same time. In starting this fire it will generally be necessary to light a pilot fire in the chimney to create a draught, and the furnace fire should be maintained for four or five days before the furnace doors are entirely closed, and gas from the producer put into the furnace. It is advisable also to dry all flues by means of fires near each manhole, previous to starting the fire in the furnace itself. Before turning the gas into the furnace, a clear bright fire should be made at each end of the hearth near the gas ports, and before opening the gas valve leading to the furnace, the producer gas should be allowed to pass for a considerable time through the flues, and out at the manhole *furthest* from the producers to sweep all the air out of the flues. After the gas has been passing for some time it should be tested by lighting at the manhole, and when it burns steadily for some minutes without going out, the manhole may be luted up, and gas passed into the furnace, care being taken that the air inlet valves are closed, and kept so. Sometimes a slight explosion occurs when the gas first enters the furnace, which may possibly extinguish the fires inside, in which case the gas must be shut off and the fires re-lit, the producer gas being allowed to burn at the manhole meanwhile. Instead of testing the gas by burning at the manhole, when it is found to burn well at the producer, if all the valves be left open to the stack, and the gas be drawn through the flues for from 10 to 15 minutes, and allowed to escape at the chimney, this will sweep all air out of the flues, and it will then be quite safe to turn the gas into the furnace. The gas should be allowed to burn in the furnace for a few hours with air admitted through the furnace *doors*, and the air valves opened to a very small extent. The valves should not be reversed for the first two or three hours, and when they have to be reversed, a most important point to bear in mind is *always to reverse* the gas valve first, and a few seconds after, the air valve. After running for two to three hours in each direction as above, the reversals may take place at more frequent intervals, the time being gradually reduced, until reversals take place every twenty minutes.

The Furnace Lining.—So far as we have gone at present, speaking generally, the details of construction and preparation of the furnace for work apply equally to the acid and basic processes. We now come to the lining of the bottom or hearth of the furnace, and, as it is this lining which forms the vital difference between the two processes, we shall describe each process separately.

THE ACID OPEN HEARTH PROCESS.

The furnace, having been dried as described, is now ready to have the bottom or hearth proper made, which is done as follows :—

Making Hearth and Tapping-Hole.—Fig. 144 represents a longitudinal section showing courses of Silica bricks on the bottom plates, and others built in steps from the side walls. The bottom is made by fritting on the purest Silica sand, and this stepped arrangement of Silica bricks at the sides is to assist in forming the banks of the hearth, as otherwise a much greater thickness of sand would have to be glazed on at the sides compared with the central part of the hearth.

In the centre of the tapping side of the furnace it is usual to leave a hole in the brickwork arched over, about 18 inches square, and before starting to frit on the sand bottom, a taper plug, usually of iron, and varying in diameter in proportion to the size of the furnace, is inserted from the outside, passing quite into the furnace, and is then well rammed round with ground ganister. When the ganister has set firmly, the plug is withdrawn from the outside, and the tapping-hole filled with lumps of

anthracite from the inside of the furnace, by pushing it in with a tool called a rabble. The rabble is shown in sketch, fig. 155, p. 167, and the end is held against the inside of the tapping-hole, while fireclay is rammed in from the outside. In the transverse section of the furnace, in Plate viii., fig. 125, are shown the shape and position of the tap-hole. The glazing on of the Silica sand bottom can then be proceeded with. Before putting in any sand it is desirable, if possible, to spread sandstone or granite chippings previously thoroughly dried and heated in a sand furnace, as evenly over the bottom as possible, and to urge the heat of the furnace by reversing the valves every twenty minutes until the chippings are fritted or fused on to the Silica bricks covering the bottom iron plates. When these chippings begin to soften, the best Silica sand is thrown into the furnace, and spread evenly over the bottom to a depth of half an inch, with a large flat-ended iron known as a broad hook, shown in sketch, fig. 155. This is then thoroughly glazed on, when another half inch of sand is added and glazed, and so on, until the bottom and banks of the furnace are of the required thickness and shape.

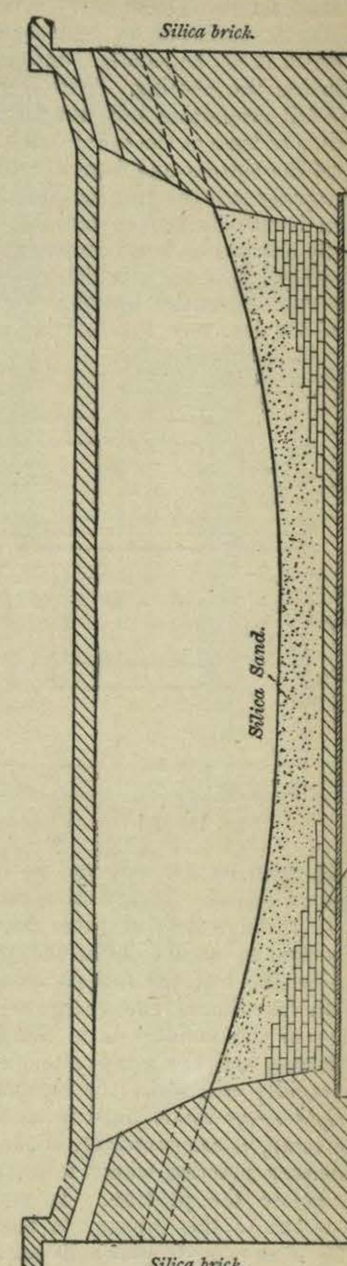
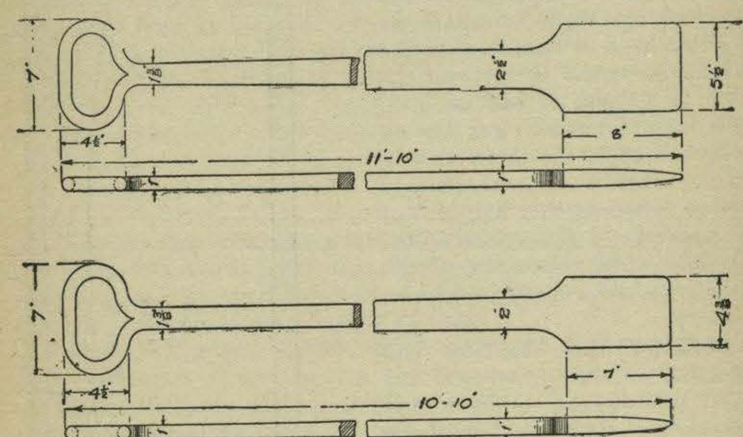


Fig. 144.—Section through Hearth of Siemens Acid Furnace.

Charging and Starting the Furnace.—In starting an acid furnace, it is customary to have what is called a "wash out" heat to thoroughly solidify the bottom. This consists in melting a small charge—say about $\frac{1}{4}$ of a full charge of pig-iron—and adding some silicious material like old red brick ends or slag from previous charges to form a fluid slag. When melted, this is well rabbled or raked about to wash the banks of the furnace, and then the charge is tapped out and taken to the scrap heap. Instead of using a small pig charge, the common custom in America is to melt a charge of acid open hearth slag in the furnace, and thoroughly wash the banks with this before charging any metal. The next three or four heats should be small ones, and should consist principally of pig-iron with a little scrap, the charge both in weight and proportion of scrap being gradually increased until the furnace is in good working order.

The proportion of scrap to pig-iron worked in a Siemens furnace will vary with local conditions, such as the quality of the pig, and the quantity of scrap available in the district, but the usual practice in this country is to use about 70 to 80 per cent. pig and 20 to 30 per cent. steel scrap. Good heavy scrap, such as bar or rail crop ends, is much to be preferred to light scrap, not only on account of the ease with which it can be handled, but also on account of less liability to oxidation during the melting. With very light scrap it is often impossible to get the full proportion into the furnace at starting, and it has to be added from time to time as the charge melts. Care should be taken to keep light scrap off the bottom and banks of the furnace, as the Oxide of Iron which forms rapidly cuts the furnace hearth away. For convenience in charging pig-iron is usually broken into half pigs, and these, in this country, are generally charged by hand, through the furnace doors with the "peel" (figs. 145 and 146), by means of which a good furnaceman will distribute his charge evenly over the entire hearth. The furnaceman rests the "peel" on the jamb of the door-way, thus getting a good leverage, another man places a



Figs. 145 and 146.—Peels for Siemens Furnace.

half pig upon its flat end, and he is able to shoot it into any part of the furnace he desires. To save time, especially in large furnaces, the charging is done through two or three doors at the same time by men working with a peel at each. After the pig-iron is in the furnace, the scrap is placed on the top, the furnace closed, and the gas turned in, and in from three to four hours the charge will be melted. The almost universal practice in this country is to charge the pig-iron first on the bottom of the furnace, and the scrap afterwards, the prevalent opinion being that scrap rapidly cuts away the bottom. This probably is so in the case of *very light scrap* which quickly oxidises, but this action, in the case of heavy scrap, is comparatively slight, as may be gathered from the results of American practice, where, in some works, it is the custom to charge the scrap before the pig-iron. In some experiments made at one of the large works in this country to test this point, practically no difference was found as regards wear and tear on the bottom when fairly heavy scrap was used.

Mechanical Chargers.—One of the most serious drawbacks to the open hearth process is the time lost in charging, especially in the case of very large furnaces, and to obviate this, numerous machines have been

devised. Fig. 147 shows a Wellman charging machine, which is largely used in America, in this country, and on the Continent.

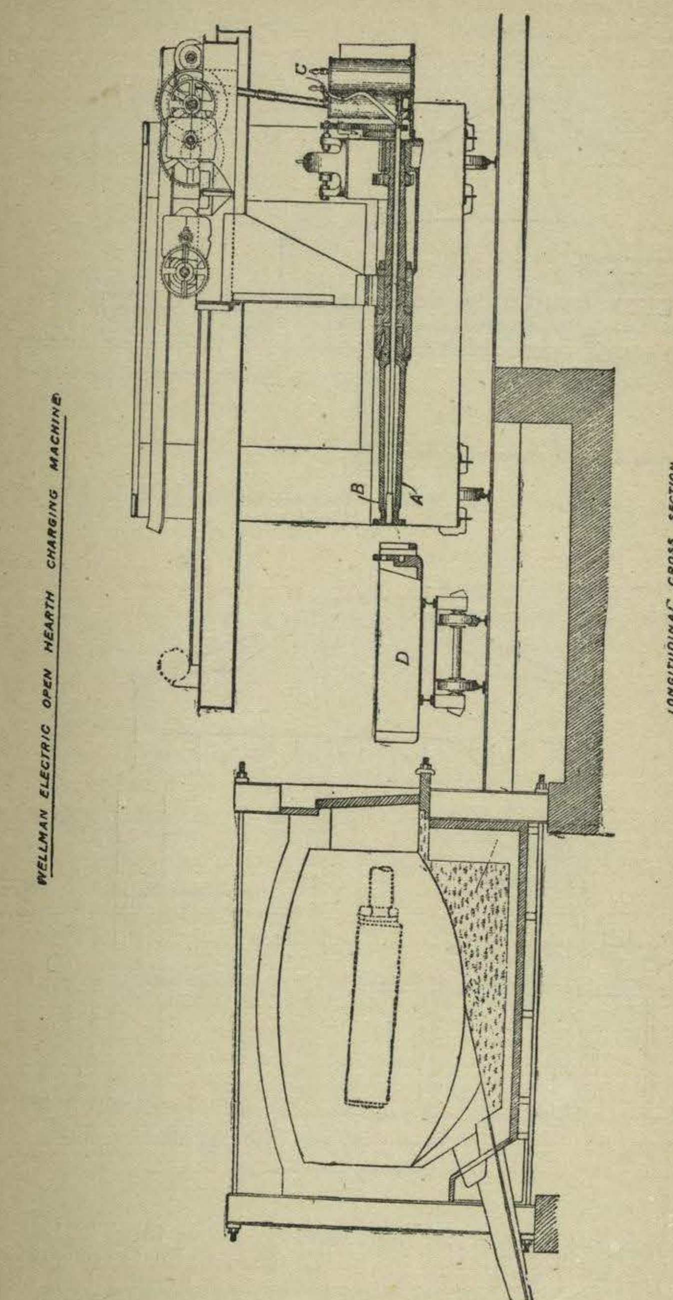


Fig. 147.—A, Hollow charging bar; B, locking bar; C, lever for actuating locking bar; D, charging box.

The Wellman Charging Machine.—In this machine the materials are charged in boxes holding about 1 ton, the boxes being picked up by the machine, pushed into the furnace, turned upside down to empty, and withdrawn. The boxes already loaded are brought up on a bogie running on rails, to the charging doors of the furnace, and the charger will pick up and empty one every minute, so that a 50-ton furnace can be charged in about an hour, provided the machine is kept supplied with loaded boxes. Fig. 147 shows a cross-section of the furnace, the charging bogie, and

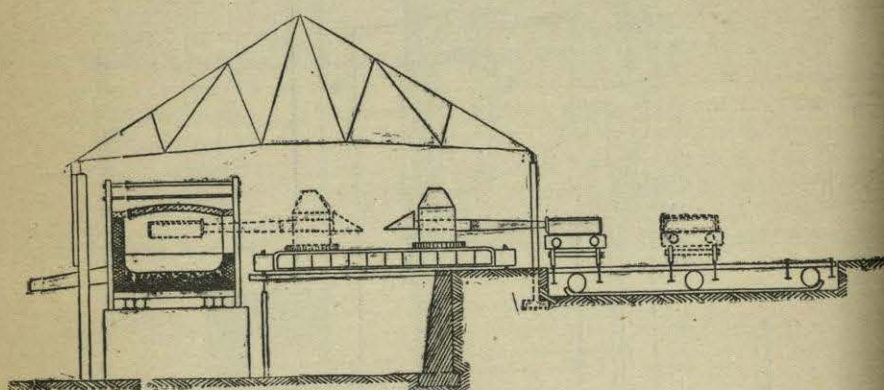


Fig. 148.—Low Ground Wellman-Seaver Charging Machine, with Slewing Motion.

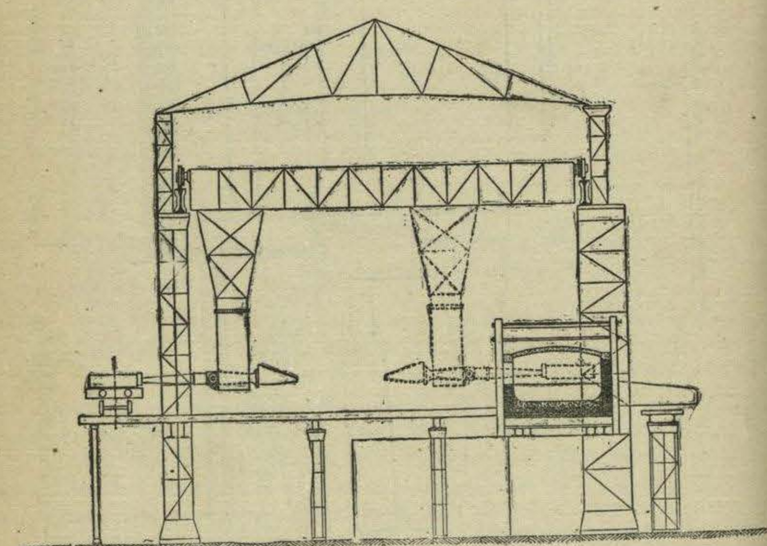


Fig. 149.—Overhead Wellman-Seaver Charging Machine, with Slewing Motion.

charging machine itself. The bogie usually carries three or four boxes. In operating the machine, the end of the charging bar is brought forward and dropped into a socket on the end of the charging box, and this is then locked in position by advancing the locking bar, B, by means of the lever, C, until the front end of the bar projects into a recess provided for the purpose in the socket of the box. The charging bar, A,

Overhead Charging Ma

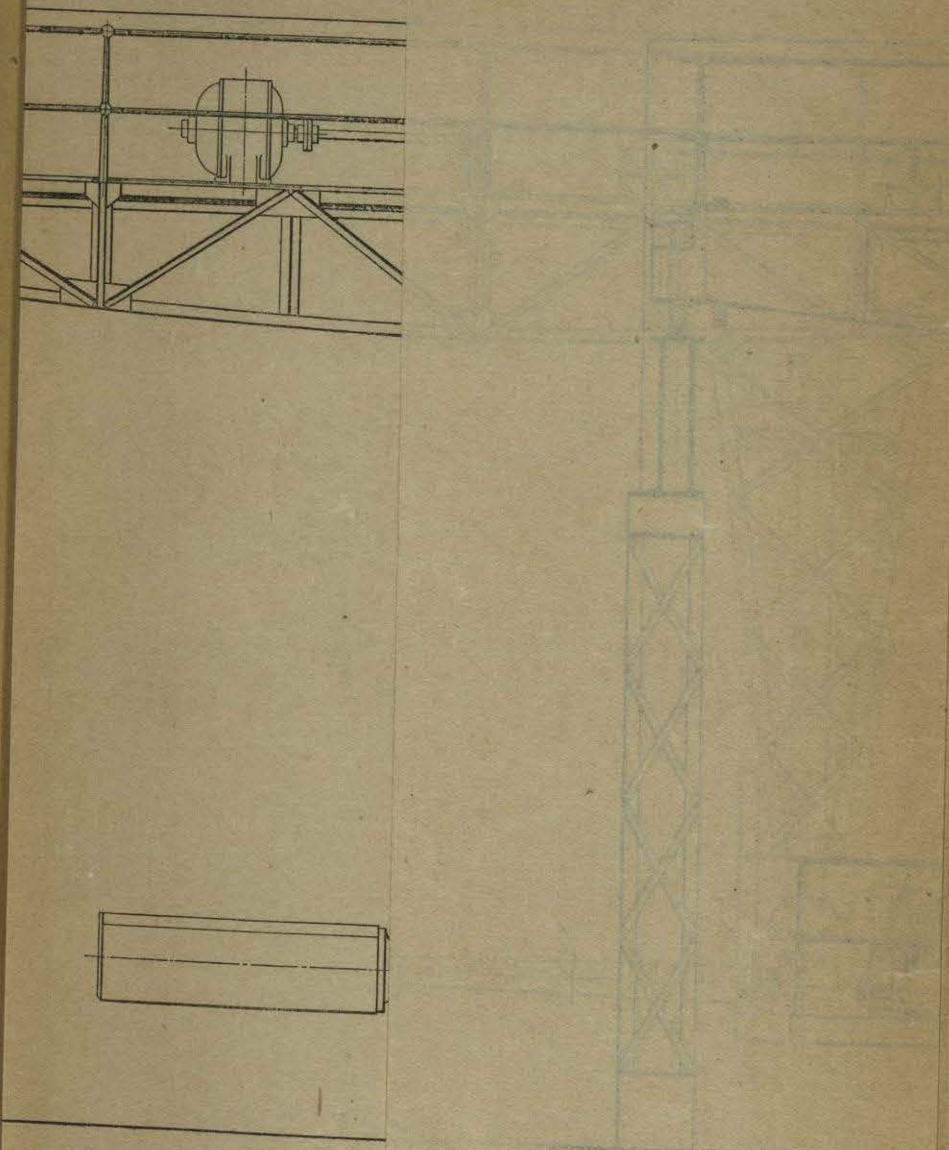


Fig. 150.

[To face p. 162.

PLATE Xa.—Broadbent Overhead Charging Machine, with Slewing Motion.

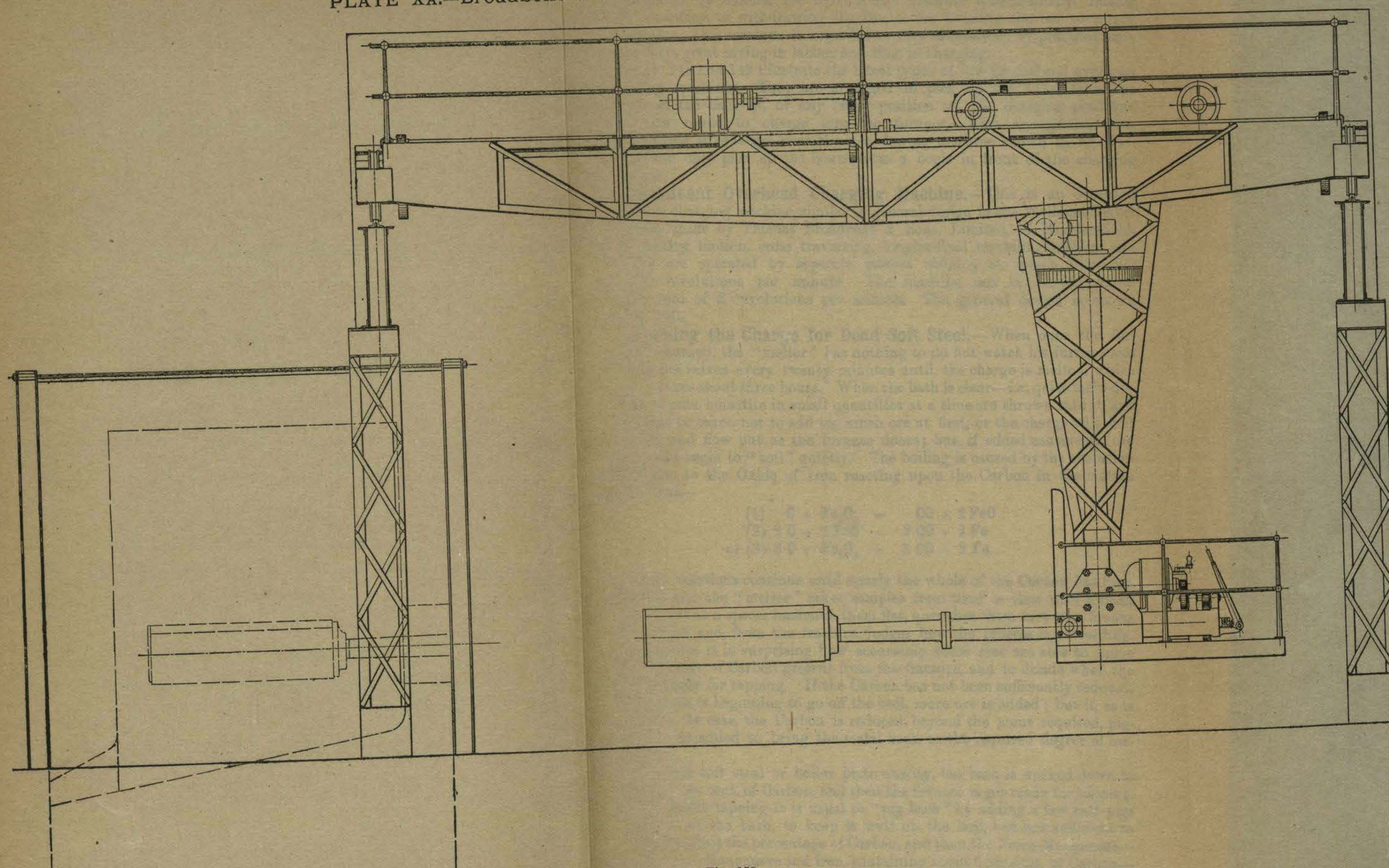


Fig. 150.

PLATE XA.—Broadbent Overhead Charging Machine, with Slewing Motion.

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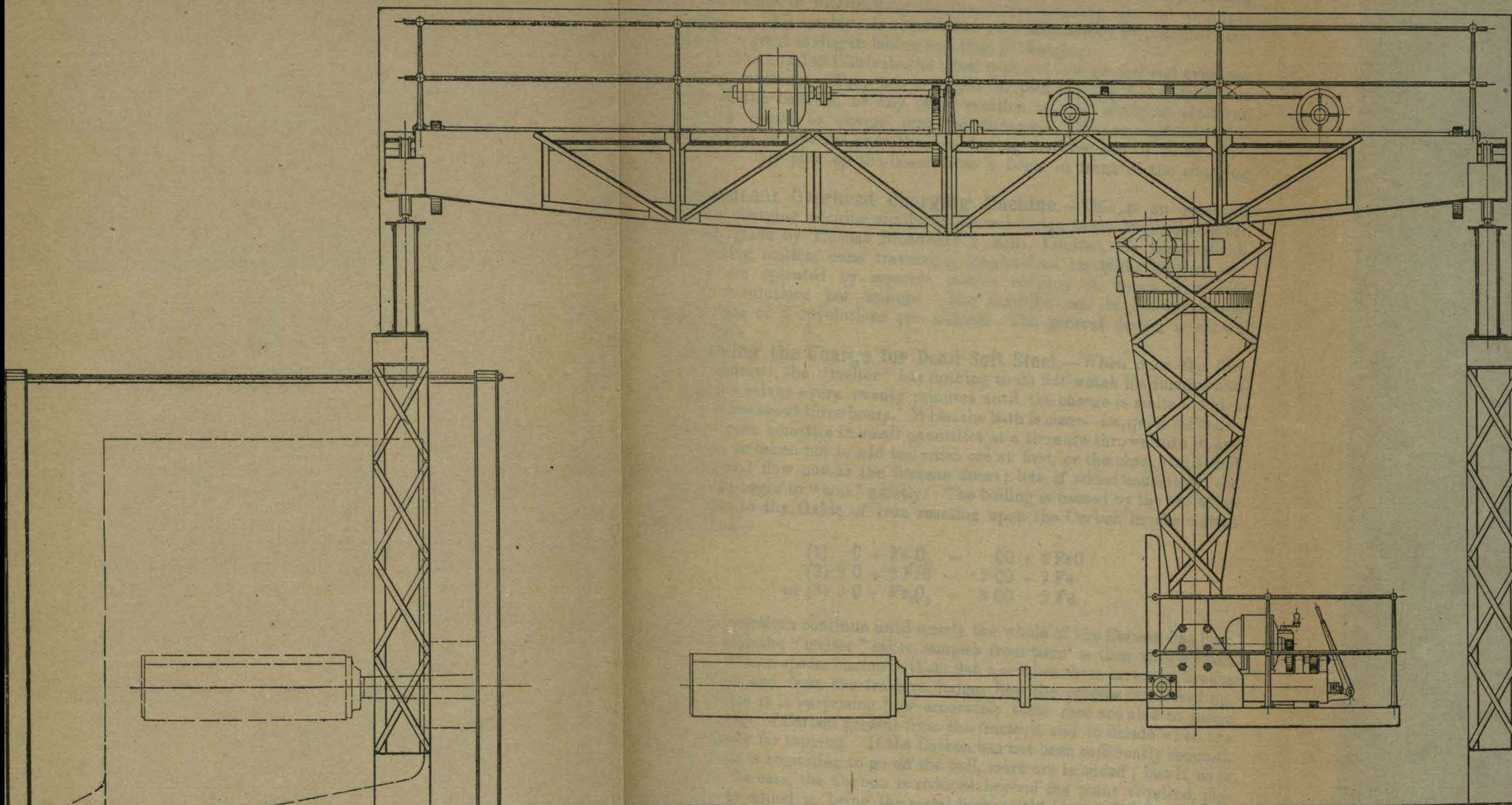


is hollow, to allow the locking bar to move within it. The machine is actuated by motors, for moving the machine longitudinally, raising and advancing, or withdrawing the bar, or for twisting the bar to empty the boxes. This machine is regarded as very satisfactory by practical men, and effects great saving in labour and time in charging.

Figs. 148 and 149 illustrate the latest types of low ground and overhead charging machines. They are arranged to pick up the boxes from the bogies at the back of, or any other position on, the charging platform, and slew round to charge into the furnace. This arrangement has considerable advantages over the non-slewing machine shown in fig. 147, which can only pick up the boxes from a bogie in front of the charging platform.

Broadbent Overhead Charging Machine.—This is an overhead electrical charging machine, similar in general design to the Wellman-Seaver machine, made by Thomas Broadbent & Sons, Limited, of Huddersfield. The canting motion, cross traversing, longitudinal travelling motion, and slewing are operated by separate motors running at speeds from 500 to 520 revolutions per minute. The machine can be slewed round at the rate of 2 revolutions per minute. The general design is shown in fig. 150.

Working the Charge for Dead Soft Steel.—When once the furnace is charged, the "melter" has nothing to do but watch his furnace and reverse his valves every twenty minutes until the charge is melted, which usually takes about three hours. When the bath is clear—*i.e.*, quite melted—lumps of pure hematite in small quantities at a time are thrown into it, and care must be taken not to add too much ore at first, or the charge will boil violently and flow out at the furnace doors; but, if added cautiously, the charge will begin to "boil" quietly. The boiling is caused by the evolution of CO, due to the Oxide of Iron reacting upon the Carbon in the molten metal, thus—

$$\begin{aligned} &(1)\quad C + Fe_2O_3 = CO + 2\,FeO \\ &(2)\quad 2\,C + 2\,FeO = 2\,CO + 2\,Fe \\ \text{or } &(3)\quad 3\,C + Fe_2O_3 = 3\,CO + 2\,Fe \end{aligned}$$

These reactions continue until nearly the whole of the Carbon has been removed, and the "melter" takes samples from time to time with a small ladle known as a spoon, hammers them flat, quenches them in water, breaks them in two, and, from the fracture, judges how the process is proceeding. With practice it is surprising how accurately these men are able to judge the percentage of Carbon present from the fracture, and to decide when the metal is ready for tapping. If the Carbon has not been sufficiently reduced, and the bath is beginning to go off the boil, more ore is added; but if, as is sometimes the case, the Carbon is reduced beyond the point required, pig-iron must be added to bring the metal back to the required degree of carburisation.

For dead soft steel or boiler plate quality, the bath is worked down to about 0·12 per cent. of Carbon, and then the furnace is got ready for tapping. Before actually tapping it is usual to "pig back" by adding a few half pigs of pig-iron to the bath, to keep it well on the boil, but not sufficient to appreciably affect the percentage of Carbon, and then the Ferro-Manganese—a rich alloy of Manganese and iron, containing about 6 per cent. of Carbon—is either added in lumps in the furnace, or, more generally, is broken very small, about the size of peas, and allowed to fall in the stream of metal as it flows from the furnace into the ladle. The complete operation usually takes about 7½ hours to 8 from the time that the furnace is charged, and allowing time for charging by hand and repairs, a charge will be tapped about every twelve hours from each furnace.

Tapping the Charge.—The tapping of the furnace is effected by driving with sledges a steel-pointed bar through the fireclay and sand of the tap-hole, and afterwards knocking the bar out by means of "dogs" fixed by wedges to its end. Directly the hole is free, the head melter, working from the charging side of the furnace, enlarges the hole by pushing a steel "pricker bar" (fig. 155) into it from the inside of the furnace, until he is satisfied that the hole is quite clear and the metal flowing freely.

During the teeming of the metal into the moulds, a small sample is caught in a hand-ladle, poured into a cast-iron mould, and taken to the smith's shop to be tested for welding and cold bending, as described under the acid Bessemer process (p. 57). The sample is afterwards used for analysis.

It is very important to have a fairly fluid slag, as, apart from retarding the oxidation of the metal during the working of the charge, a thick pasty slag is very troublesome when tapping.

If the slag has a tendency to be thick, the melter often thins it by throwing a lump or two of limestone into the furnace. On the other hand, it is equally important not to have a very thin slag, as this usually means a slag very rich in Oxide of Iron or Manganese, and liable to produce wild over-oxidised metal. At the end of the operation the slag should be what is known as clean—*i.e.*, as free as possible from oxide, and fairly thick, but, at the same time, fluid and not pasty. To be able to decide what is and what is not a good "tapping slag" requires considerable experience, and is one of those things which can be learnt only by practice; but it is a matter of great importance, and a practical point which should always receive most careful attention.

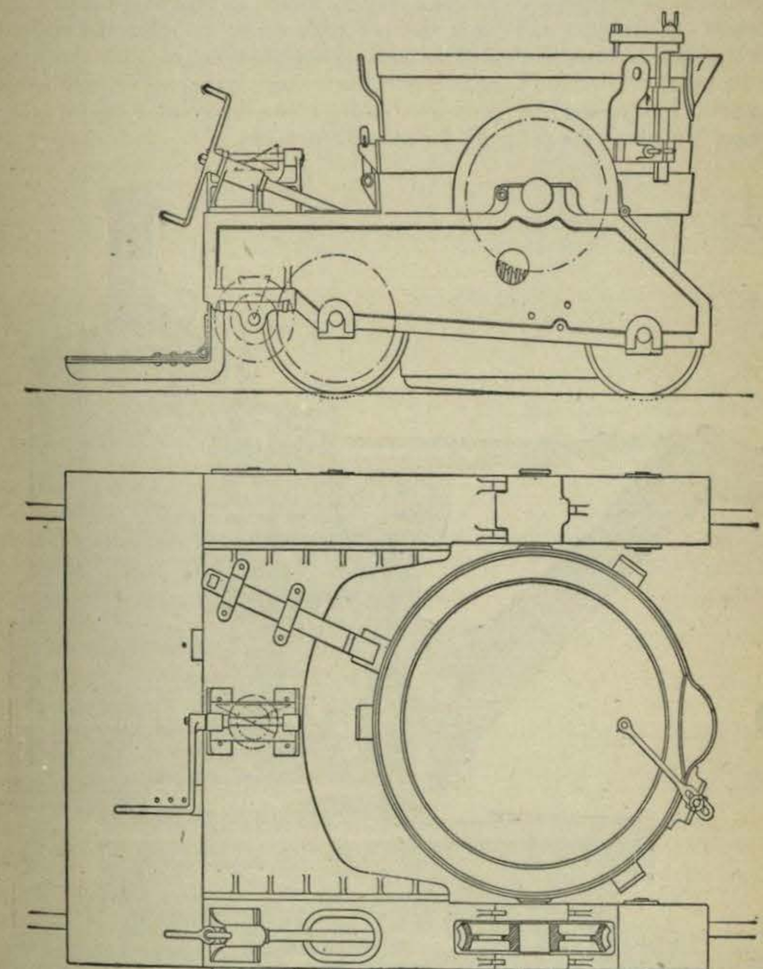
Precautions to be Observed.—A most important point in working a Siemens furnace is to always see that the tapping-hole is kept free from metal and slag, and a good furnaceman will take the greatest care to see that all metal is worked out of the hole before he proceeds to "make it up" again with anthracite and fireclay for another charge, which is usually done about fifteen minutes after tapping.

If the tapping hole is carefully attended to, "break outs" or "hard taps" will be very rare, although, despite the greatest care, they will occasionally occur.

In the event of a break out—*i.e.*, the tapping-hole giving way before the heat is finished—the ladle, if possible, is got under the tap-hole; but, if this cannot be managed, the metal must be allowed to run into the pit, and be broken up as soon as possible. In case of hard taps, little can be done except to sledge away until the bars penetrate the hole, and a set of well-pointed bars should always be at hand for such an emergency.

The Ladle.—The casting ladle, as regards arrangement of stopper and other details, is identical with that described on p. 25, fig. 31, used in Bessemer practice, but instead of being carried on a centre crane it is more usually mounted on a carriage with wheels which can be moved by hand gearing or drawn along by a locomotive, or by other means. The arrangement shown in figs. 151, 152, from drawings supplied by Messrs. Stevenson & Co., of Preston, is the one usually adopted in England, where the straight pit (Plate viii., fig. 125) is used, although in some works centre casting cranes similar to those employed for Bessemer works are employed. Where the system of casting on cars is being introduced into works, the ladle mounted on the carriage (as shown in the figure) is not suitable, as there is no means of raising the ladle up above the floor level, and

if used it necessitates running the ingot cars on rails in a pit sunk below the floor level. By far the best arrangement, and that now being generally introduced into modern works, is one in which the ladle is suspended from an overhead crane running in front of the furnaces. This enables the ladle to be very readily raised or lowered, to be moved along to any furnace, and the casting to be done any reasonable distance in front of



Figs. 151, 152.—Casting Ladle for Siemens Furnace for use with straight pit.

During teeming the carriage can be moved from mould to mould either by tooth gearing worked by hand, or it can be drawn along by chain or rod attached to a locomotive, and when it is required to move it any distance, as from one end of the shop to the other, the latter is always used. It is turned over by the worm which gears into the worm wheel keyed on to the trunnion, as shown in the sketch.

the furnaces, according to the span of the crane. In fig. 153, Plate xi., is shown a modern electric overhead crane, with all the latest improvements to ensure rapidity in working and easy control, combined with safety to the workmen. The details will be readily understood from the sketch and description.

Cranes for Ingot Stripping.—The difficulty in "stripping" the ingots and clearing the pit of a Siemens furnace plant is not nearly so great as in the case of the Bessemer plant, as heats from each Siemens furnace are ready for teeming only once in every 10 hours instead of 40 to 50 minutes. In a large Siemens plant different furnaces may be ready to tap at frequent intervals, but the pit space in front of any particular furnace will be required only once every 10 hours, so that there is this time to remove the ingots and reset the pit with other moulds. In ordinary work the pit is usually cleared as rapidly as possible, so that the ingots may be taken while hot to the re-heating furnaces; but apart from this there is no great hurry, and one good locomotive crane, by going from furnace to furnace, can do all the pit work for several furnaces.

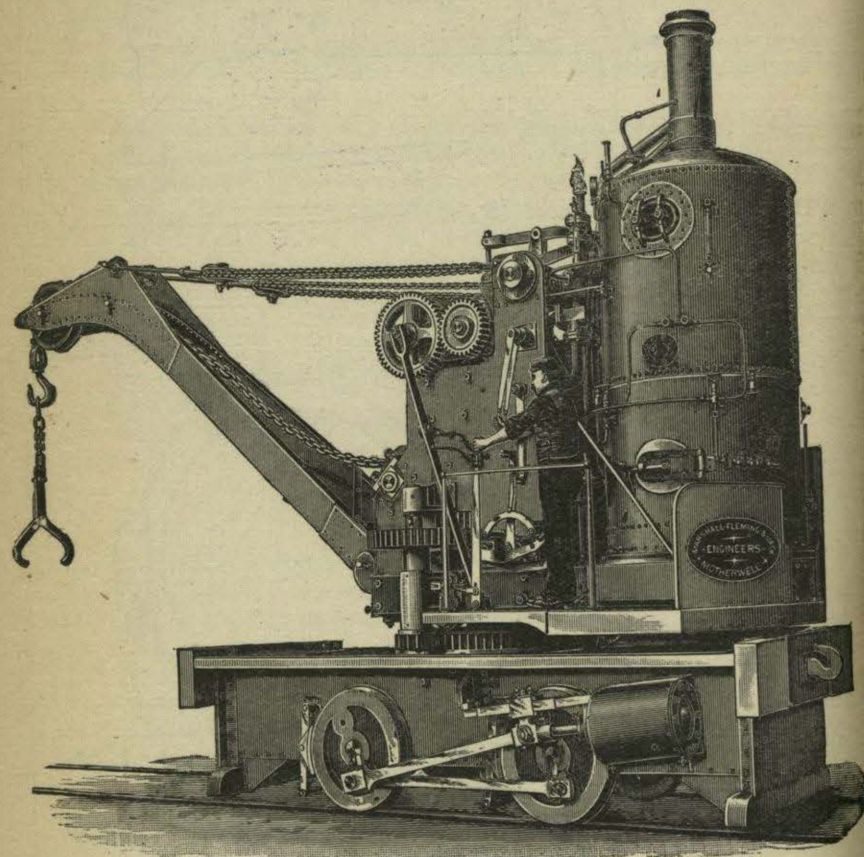


Fig. 154.—Travelling Crane for Steel Works.

Fig. 154 shows the type of crane commonly employed in an open hearth plant for handling the ladle carriage and lifting the ingots and moulds, the one in question being made by Messrs. Marshall, Fleming & Jack, of Motherwell. The travelling wheels are driven by engines separate from those used for lifting and slewing the load, thus giving a considerable increase in speed and convenience in working. The crane will lift 8 tons at 15 feet radius, or 12 tons at 10 feet, and can be used for shunting trucks or bringing in materials from the sidings for use in the mills or melting shop.

head Lad

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The main bottom block consists of a heavy steel forging, A, having its two ends turned to form gudgeons, on each of which is pivotted a compensating beam, B, with arms of equal length. The extremities of these beams receive the nests of sheaves, C C, which form the lower ends of the four sets of lifting tackle. The steel forging, A, serves as a distance piece to maintain the tackles in their relative vertical positions, and also as a suspension bar for the two long forged-steel hooks, D D, in which the trunnion of the ladle rest, and which are clamped to the suspension bar. Besides these, a short double hook, revolving on ball bearings, is attached to the bar at its centre for lifting weights other than ladles. This latter is not shown in the sketch.

PLATE XI.—Electric Overhead Ladle Crane.

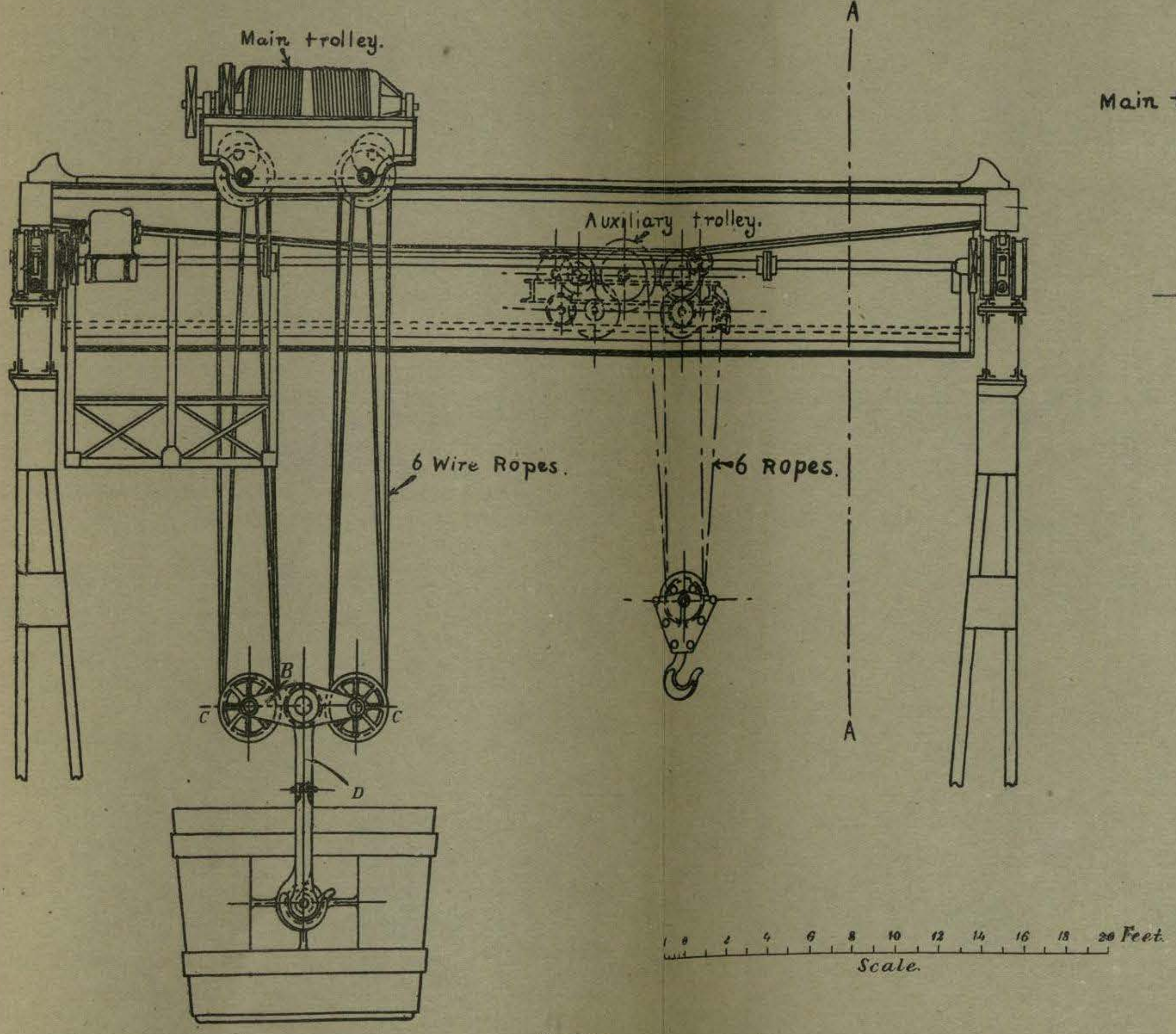

Fig. 153.

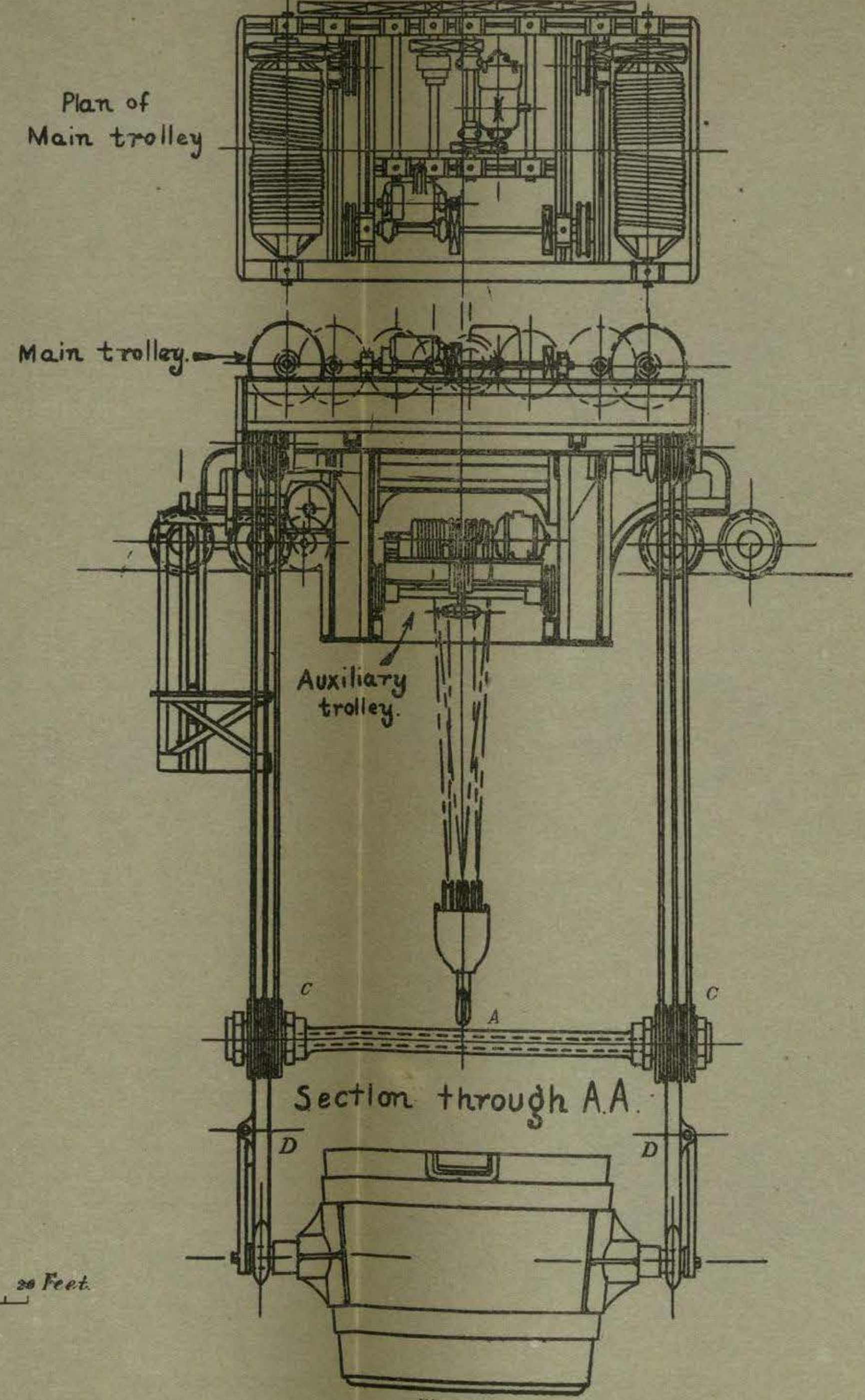

Fig. 153a.

Repairing the Bottom.—After the charge has been tapped from the furnace the tapping hole is "made up," as described, with fireclay and anthracite; the bottom of the furnace should be carefully examined for any holes, and if these exist, or the banks are cut away, they must be carefully repaired by spreading silica sand over the bad places, and glazing

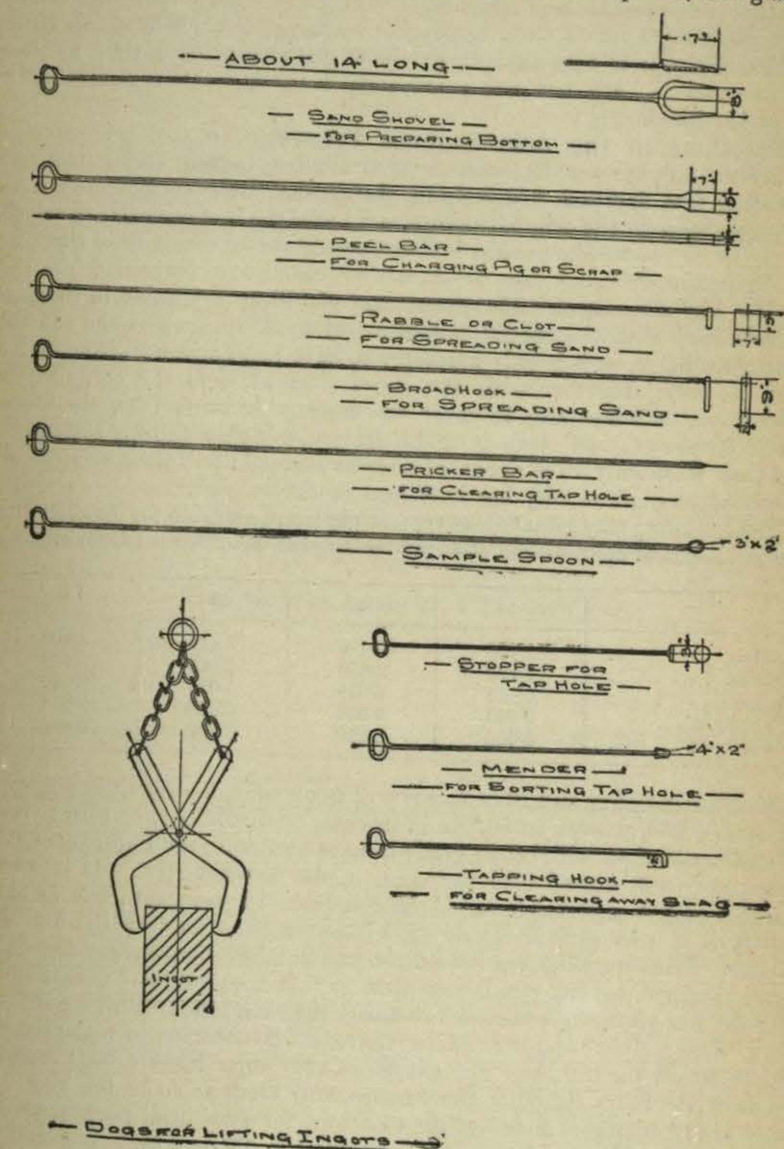

Fig. 155. —Principal Tools used at Siemens Furnace.

it on, after which the furnace is ready for another charge. It is important to lose as little time as possible between the charges, not only on account of the actual saving in time, but also to avoid the cooling down of the furnace. In fig. 155 are given sketches of the principal tools used in repairing and working a Siemens furnace.