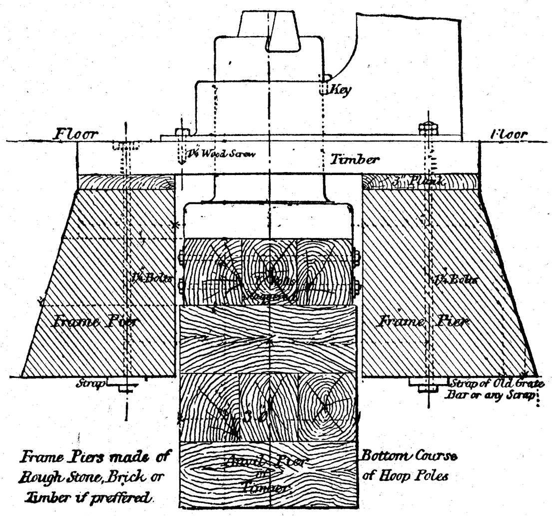


Fig. 3054.

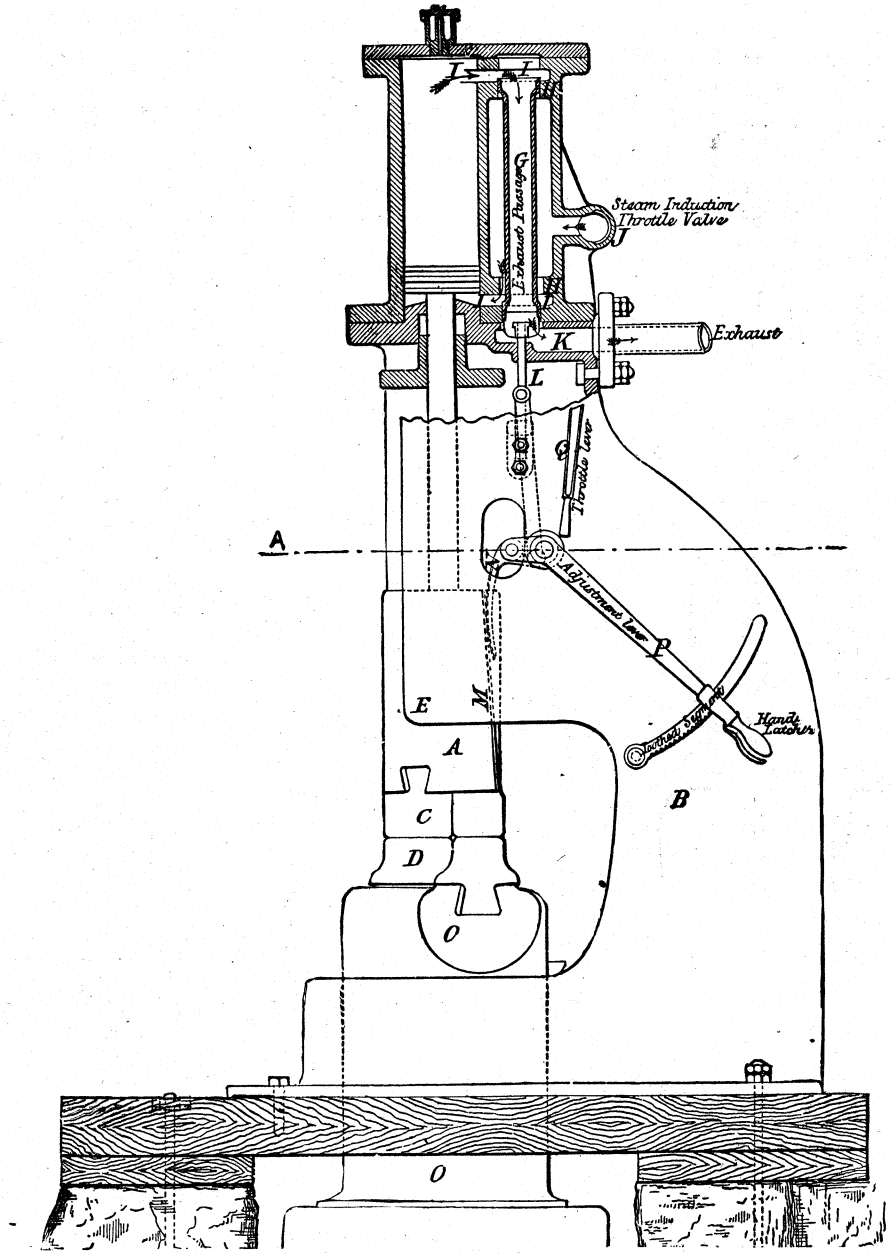


Fig. 3055.

on the treadle, the blows of the hammer will be continuous; but upon removal of the pressure, the hammer will assume its original position.

To procure variable blows, the operation is as follows:—

Pressure upon the treadle connected to the lever which operates the upright rod communicates itself to the treadle that opens the clamps, and the hammer falls; a locking device (not shown in cut) keeps this treadle down, and on completion of the variable blows wanted, removal of the foot from the treadle disconnects the locking device, and the hammer goes up to its original position, and is there held by the clamps.

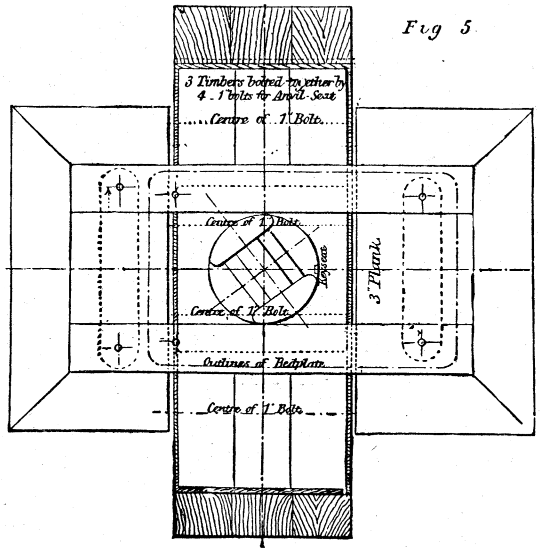


Fig. 3056.

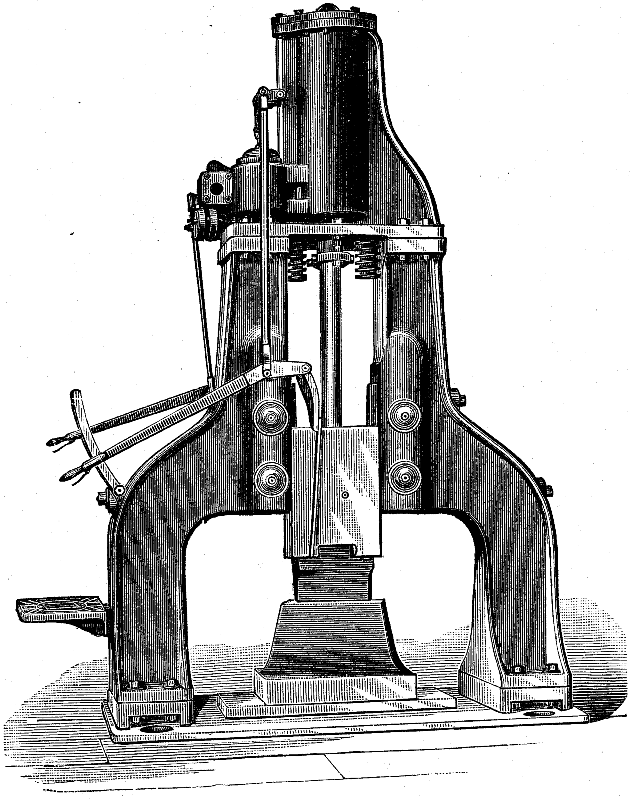


Fig. 3057.

When the work is such that the operator requires an assistant, variable blows may be obtained by the use of the hand lever by this assistant.

A gentle pressure upon the treadle will allow the hammer to go down slowly, but it will stop and remain suspended at any point as soon as the pressure is removed. The hammer can also be arrested at any point on its way up, by bringing into action the hand lever, so that the next blow can be given from a state of rest at a less height than the collar is set for. The clamps in holding up the hammer keep the board from touching either roll, and prevent the same from being worn uneven when not in use.

The back roll is made adjustable to different thicknesses of lifting board, as are also the clamps.

Figures from 3052 to 3056 represent a steam hammer. The head A is set at an angle in the frame. The anvil or die C is oblong, as is also the anvil die D. The object of this arrangement is to enable the workman, after drawing out his work across the short way of the die, to turn it and finish it lengthwise without being inconvenienced by the frame. By this means skew and **T**-shaped dies can be dispensed with, and the full service of the ram utilised. The latter is moved between the guides E E, and held in place by the steel plate F, bolted through the frame B. The valve G is a plain cylinder of cast iron, enlarged at each end to work in the cylindrical seats H H, in which the ports I I are placed. Steam is admitted through the valve J, and circulates round the valve G, between the seats. The exhaust chamber K is below the cylinder, which therefore drains condensed steam into it at each stroke through the lower steam port. The exhaust above the piston passes down through the interior of the valve, as shown by the arrow on the drawing. The valve stem L is connected with the valves in the exhaust chamber. No stuffing box is therefore required, there being only atmospheric pressure on each side of it. This combination enables the valve to be so perfectly balanced that it will drop by its own weight while under steam.

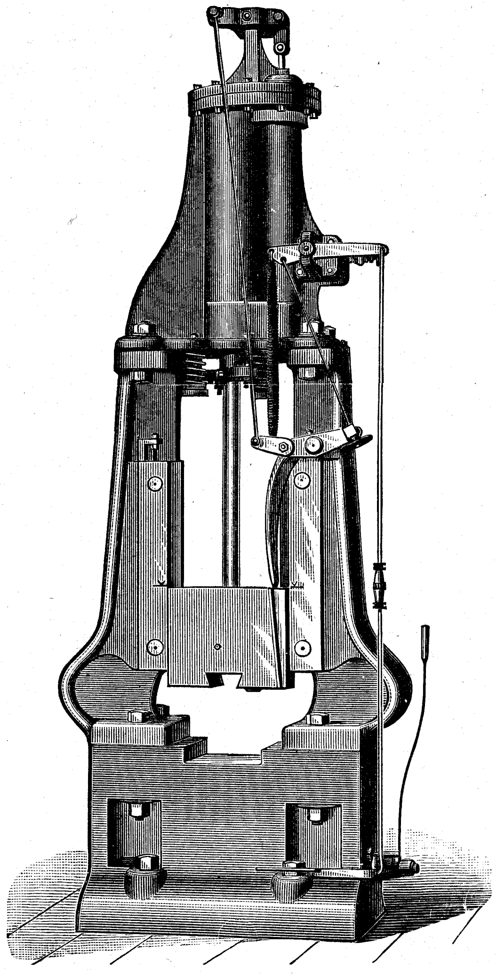


Fig. 3058.

The automatic motion is obtained by an inclined plane M upon the ram A, which actuates the rocker N, the outer arm of which is connected by a link to the valve stem, and thus gives motion to the valve. The valve is caused to rise in the up-stroke by means of the rocker N and its connections, through the inclined plane. The steam is thus admitted to the top, which drives down the piston, while the valve and its connections follow by gravity, thus reducing considerably the friction and wear upon the valves. In very quick work the fall of the valves may be accelerated by the aid of a spring; or it may be retarded in heavy work by friction springs, so as to obtain a heavier blow by a fuller admission of steam. For general work, however, the arrangement shown is perfectly effective, and as the rocker N is hung upon the adjustment lever P, any required variation can be obtained by the movement of the lever. Single blows can be struck with any degree of force, or a rapid succession of constant or variable strokes may be given.

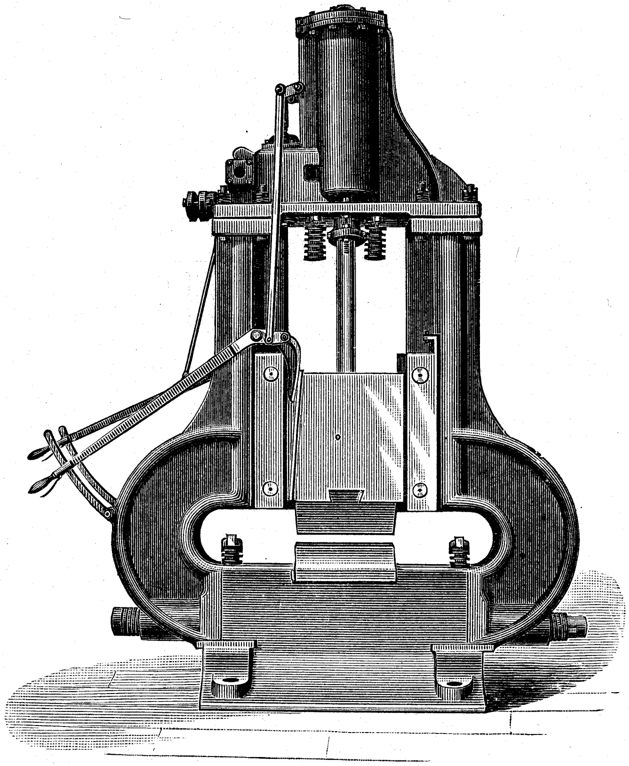


Fig. 3059.

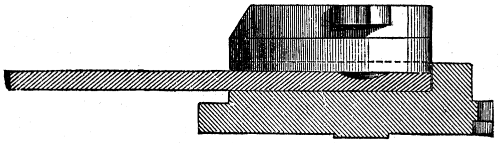


Fig. 3060.

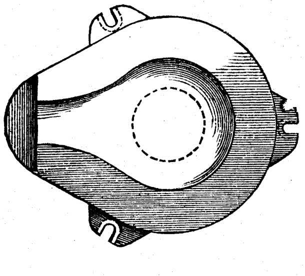


Fig. 3061.

The anvil O rests upon a separate foundation, in order to reduce the effect of concussion upon the frame. The drawing illustrates the arrangement. The bed is long, extending beyond the hammer on each side so as to give plenty of area, and the ends are left open for convenient access in case the anvil should settle and require re-adjustment.

Other forms of hammers having the same general principles of construction are as follows:—

Fig. 3057 represents a double frame hammer, the weight of the hammer being supplemented by steam pressure. The spiral springs shown beneath the cylinder are to prevent the hammer from striking the cylinder and causing breakage from careless handling by the operator. The valve gear is arranged for operation either automatically or by hand.

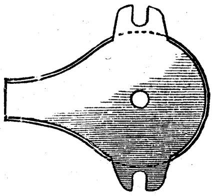
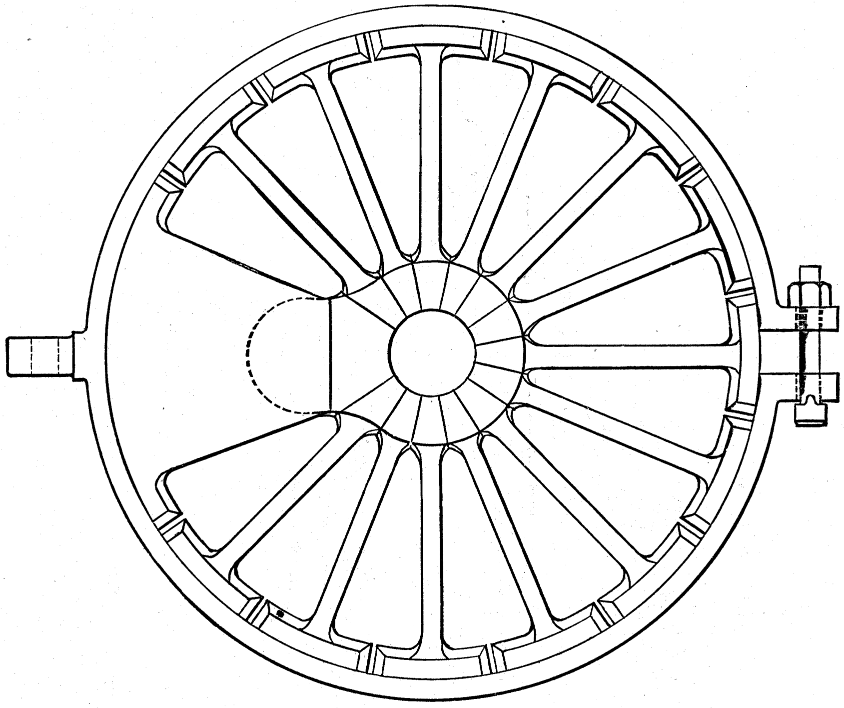


Fig. 3062.

Fig. 3058 represents a double frame steam drop hammer for stamping work out in formers or dies. The frames are bolted to the anvil base and the ram for the top die is guided by vertical slides on the inner face of the frame. Shoes are provided, whereby the wear of the ram and of the slides may be taken up, and the upper die kept properly matched with the lower one.



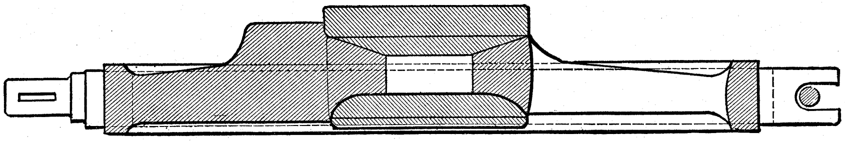


Fig. 3063.

Fig. 3059 represents a double frame steam drop hammer for locomotive and car axles and truck bars. The frame is spread at the base to admit wide work, and the upper surface of the base is provided with rollers supported by springs, these rollers supporting the work. The same may be operated automatically or by hand.

The hydraulic forging press at the Edgemore Iron Works of Wilmington, Delaware, consists of a piston operating in a cylinder, and having at its lower end a head guided by four cylindrical columns that secure the base plate, or anvil, as it may be termed, to the cylinder. To the above-mentioned head is secured the upper die, the lower one being secured to the base plate.

Figures from 3063 to 3066 represent a locomotive driving wheel ready to have its hub welded by hydraulic pressure. The spokes having been forged are held together by a band or hoop, as shown. The thickness of the hub or boss is made up by the rings or washers shown in the sectional view. The dies under which the welding is done are shown in Figs. 3064 and 3066.

Thin forgings are often made by compression between two rollers, the form of the surface of the rollers, or projections or depressions upon the same, pressing the forging to shape.

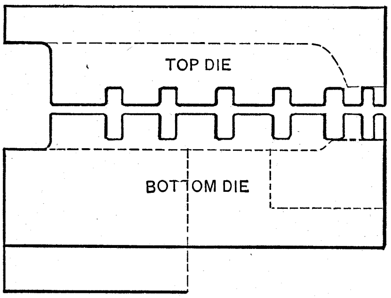


Fig. 3064.

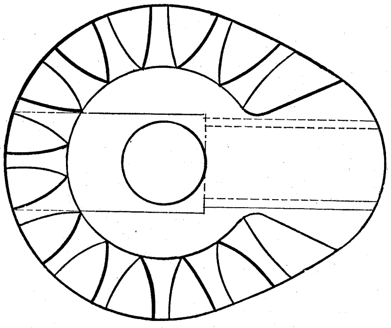


Fig. 3065

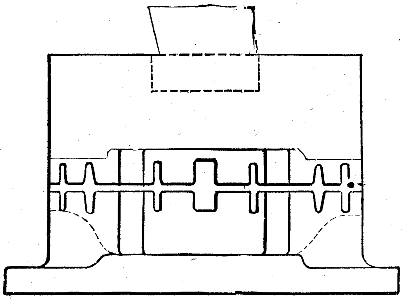


Fig. 3066.

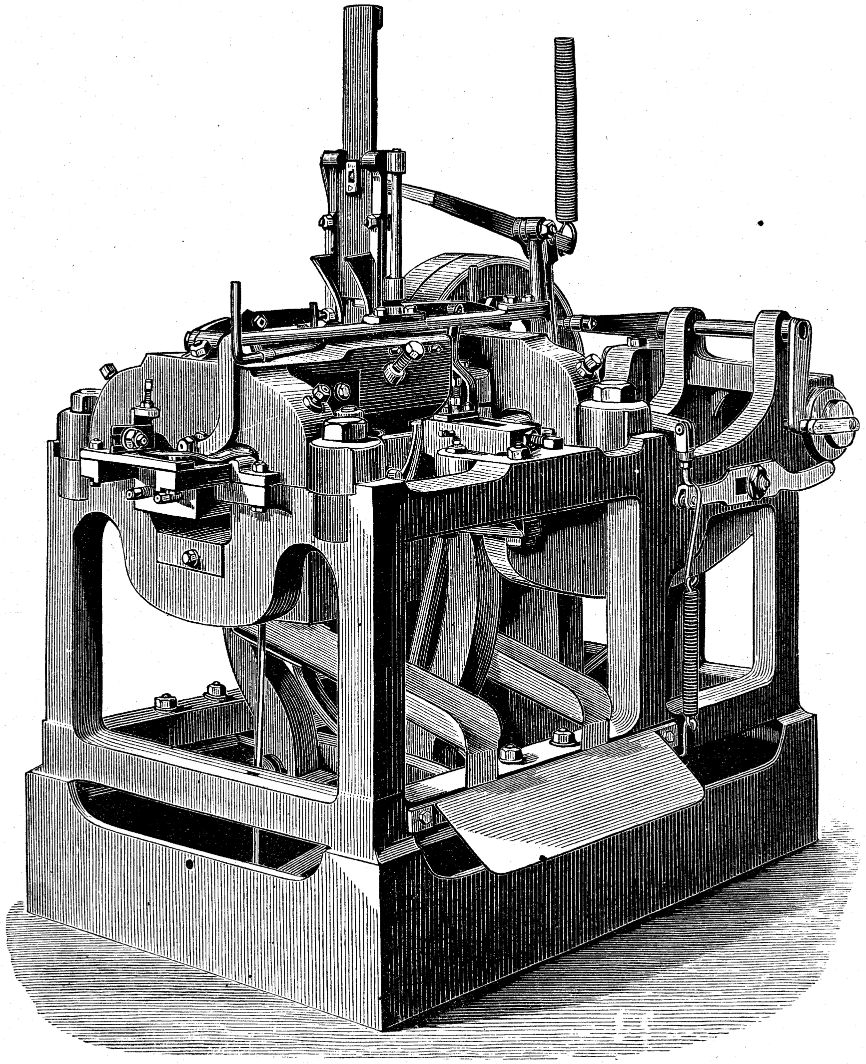


Fig. 3067.

Fig. 3060 represents a female die, and Fig. 3061 plan of another female die, and Fig. 3062 plan of male die used in connection with the press to forge the eye bars for the Brooklyn Bridge, five pieces each an inch thick being welded to the bar and pressed into shape at one operation.

Thus, in Fig. 3068 are shown a pair of rolls A B, P representing a piece of work, and C D two cam pieces fast upon the roll surfaces; S is a fixed stop.

Suppose the work to be pushed through the rolls and to rest against the stop S, then when the cams C D meet it they will pull it through and reduce its thickness by compression towards the workman. The rollers are obviously rotated by gear wheels; but they are sometimes provided with a certain amount of give or elasticity at their bearings, so that the reduction of work diameter may be obtained by several passages of the work through the rolls.

The shape of the cams, as C D, determines that of the work; thus in Fig. 3069 is shown a pair of rolls for forming knife blades, each cam having sunk in it a die equal in depth to half the thickness of the knife.

If the work is very short in comparison with the circumference of the rolls, two, three, or more cams may be arranged around the circumference, making an equal number of forgings or impressions, as the case may be, at each revolution of the rolls.

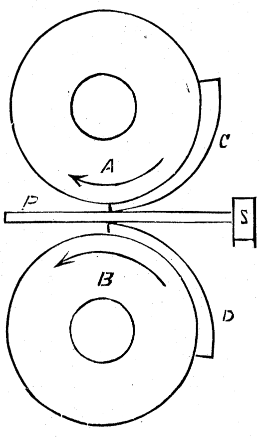


Fig. 3068.

In Fig. 3067 is shown a nail-forging machine for producing, from strip iron, nails similar to hand-made, at rates varying from two to three hundred per minute, and lengths of from six to one inch, two nails being completed at each revolution of the driving shaft of the machine. The framing consists chiefly of a main casting, to which are fixed an upper frame, carriages for the driving shaft, and other details. The principal moving part is a heavy steel slide, deriving its motion from a crank pin with adjustable throw; this slide carries two shears, two gripping dies, and sundry indispensable appendages, to some of which it imparts motions for guiding the nails between the stages of cutting off and finishing.

The successive operations by which each nail is perfected are as follows:—

A piece of iron about six inches long, and of a width and thickness respectively of the finished nail, is inserted at a red heat to the feeder of the machine; a narrow strip is immediately cut off the lower side of the heated iron, and by the motion of the steel slide is carried to and pressed against a fixed die; while in this position another die rises at right angles and presses the partially formed nail against another fixed die. Thus the headless nail is firmly held on its four sides, and while in this position a lever, moved by a cam, and carrying a suitable tool, advances and forms the head, thus completing the nail. The return motion of the steel slide releases the nail, leaving it free to fall, but as its weight is not sufficient to insure this happening, a "knocker off" is provided, which at the right moment forcibly ejects the nail by way of a guiding shoot into a receptacle placed outside the machine. It is to be noted that the tools for shearing and gripping, and which have to be changed with each different size of nail, are made of a special mixture of cast iron. They are thus easy of preparation and renewal, while at the same time answering their intended purpose as well as or better than the finest cast steel, at less than half the cost. The whole of the machine is carried upon an open-top cast-iron water tank, serving as a receptacle for the tongs and tools heated in withdrawing the iron from the furnace.

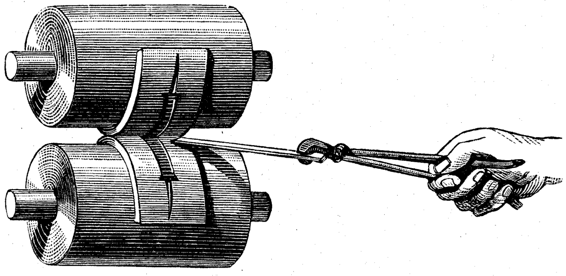


Fig. 3069

Figs. 3070 and 3071 represent a machine for forging threads on rods and screws. As forgings, the threads are beautifully clean, and for the general work of coach screws much stronger than the cut threads. A perspective view of the machine is given in Fig. 3070, and a vertical of it shown in Fig. 3071. In the former figure, *a b* are the screw dies. The rod or bolt to be threaded is placed upon the lower die *b*, and fed forward while screwing it. The upper die is mounted on a slide *c*, which is actuated in the downward direction by an eccentric *e* on the main shaft and the toggle-bar *d*, the upward motion being obtained by an internal spiral spring *f*. The lower die *b* is carried in a slide *g*, and is adjusted at the proper distance from the upper die by means of wedge *h*, and the inclined plate *i*, beneath the slide *g*. The wedge *h* is operated by a pedal *l*, and secured in its highest position by a bolt *j*, received in a mortice made in the plate *i*, the bolt being operated by a pedal *m*. In order to release the wedge and return it to its lowest position, the bolt is raised by pressing down the pedal *m*, whereby the wedge is free to be returned by the counterweights *k*, in connection with pedal *l*; slide *g*, carrying the lower die, then descends by its own gravity, and so separates the two dies sufficiently to allow of the removal of the screw-bolt or rod therefrom. To compensate for the wear of the dies, and admit of their adjustment, another wedge *o*, with screw adjustment, is disposed below the inclined plate *i*.

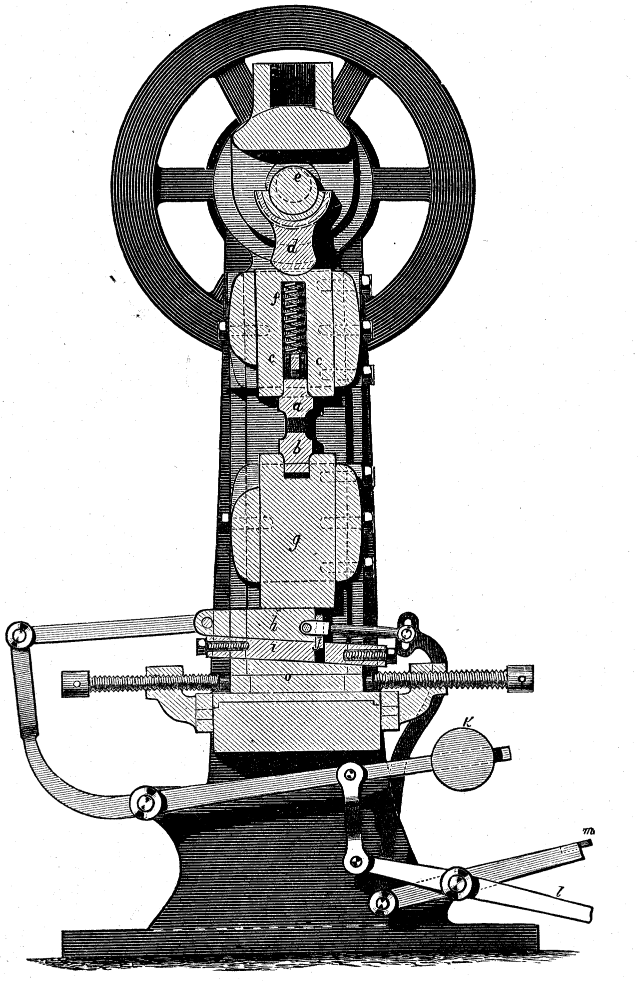


Fig. 3070.

Fig. 3072 represents a lag screw forged by the machine.

Fig. 3073 represents a finishing machine for horseshoes. The

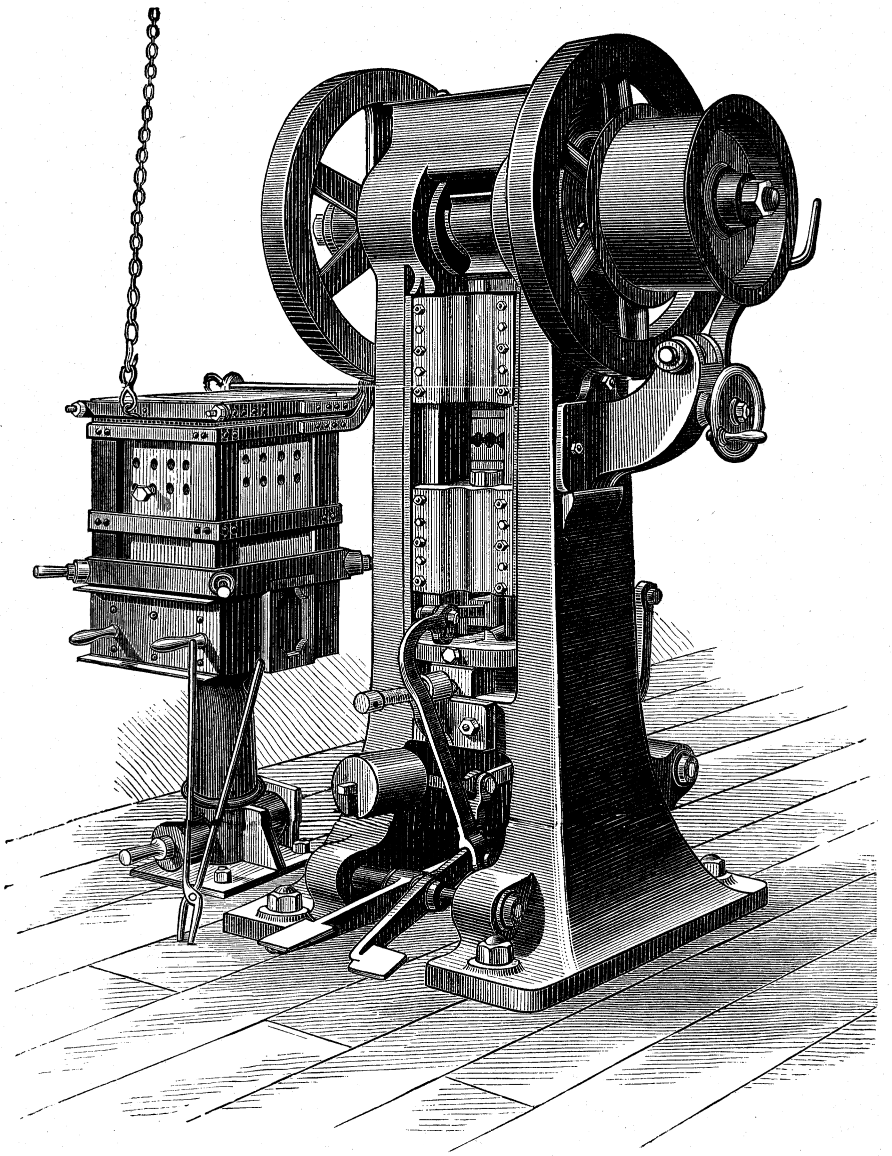


Fig. 3071.

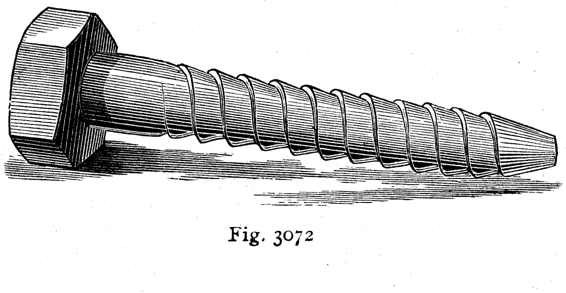


Fig. 3072

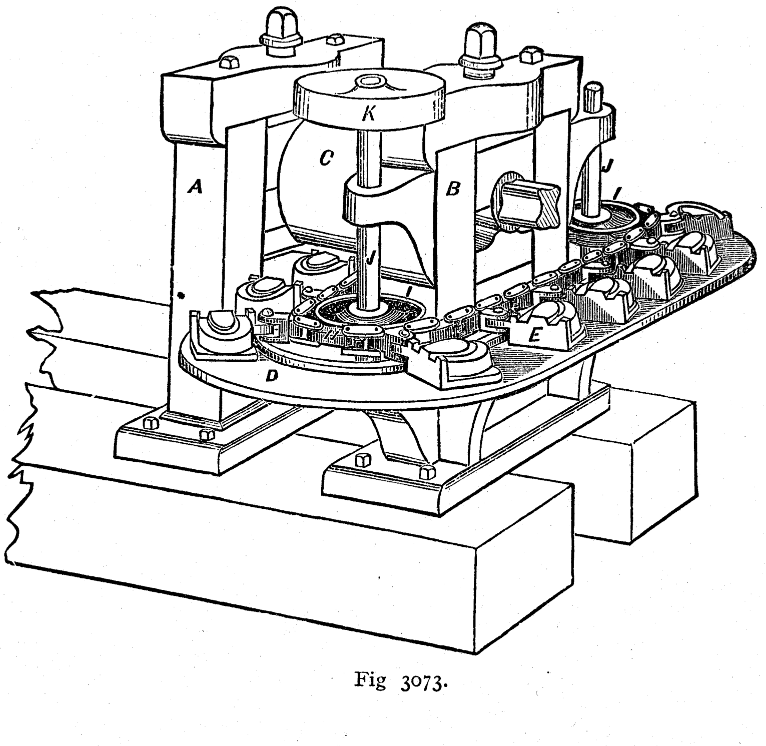


Fig 3073.

bars of iron are rolled with the creases (for the nail heads of the finished shoe) in them. The blanks for the shoes are then cut to length and bent, and the nail holes punched. The shoes then pass to a machine, Fig. 3073, which consists of a frame A B, carrying the roll C, above the table D, and a second roll, not shown in the cut, but being directly beneath C, there being between these two rolls sufficient space to let the dies (which press the shoes into shape) pass.

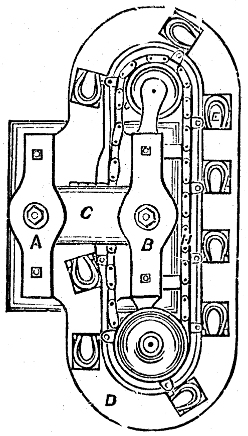
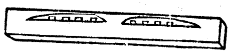


Fig. 3074.

These dies rest upon the table D, and are carried around upon it in a direction from left to right of the chain H, to the links of which the dies are attached. This chain is operated by the vertical shaft J, having a pulley for belt power at K.



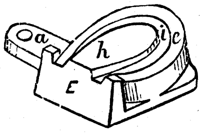


Fig. 3075.

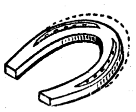


Fig. 3076.

As each die approaches the rollers, a shoe (cut to length, creased, and punched as already described) is placed on it, and on reaching the rolls the shoe is pressed into form on the die by the rolls, the bottom roll serving as a rolling bed so as to reduce the friction that would be due to a sliding motion on the bottom of the die. The top roll C, which presses the shoe into the die is driven by power.

A plan view of the machine is shown in Fig. 3074, and a view showing the shape of the dies is given in Fig. 3075.

The surface *h* forms the frog. To give the required concavity to the toe and sides of the shoe, the surface *i* is made convex, and tapered or inclined towards *h*. The tread *e* is deepest at the heel on both sides, and highest at the toe. It is obvious that by suitably shaping the surfaces *h*, *i*, and *e*, any required form may be given to the shoe. Fig. 3076 represents a shoe creased, punched, and bent ready to be passed to the machine.

Fig. 3077 represents a circular saw for cutting off hot iron; A is the frame of the machine, the arm B pivoted at C carrying the saw D; F is a spring bolted to the frame and serving to hold the saw in the position shown. The work E is gripped by the lever L, which is pushed over by hand. The lever L is adjusted to suit different sizes of work by the screw G, which raises or lowers the piece H, to which L is pivoted. The saw is brought into contact with the work, and fed to it by applying the foot to the lever or arm B at I, the screw J being made to contact with the foot of the machine by the time the saw has passed through the work, thus preventing the saw from moving too far forward after passing through the work.

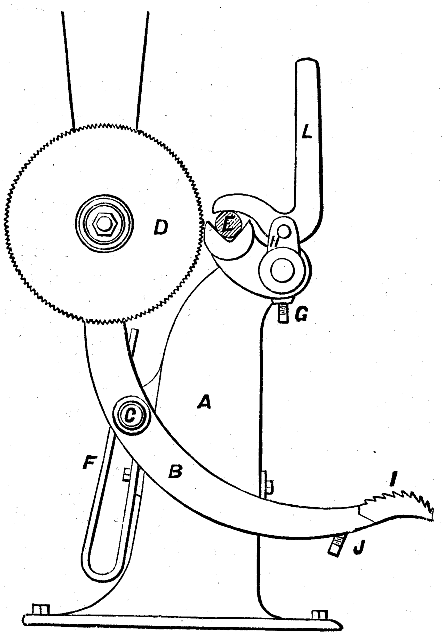


Fig. 3077.