plate, and the superimposing of one set of moulds upon another. The general arrangement in plan and elevation is shown in figs. 44 and 45, in which there are only two sets of moulds, one over the other, although in some cases they are cast three high. Between each bottom and top mould is inserted a division brick, as shown in figs. 46 and 47, which allows the steel to flow from the bottom to the top mould without chilling, and the top set of moulds has a vent brick inserted in each (fig. 48.) The top ingots are thus connected by a short neck to each of the bottom ingots; these necks, however, part very readily when the moulds are stripped off and the ingots lifted up, as they are very short and contract less than the ingot, owing to their being kept hot by the bricks.

As many as 120 ingots have frequently been cast by this system from one charge of steel, and it was the regular custom for some years to cast 72 ingots from 10 tons of metal at the Weardale Steel Co. The usual size of ingots cast is from 4 to 7 inches square, or 6-inch by 5-inch slabs. Some years ago the author saw the system at work near Birmingham, and, so far as could be seen, the results were very satisfactory. Provided that special conditions render it necessary to cast small ingots, this method of casting is as good as any that has been devised. The cost of making such ingots must, however, always be heavy, owing to the labour of stripping, cost of runner bricks and production of wasters, resulting from some of the moulds not completely filling, especially if the metal is rather cold. It is therefore only applicable to small works where they have not the necessary plant to cog down large ingots, and where special considerations render it essential that they should make their own steel rather than purchase billets, &c., from large steel makers. It need hardly be pointed out that in all systems for casting small ingots in groups, it is essential that the metal should be teemed hot, otherwise very few of the moulds will fill.

Bottom Casting *versus* Top Casting.—The question of bottom *versus* top casting is one that has been much discussed, and generally it may be said that when small ingots are required, bottom casting is resorted to, but that large ingots are more usually cast from the top. The general opinion is that sounder ingots are obtained by using closed-top moulds and casting from the bottom, and when specially sound material is required for forgings, &c., even large ingots are often cast in this way. In the case of small ingots it would be impossible to cast them all separately, especially when dealing with dead soft steel, as the metal would set in the ladle round the nozzle before they could be all filled. One of the great disadvantages of bottom casting is the large amount of runner scrap made, as each runner brick is full of metal, and this has to be re-melted as scrap. Another serious matter is the extra labour in removing the ingots from the mould and breaking off the steel runners from each ingot. To overcome these difficulties, at the new steel plant of the Hamilton Steel and Iron Co. in the United States, the bottom runner is replaced by a horizontal ingot or big runner, so that all loss from runner scrap is done away with. The vertical ingot moulds are separated from the horizontal runner by bricks, 1 inch thick, which are let into the bottom casting plate, and these bricks have holes under each mould to allow the steel to come up from below.

When the vertical ingot moulds are stripped off the horizontal ingot, the short necks of steel connecting these ingots to the horizontal one are easily broken, and the moulds are at once placed on another bottom-plate resting on a car ready for another cast. The ingots are 6 inches square and 5½ feet long, and are cast in groups of 22, three sets being required to take the furnace charge. The horizontal ingots are said to be perfectly sound and to give excellent results in the mill. The bottom-plates carrying each group of ingots rest on cars and are run under the nozzle of the ladle, although in the particular works mentioned, a fore hearth or ladle attached to the tilting furnace is used. This will be found described under the heading of the Wellman tilting furnace.

Ingot Cranes.—In the older works the ingots are all cast in pits, known as casting pits, of such a depth that the top of the mould stands a

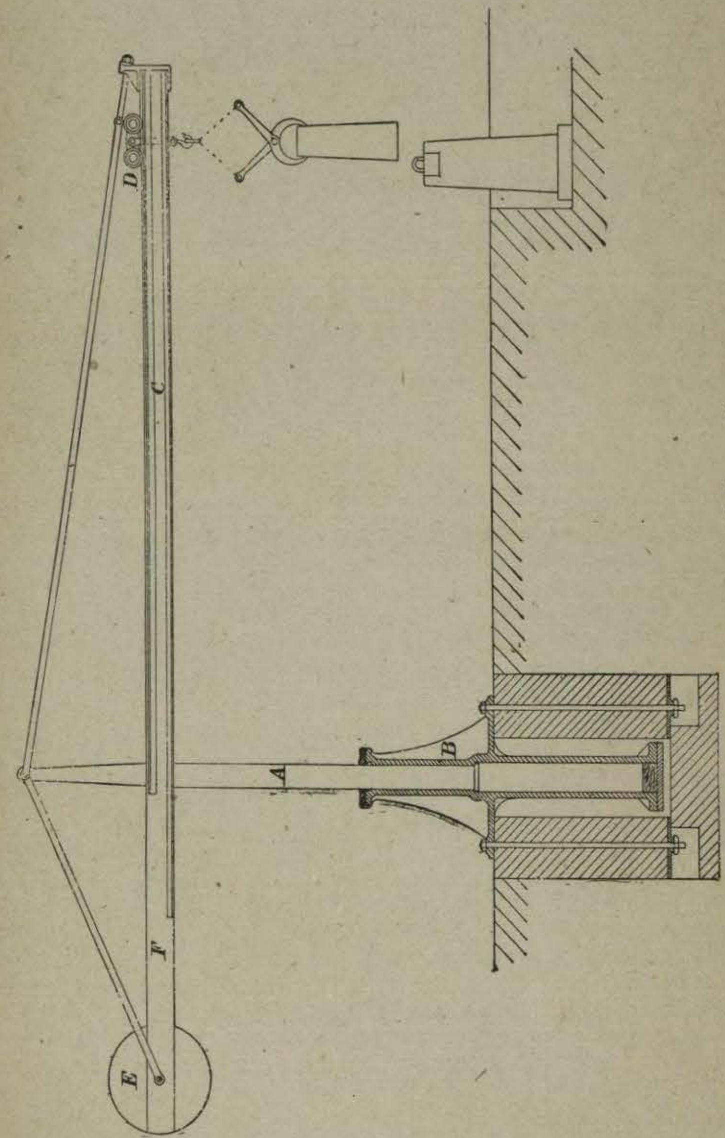


Fig. 49.—Bottom-supported Ingot Crane.

little above the ground level. After standing a few moments to enable the fluid metal to set, the hot moulds are lifted off the ingots by a crane by the wrought-iron loops which are cast into the moulds, and to which the

crane hooks are attached. Two or three cranes are usually provided for each pit, and are generally of the type known as "ingot cranes," first devised by Sir Henry Bessemer; cranes much more rapid in action than any existing when his process was introduced became a necessity, if the output, even of those days, was to be removed with sufficient rapidity to prevent the melting department standing idle while the pit was being cleared.

The ingot crane (fig. 49) consists of a ram, A, standing vertically in a cylinder, B, into which it fits freely, capable of being raised by admitting to the cylinder water under a pressure most frequently of 400 to 800 lbs. per square inch, whereby the ram is raised to the height required, and, the admission valve being closed, the incompressibility of the water keeps the ram perfectly steady. By opening a second valve the water can be run out, and the ram descends at any speed desired. From the ram projects a horizontal arm or jib, C, on which a small carriage, D, provided with a hook, can travel to and fro, a weight, E, on an arm, F, projecting from the opposite

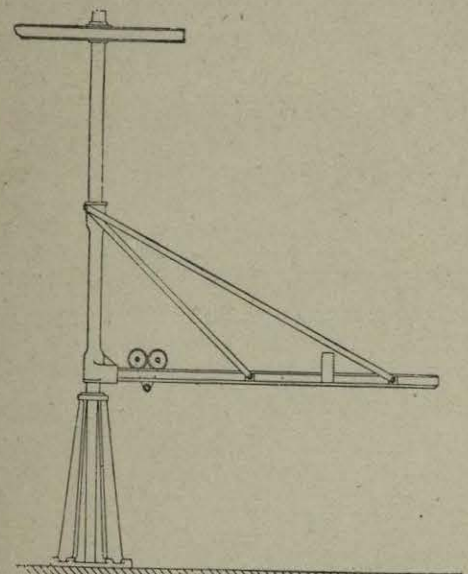


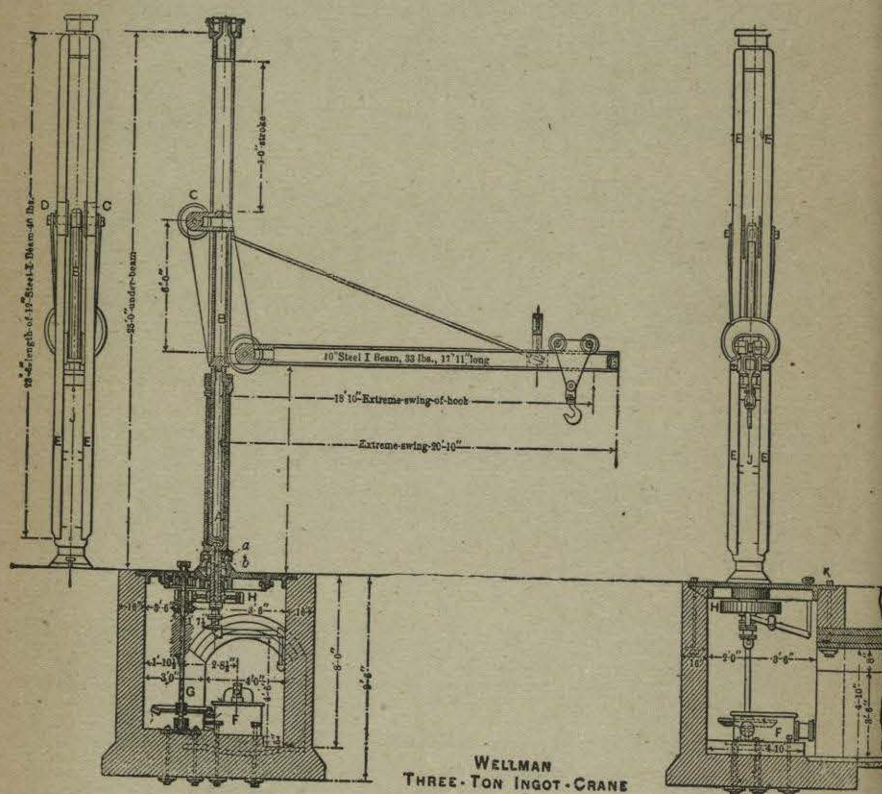
Fig. 50.—Top-supported Ingot Crane.

side of the ram, partially balances the load. The ram, being supported on the water, turns very easily, and a workman, provided with a hooked rod, can run the load backwards and forwards along the jib, or swing the whole crane round with loads of 1 or $1\frac{1}{2}$ tons. For weights greater than this some method of travelling the load along the jib is usually provided; either a hand purchase or a small direct-acting cylinder. In England the only support for the ram is usually the cylinder below the jib, but in America the ram is carried up into the roof (fig. 50), where a second support is provided, the crane being then known as a top-supported crane.

Fig. 51 shows a top-supported Wellman crane, with details of foundation, &c.

The ordinary ingot crane consumes a vast quantity of water compared with the useful work done by it, which is only about one-third to one-sixth of the total energy expended, and a large number of devices have been employed in view of overcoming this defect; but the extreme simplicity of Bessemer's original design, and its rapidity of working, have secured the adoption and retention of this type in the great majority of Bessemer steel works all over the world.

Stripping the Ingots.—When the ingot mould is raised by the crane, the weight of the ingot is frequently sufficient to cause it to drop out, and if the moulds are in good condition the latter will "strip" from the ingots easily, and leave them standing in the pit. This, however, is not always the case, especially when the moulds have become somewhat worn, and then it is often necessary to strike the mould heavily several times with a sledge, while it is suspended from the crane, before the ingot will fall out.



WELLMAN THREE-TON INGOT-CRANE

Fig. 51.

When the moulds are in bad condition the amount of sledging may be very considerable, and the cost of labour and the delay are serious matters. To obviate these difficulties in modern works where casting on cars has not been adopted, the ingot moulds, with the ingots in them, are hoisted by the ingot crane upon a bogey, and taken away to a hydraulic ram, known as a stripper, which rapidly removes the ingots from the moulds, and places the latter on another bogey to be returned to the Bessemer shop. In an old-fashioned Bessemer shop, where all the ingots are stripped at the pit,

the heat from the masses of hot metal is very trying to the men, and largely interferes with their work, and one of the advantages of the ingot stripper is that it can be any reasonable distance from the Bessemer shop, and consequently the stripping does not interfere with the work at the casting pit.

The "Ingot Stripper" is a most efficient machine, not only saving considerable amount of labour, but also all damage to the moulds from sledging to remove the ingots. The Evans ingot stripper, which has been giving most satisfactory results at the works of Messrs. Crawshay Bros., Cyfarthfa, South Wales, since 1898, is designed to strip two ingots at a time, and is illustrated in figs. 52, 53, and 54, which, together with the description, are taken from the *Iron and Coal Trades Review*. Both long and short ingots can be stripped with equal ease, the shortest piece on which the stripper will exert its full force of 75 tons being 1 foot 6 inches. The height of this stripper is 34 feet 9 inches, which is considerably less than that of many others. The reduction in height is obtained by the use of three comparatively short rams, instead of one long one (which is used in some other strippers), whereby the long stroke of this one ram is converted into two comparatively short strokes, giving the machine a great increase in stability, &c. When a stripper is used, it is necessary to have lugs cast on the outside of the mould, as shown in fig. 52, instead of loops as shown in figs. 38 to 41, in the old form of moulds intended for hand-stripping.

Of the three stripping rams shown in the figures, the two outside ones (fig. 52), pull the mould up, while the centre ram holds the ingot down. The centre ram uses no pressure water, but is kept immovable at the top of the ingot by means of non-pressure water, which flows by gravity into the barrel of the ram, and being locked therein by an automatic operating valve, prevents the ram from rising. This non-pressure water is again liberated automatically when the stripping is complete by means of the above mentioned valve.

The consumption of pressure water is also greatly economised by differentiating the diameters of the side rams, a large diameter being used for the initial pull upon the mould, and a smaller diameter for the easier work of raising the mould clear of the ingot.

The working of the machine is made exceedingly simple for the operator, since all he has to do is to take the pressure off, thus allowing the three rams to descend, the centre ram stopping of itself upon the top of the ingot and the two side rams continuing to descend until the stirrups engage the lugs upon the mould, when he puts the pressure on, raises the mould, and so completes the operation.

The machine consists of the following parts :—

1. The gantry, A (fig 52), spanning the two roads B and C, B being the road upon which the bogies carrying the full moulds are brought up, and C being the road upon which the bogies carrying the empty moulds are returned to the casting shop.

2. The carriage, D, upon which are the two sets of stripping cylinders. This carriage is moved backward or forward along the gantry by means of the traversing cylinders, E, with their rams, F.

The drawings represent the machine as designed to strip two ingots at one time; there are, therefore, two sets of stripping cylinders with their rams, each set capable of being worked either independently or together.

Each set of stripping cylinders comprises :—

1. Two outside differential rams, G, with their top barrels, H, and bottom barrels, I; each of these outside rams has a hole, J, in its centre, through which the pressure is conveyed from the bottom barrel of large diameter to

the top barrel of small diameter. When the pressure is put into the bottom barrels, I, the two rams, G, together with their top barrels, are raised through the stroke allowed by the bottom barrels; the pressure water then finds its way through the holes, J, in the side rams, G, and acts upon the tops of these rams, raising the top barrels through the stroke allowed them.

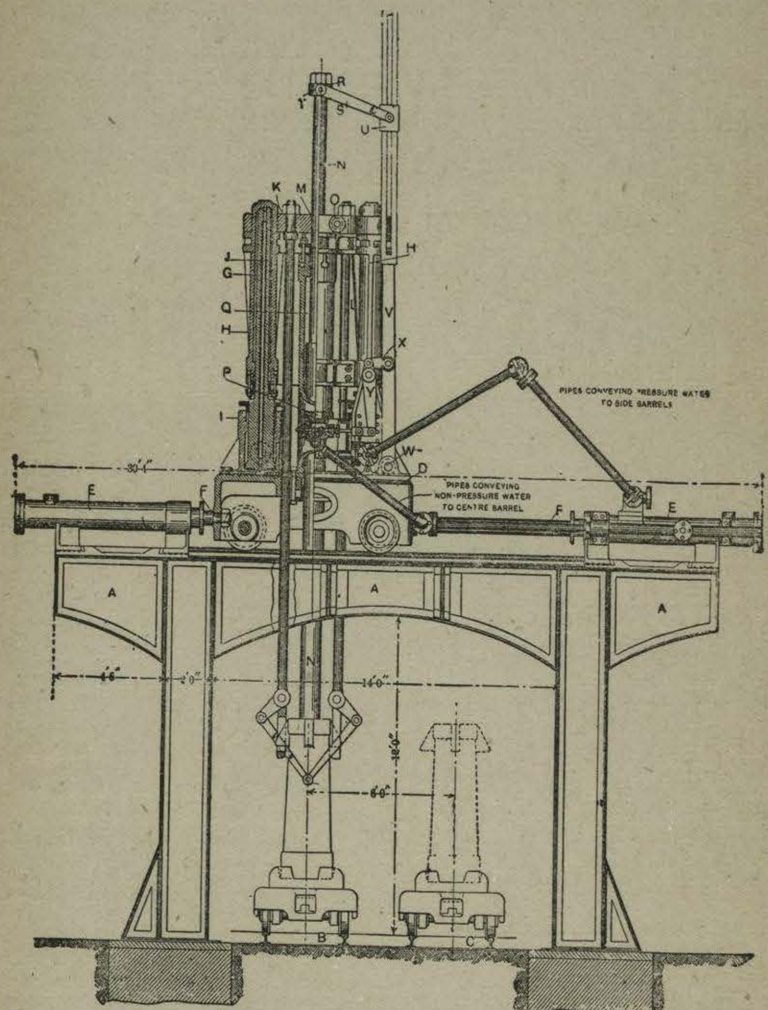


Fig. 52.—Evans Ingot Stripper—A, Gantry; B, truck with full ingot moulds; C, truck with empty moulds; D, carriage carrying stripping cylinders; E and F, hydraulic cylinders and rams for moving D; G, two outside differential rams; H and I, top and bottom barrels for rams G; J, central hole in ram G; K, crosshead; L, slings connected to K to engage lugs on ingot moulds; M, hole in crosshead for N to pass through; N, centre ram; O, friction roller; P, valve controlling supply of non-pressure water to centre barrel, Q; Q, barrel for centre ram, N; R, boss on top centre ram; S, lever; T, heel on level; U, block embracing lever V; V, a lever pivoted at W; X, pivot connecting levers V and Y.

2. A strong crosshead, K, which rests upon the tops of the upper barrels of the side rams, and to which are attached the slings, L, for engaging the lugs upon the ingot moulds. In this crosshead, midway between the two

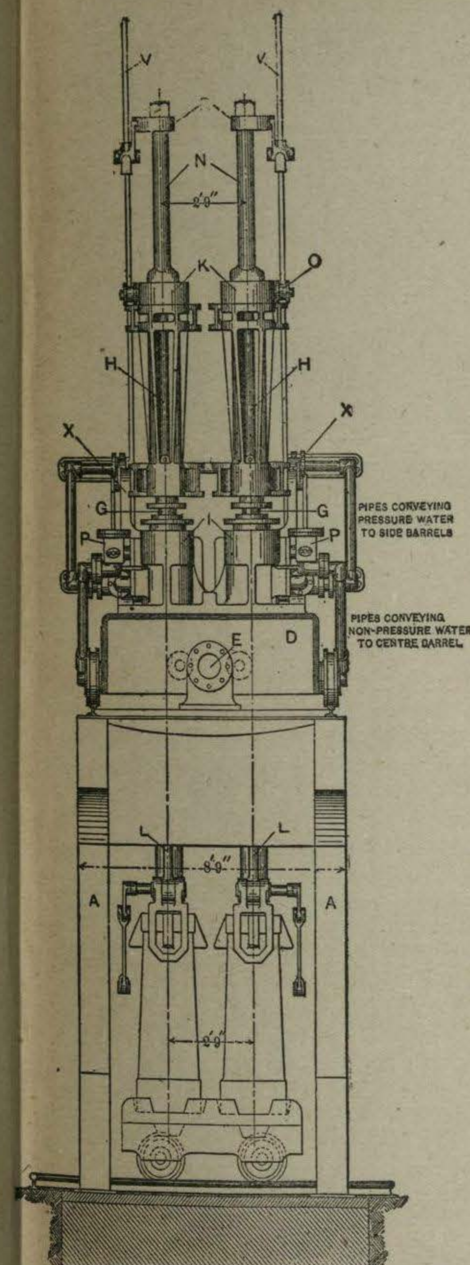


Fig. 53.—Side Elevation.

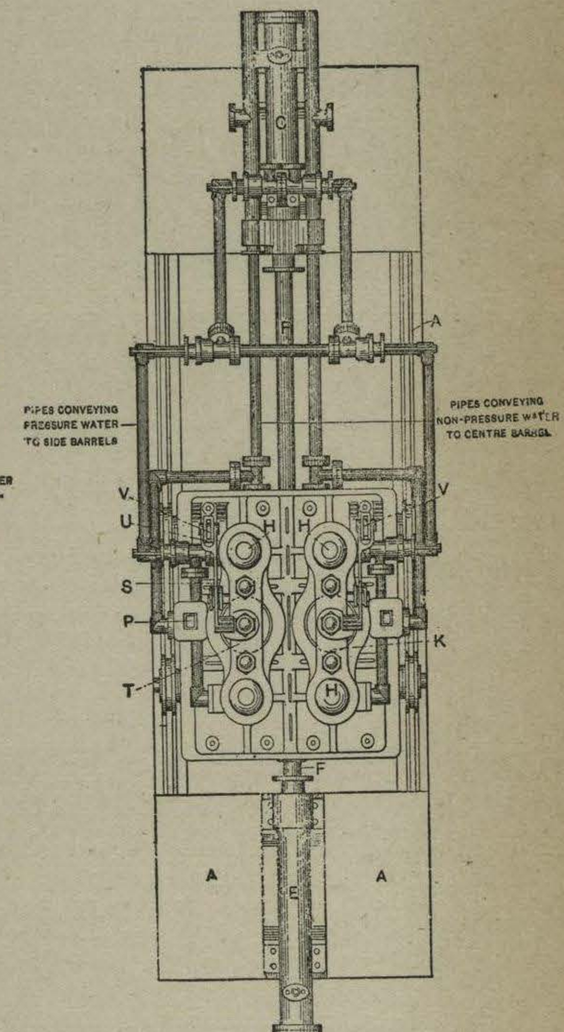


Fig. 54.—Evans Ingot Stripper—Plan.

side rams, is a hole, M, through which the extension of the centre ram, N, passes; and fixed to the side of the crosshead is a friction roller, O, which operates the automatic gear for opening and shutting the valve, P, controlling the supply of non-pressure water to the centre barrel, Q.

3. The centre ram, N, with its barrel, Q, which merely acts as a stopper, preventing the ingot from rising when the mould is being pulled up. The top end of this ram is of smaller diameter than the bottom, and is furnished with a boss, R, and it is by means of this boss that the centre ram is moved, as the boss rests upon the crosshead whenever the centre ram is not upon an ingot. To the top of the centre ram is attached the lever, S, which is operated by the friction roller, O, and which operates in its turn the levers for working the automatic valve controlling the supply of non-pressure water to the centre barrel.

4. The automatic gear for operating the valve controlling the supply of non-pressure water to the centre barrel, consisting of the lever, S, which is attached to the boss, R. This lever has a heel, T, which engages a projection upon the boss, and thus its downward movement is restricted. Upon the other end of the lever is a side block, U, embracing the long lever, V, which is pivoted at W. This side block moves up and down upon the lever, and by means of its weight moves the lever in towards the centre ram, and so locks in the non-pressure water. This lever is connected at X to another lever, Y, which is connected direct to the stock of the valve, P. The object of this lever, Y, is merely to multiply the stroke of the lever, V, so as to insure sufficient stroke for the valve, P.

Assuming that there is a bogie containing a full mould under the stripper, upon the road, B, and that the stripping rams are raised ready for lowering upon the ingot, and also that there is an empty bogie upon the road, C, for receiving the moulds when stripped off the ingots; then, the rams being in the same position, the crosshead, K, will be supporting the centre ram, N, by means of its boss, and consequently the friction roller, O, will be up against the lever, S, holding the latter in a horizontal position. When this is the case, the other levers—viz., V and Y—will occupy such positions as to keep the valve, P, open, so that there is free access for the non-pressure water into the barrel of the centre ram.

The operator now takes the pressure from beneath the two side rams, G, causing these rams, together with their top barrels, the crosshead and the centre ram, to descend together.

The whole of the above descend together until the centre ram comes in contact with the top of the ingot—which is either a short piece or full-sized—when the centre ram stops; but the two side rams, together with their top barrels and the crosshead, continue to descend, and in descending the friction roller, O, leaves the lever, S, which drops by means of the weight of the side block, U, into the position shown in the drawing. This movement of the lever, S, draws in the long lever, V, and so shuts the valve, P, so that the non-pressure water is now locked in the centre barrel. The side rams continue to descend until they reach the bottom of their lower barrels, but the top barrels still descend until the stirrups on the slings engage the lugs on the ingot moulds.

The operator now puts the pressure under the side rams, which, together with their top barrels and the crosshead, K, rise, and so strip the mould off the ingot, as the centre ram is unable to rise owing to the non-pressure water being locked in its barrel. The side rams, with their top barrels, together with the crosshead, continue to rise until the friction roller again comes in contact with the lever, S, and raising it again into a horizontal position, pushes out the long lever, V, and so unlocks the water from the

centre cylinder by opening the valve, P. The centre ram, N, is now able, by means of its boss, to be raised by the crosshead, K, and thus the crosshead and centre ram now rise together; the crosshead, by means of the slings, carrying the moulds, which have been stripped.

The pressure being still under the side rams, the operator now moves the carriage, D, above the road, C, by means of the traversing cylinders, E,

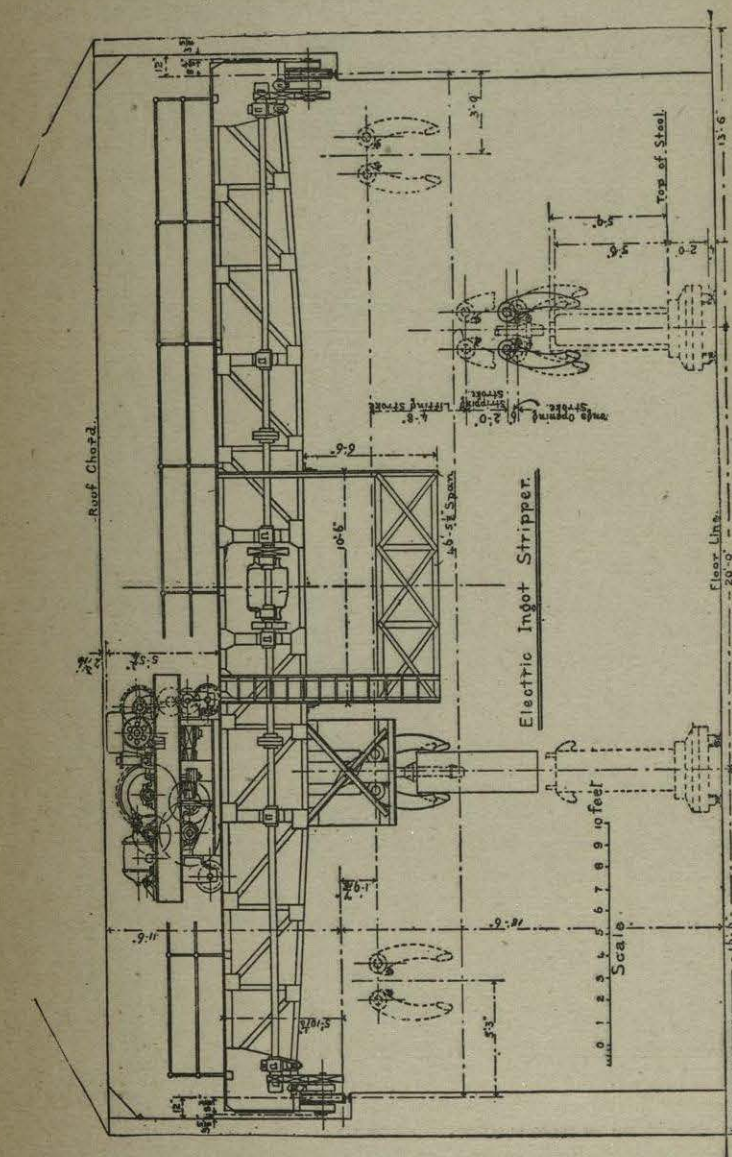


Fig. 55.—Wellman Electric Ingot Stripper.

carrying with it the stripping cylinders and also the moulds. When the empty moulds are over the bogie, which is ready to receive them, the operator takes the pressure from under the side rams, allowing the moulds to be lowered on to the above-mentioned bogie; the stirrups on the slings automatically disengaging themselves from the lugs on the ingot moulds by means of a simple arrangement of a chain and weights not shown on the drawings. The operator now moves the carriage, D, carrying the stripping cylinders, back above the road, B, in readiness for the next ingots brought up, thus completing the operation.

One of the early forms of electric strippers designed by the Wellman-Seaver Engineering Company is shown in fig. 55. It consists of an ordinary electric travelling crane with the operating cage suspended from the middle of one of the main girders, and special appliances for seizing the ingot mould and removing it from the ingot. The electric traveller is fitted with three motors—one (25 H.P.) fixed outside one of the two main girders which carry the trolley for effecting the longitudinal traverse of the whole machine; one (5 H.P.) for cross traverse of the trolley, and another (25 H.P.) for driving the hoisting and lowering gear, the

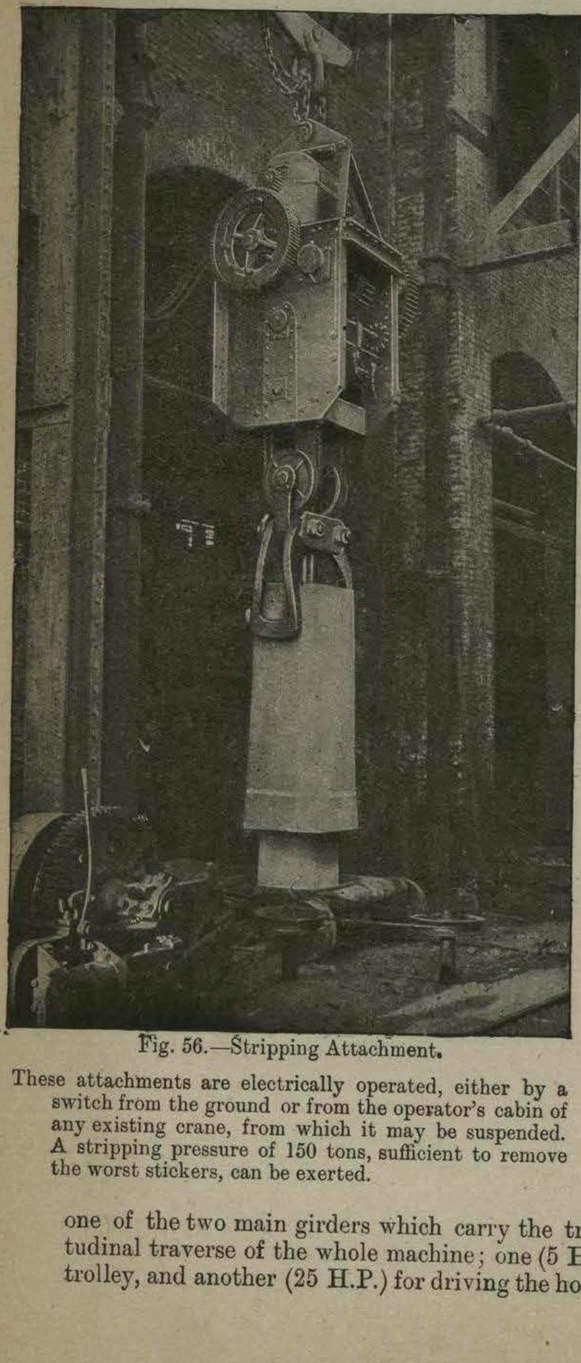


Fig. 56.—Stripping Attachment.

These attachments are electrically operated, either by a switch from the ground or from the operator's cabin of any existing crane, from which it may be suspended. A stripping pressure of 150 tons, sufficient to remove the worst stickers, can be exerted.

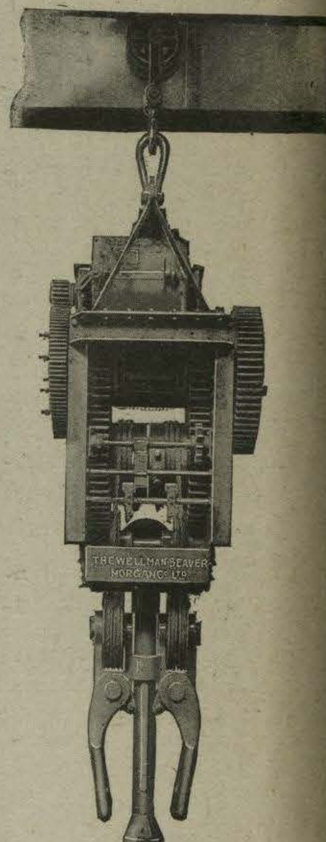


Fig. 57. — Sketch showing Details of Ingot Stripper Attachment.

last two being of course on the trolley. Two more motors, also on the trolley, furnish the power required to operate the extractor. One (3½ H.P.) is used to rotate the vertical sleeve carrying the extractors about its axis, thus enabling the machine to pick up an ingot mould which has not been placed square underneath it; the other (100 H.P.) furnishes the power necessary for the separation of the mould from the ingot In this last operation the electric stripper possesses an economic advantage over the hydraulic stripper, because in the former case the energy expended is proportional in each case to the resistance to be overcome in starting the mould from the ingot, whereas in the hydraulic machine an equal quantity of water at a constant pressure is consumed, whether dealing with a "sticker" or with an ingot that drops out of its mould without the application of any appreciable force. The hoisting motor is fitted with a powerful automatic electric brake, which stops the gear dead in any position when for any reason the current is cut off. All other motors which are liable to over-run, or which are not stable in any position, are fitted with electrical or mechanical friction brakes.

Fig. 58.—Guided Ingot Stripper.

The stripping gear is similar to the stripping attachment (fig. 57), but guided. The gear is carried on a trolley on the main girders, which traverses across similar to an ordinary overhead crane. All the motions—stripping, hoisting, cross traverse, and long travelling—are under the complete control of one man.

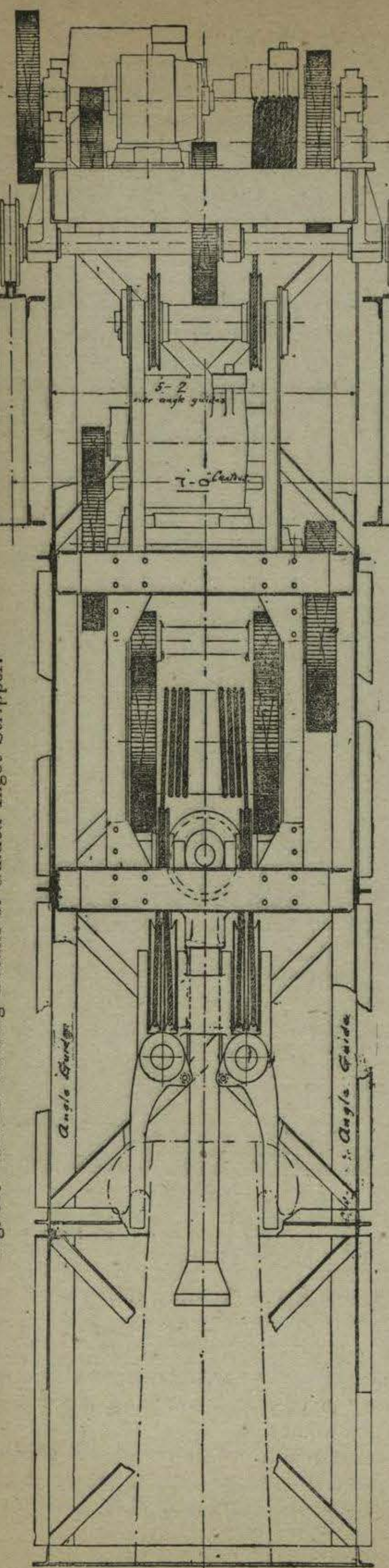


Fig. 59.—Sketch showing Details of Guided Ingot Stripper.

For works where the output is small and a separate stripper and ingot charging crane cannot be kept fully employed, a combined stripper and charger, for use with vertical ingot reheating furnaces has been designed, with what is known as a stripping attachment. This latter is installed at the works of the Soc. Siderurgica, Savona, Italy, and is illustrated in figs. 56 and 57; it can be suspended from any convenient position.

The latest form of Wellman-Seaver electric stripper is what is known as the guided ingot stripper, shown in figs. 58 and 59.

Stripping the Pit.—Whether a stripper is used or the ingots are stripped at the pit, a most important point is their rapid removal from the pit, and the substitution of empty moulds ready for the next charge. It is also essential to have ample facilities for repairing and re-stoppering, and when necessary the replacement of ladles by re-lined ladles. These operations can keep pace with rapid blowing only if ample crane power is provided; and ingot cranes should be arranged round the pit as close together as possible, just sufficient room being allowed for their respective jibs to swing clear of each other.

Generally one end of the pit, or in the case of a very large pit where two or three centre cranes serve four or more converters, each end of the pit is reserved for minor ladle repairs, such as removing slag, patching ladles, replacing nozzles, &c. Such an arrangement of cranes is shown in the plan of the North-Eastern Steel Co. (fig. 63), which may be taken as typical of the practice prevailing at works where pit casting is still maintained.

The actual re-lining is more

generally done in a separate shed, generally a part of, or near to, the converter bottom repairing shop, where a furnace is usually provided for drying ladles.

Arrangement of Bessemer Shop.—Having described the principal appliances used in Bessemer works, there now remains to be considered the

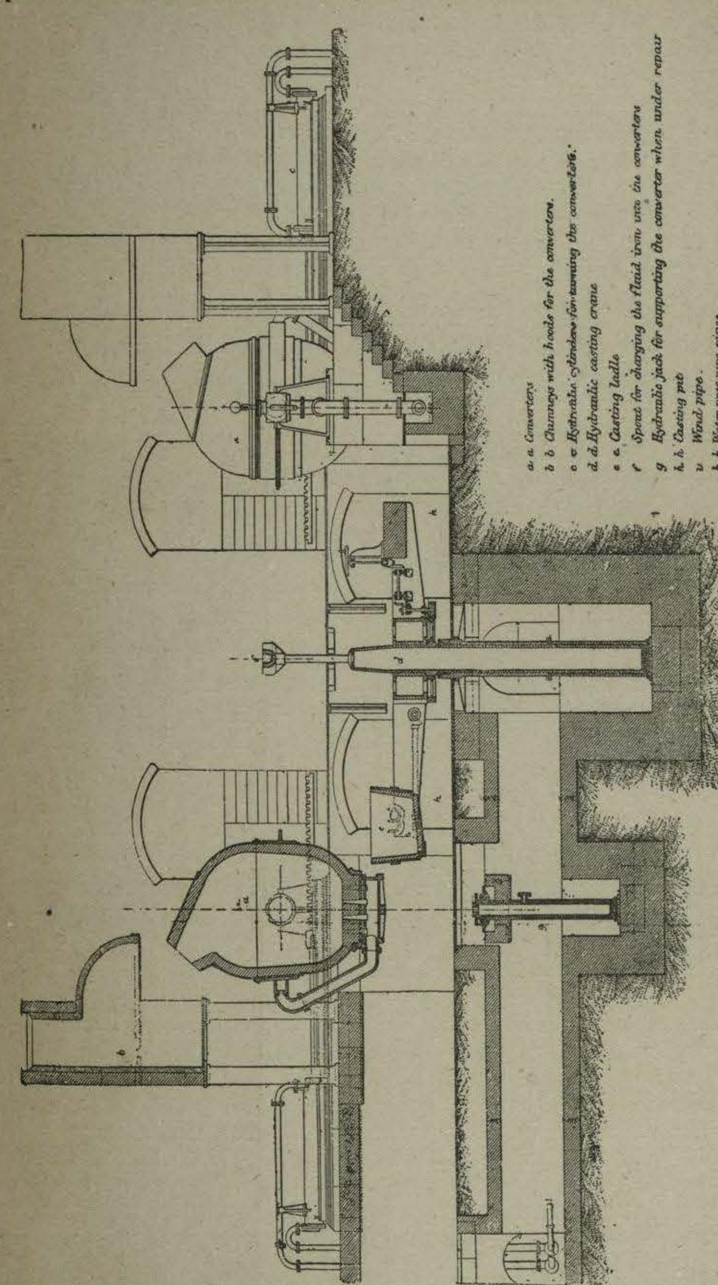


Fig. 60.—Bessemer Plant showing arrangement of Converters, Casting Ladle, and deep Casting Pit in early English Plants.

disposition of plant best suited for carrying out the various operations during the process of manufacture.

It is necessary that the operations should be conducted so that they in