no way interfere with each other, with the minimum expenditure of labour and time, and with as little wear and tear to the machinery as possible.

In the early Bessemer plants it was usual to place one converter on each side of a deep circular pit, so that they could each be served by one centre crane carrying the ladle, the casting pit being between the two vessels, as shown in fig. 60. Cupola metal was always used, the cupolas both for melting the iron and spiegel being arranged on a platform at such a level that when the converter was turned down the molten pig-iron could be tapped either directly into the vessel by means of a runner, or into a ladle at the same level as the converter, so that after weighing the metal could be poured into the latter. Although many works designed in this way have done excellent work, still, in these days of large outputs, the working space is so cramped that it is impossible to handle the moulds, ingots, ladles, &c., rapidly enough, and the heat on the cupola platform and in the pit becomes so excessive, that it is impossible for the men to do as much work in a given time as they would do under better conditions.

To avoid these disadvantages, the first step was to increase the working space in front of the converters, and instead of placing the latter opposite each other, the converters were placed in one line, and the deep circular pit was replaced by a large shallow semi-circular or circular one.

Two converters are usually served by one central casting crane similar to that described in fig. 36, the radius of the jib being such that it carries the casting ladle well under the converter at the back of the pit, and allows it, when swung round, to cover the ingot moulds, which are generally arranged round the circumference of the pit.

If the metal is poured direct into the ladle on the centre crane, the distance between the converters and the circumference of the pit is limited by the radius of the jib of the crane, and as a modern crane constructed as shown (fig. 36) will have to carry from 12 to 15 tons of metal in the ladle, the maximum length of jib consistent with safety and easy handling is soon reached. Various devices have been suggested to meet this difficulty, and one in use in this country is to have special jib cranes arranged near the converters, known as the receiving cranes, on which the metal ladle is supported during the pouring of the metal from the converter.

The ladle is then transferred to the centre casting crane by bringing the jibs of the two cranes together, and lifting the ladle bodily from the receiving crane. This plan is in use in the North-Eastern Steel Works, Middlesbrough, and it increases the working space between the circumference of the pit and the converter by an additional distance equal to the length of the jib of the receiving crane. Figs. 61 and 62 are fairly representative of many existing English and American Bessemer plants, although, as will be shown, in the most modern works the pit is being dispensed with altogether. The description accompanying the drawings explains the details. In America, at South Chicago Union and Wheeling,* this removal of vessels from the casting pit is carried a step further. The metal is poured into the ladle on a receiving crane with a short jib near the converter, from which it is transferred to a track leading to the casting pit, along which it is pushed by a hydraulic ram attached to the receiving crane, and it is then drawn on to the casting centre crane by the radial hydraulic cylinder of the latter. This increases the distance between the converters and the circumference of the pit by the length of the track.

In some Continental works the circular pit is dispensed with, and a straight pit used, in which case it can be either in a line with, or parallel to, the converters; the metal is then poured into a ladle, supported on a carriage

* Howe, *Metallurgy of Steel*, pp. 331 and 332.



ssemer Steel Plant—(

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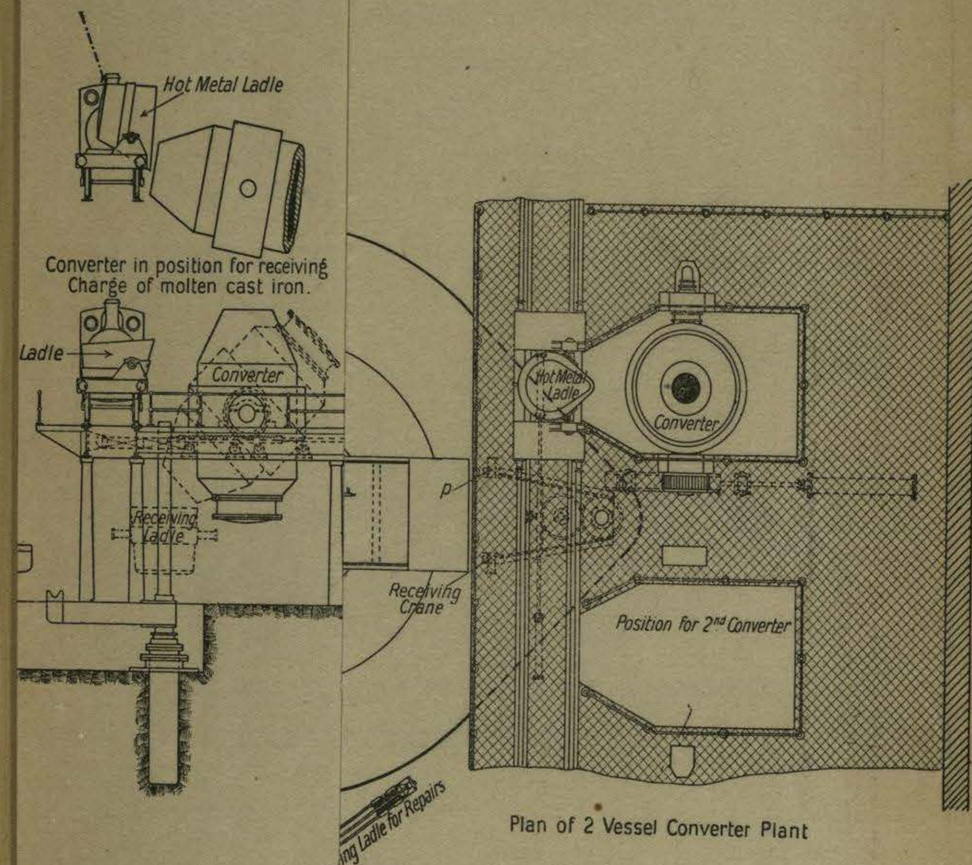


Plan of 2 Vessel Converter Plant

The sketch shows the general arrangement of Bessemer Plant, with receiving crane, casting crane, and ingot cranes. The hot metal is brought in the ladle along an elevated railway track in front of the converters, as shown in plan and elevation. Molten iron is poured from the ladle into the converter by attaching one end of a chain to a lug on its bottom, and tilting, as shown in the sketch, by means of a hydraulic ram or other suitable appliance connected with the other end of the chain.

In the elevation the converter is shown in the three different positions—nearly horizontal with molten cast iron being poured in through the nose from the ladle, vertical for blowing, and in the position for teeming into the receiving ladle, the latter being shown by dotted lines.

The receiving crane, as shown in the plan, is placed between the two converters, so that the ladle which it carries can be swung under either converter as required.

The centre or casting crane is shown with casting ladle in position ready for teeming the steel into the ingot moulds. One ingot crane in the elevation is removing the mould from the ingot which remains standing in the pit, and another one is lifting an ingot after removal of the mould.

## PLATE III.—Bessemer Steel Plant—General Arrangement.

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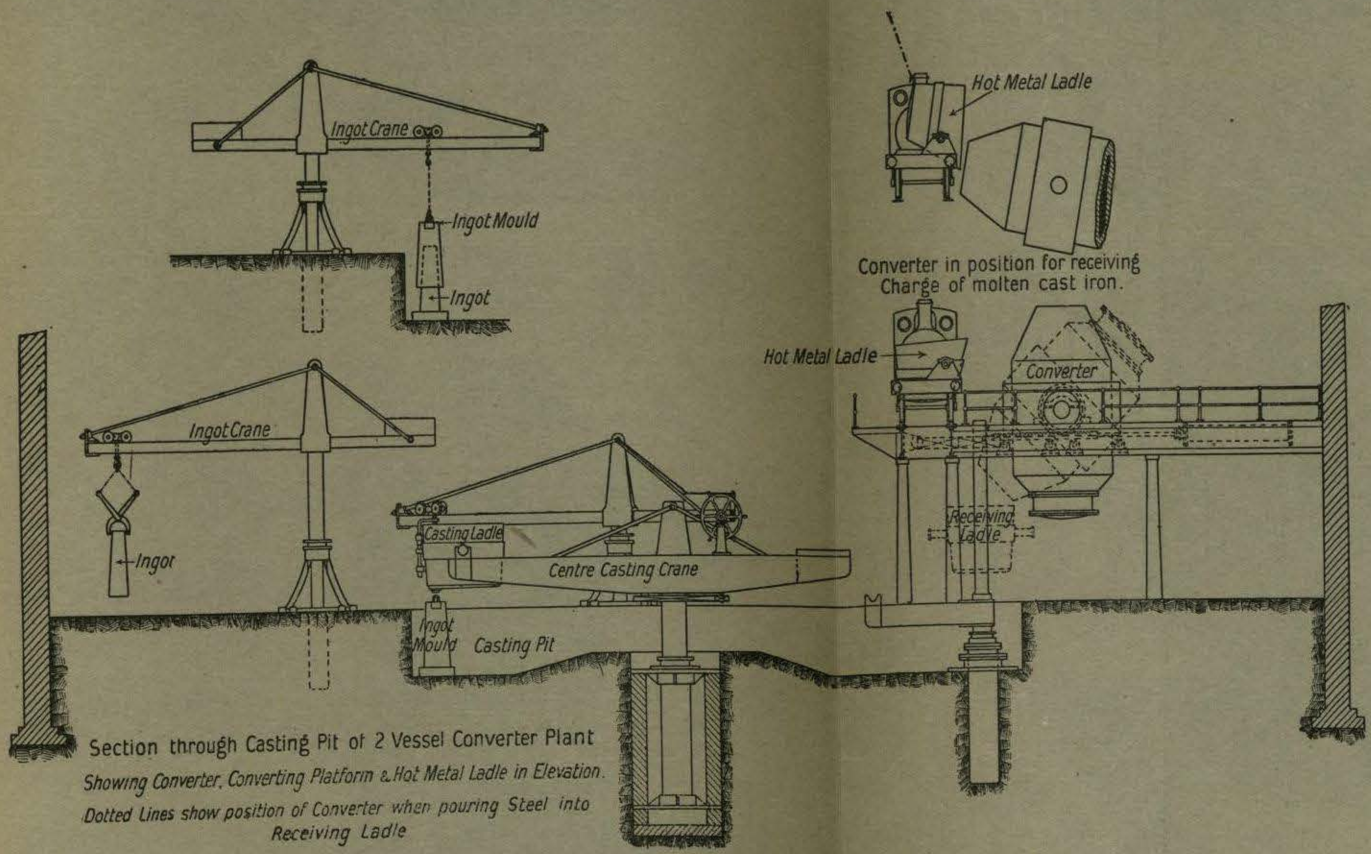


Fig. 61.

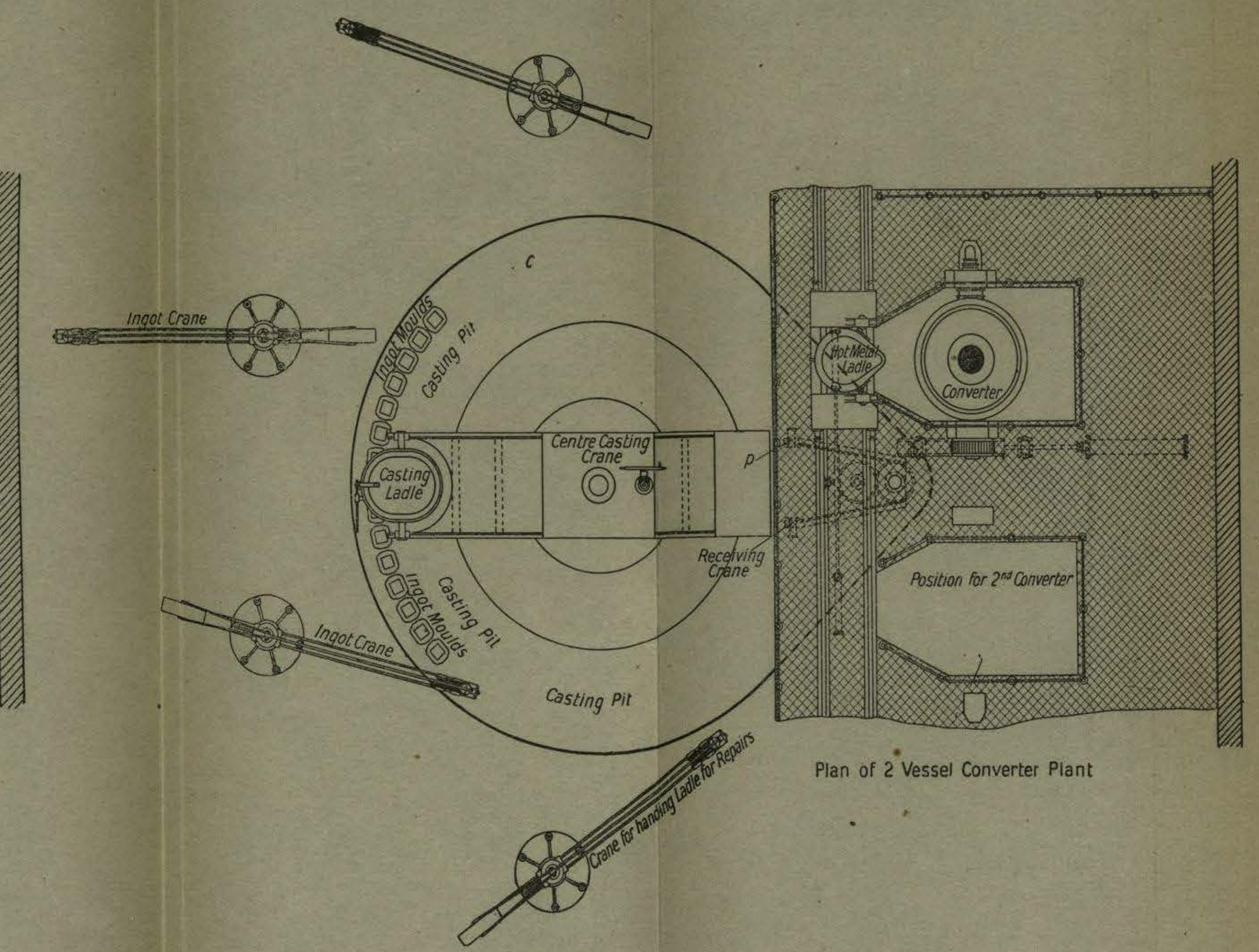


Fig. 62.

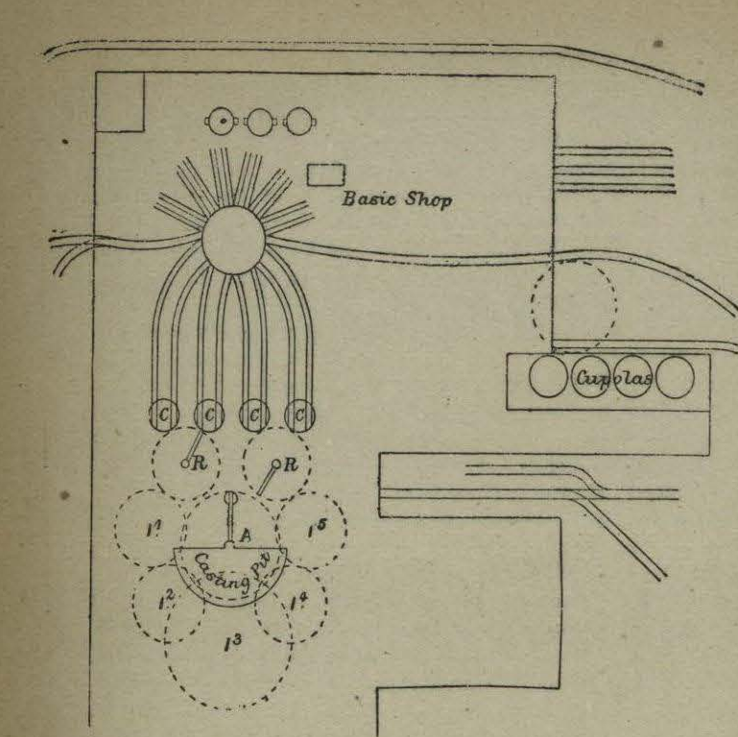


Fig. 63.—Plan of Basic Bessemer Plant, North-Eastern Steel Works.—C, Converters; R, receiving cranes; A, transfer central casting crane; $I^2$, $I^3$, $I^4$, ingot crane; $I^1$, $I^5$, ladle cranes.

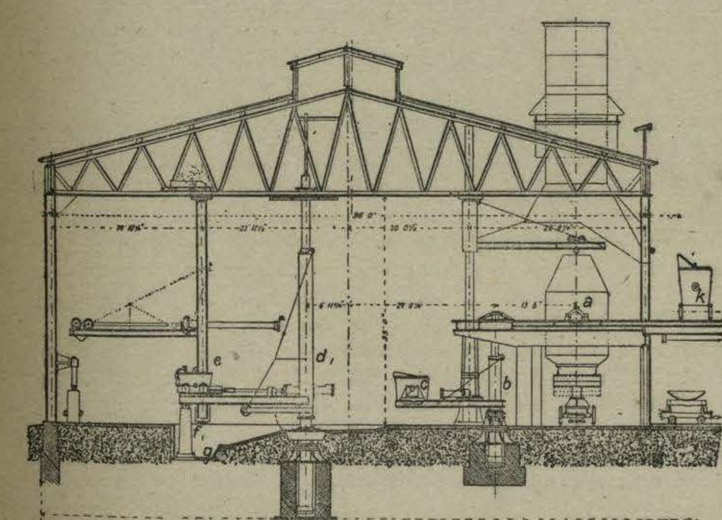

Fig. 64.—Section through the Bessemer Shop Cambria Iron Works, 1890, showing Converter with Receiving Crane and Transfer Central Casting Crane—(*a*) Converter; (*b*) receiving crane; (*c*) receiving ladle; (*d*) transfer casting crane; (*e*) casting ladle.

or on a receiving crane; in the latter case it is transferred to a carriage, and drawn along by a locomotive; but this cannot be so readily moved backwards and forwards in casting as the jib of a centre casting crane, and has no vertical movement to allow for difference in height of the ingot moulds. It has not been adopted to any extent in Bessemer works in England, although similar arrangements are in common use in Siemens works.

Fig. 63 is the plan of the Bessemer shop of the North-Eastern Steel Works, showing the central casting and receiving cranes, and fig. 64 is a section through the Bessemer shop at the Cambria Iron Works, where a similar arrangement was installed some years ago. It will be noted that the pit, even at its deepest part, is only about 3 feet 6 inches in depth, and the facility with which the ingots can be stripped and removed is very great when a comparison is made with the old circular pit shown in fig. 60.

**Re-pouring Metal before Casting.**—Instead of pouring the finished steel direct into the *casting ladle* on the receiving crane, in some cases the metal is poured into a *receiving ladle—i.e.*, a ladle similar to the direct metal ladle, with lip for pouring—and the metal is conveyed to the casting pit, and is re-poured into the casting ladle on the casting crane.

If the ladle is on a carriage, this allows the casting pit to be any reasonable distance from the Bessemer shop, and it also insures the thorough mixing of the steel during the transference from one ladle to another. Against these advantages must be set, especially in the case of dead soft steel, the risk of the metal being chilled and partially setting in the ladle; and as there seems little evidence that the metal is appreciably improved by re-pouring, this method of transference has not been generally adopted, the opinion of practical men, as shown by the design of recent works, being in favour of removing ladle and metal bodily to the casting crane.

*Allen's Agitator.*—Many years ago Mr. Allen, of Sheffield, introduced an agitator for thoroughly mixing the metal in the ladle; but although it is stated to have very appreciably improved the regularity of the steel, it has not come into general use.

**Car Casting.**—The most recent development in casting has resulted in the abolition of the casting pit altogether, and in the casting of the molten metal into ingot moulds, carried on bogies, running on rails at the ordinary floor level. The centre crane carrying the casting ladle full of metal is swung round into a fixed position over the first ingot mould to be filled, and instead of the ladle being moved over the next mould, each mould as it is filled is pushed forward by a mechanical appliance known as the car-pusher, and an empty one takes its place under the nozzle of the ladle. As the level of the ladle would be too high to manipulate conveniently the lever from the floor level, a tapping staging is built a few feet in height from which the teeming is done. It is very important that each mould should be placed centrally to the nozzle of the ladle to prevent the metal splashing on its sides, and also loss of metal. To insure this, the moulds are moved forward one by one by a fixed finger which is attached to a hydraulic ram on the floor level and which gears into the bogies carrying the moulds. This car pusher for moving the moulds into position is shown in figs. 65 and 66. At the Barrow Works, where this system is in operation, about 100 bogies carrying moulds are always in use, and by keeping them in proper rotation, the moulds become sufficiently cool for use again without water-cooling. About ten minutes after casting, in the case of 2-ton ingots, the bogies are drawn away to the ingot stripper, which is situated outside the Bessemer shop proper, and which strips the moulds from the ingots and places them on another bogie to be returned to the Bessemer shop for the next cast. The ingots, which are not removed from the bogie,



are then taken straight away by locomotives to the re-heating furnaces. Figs. 67 and 68 are a plan and transverse section through the Barrow Bessemer shop, kindly supplied by Mr. J. M. While, the general manager of the Barrow Company. They show a plant which is replete with every modern appliance for giving the maximum output with the minimum amount of labour. It is thoroughly typical of a first-rate modern plant.

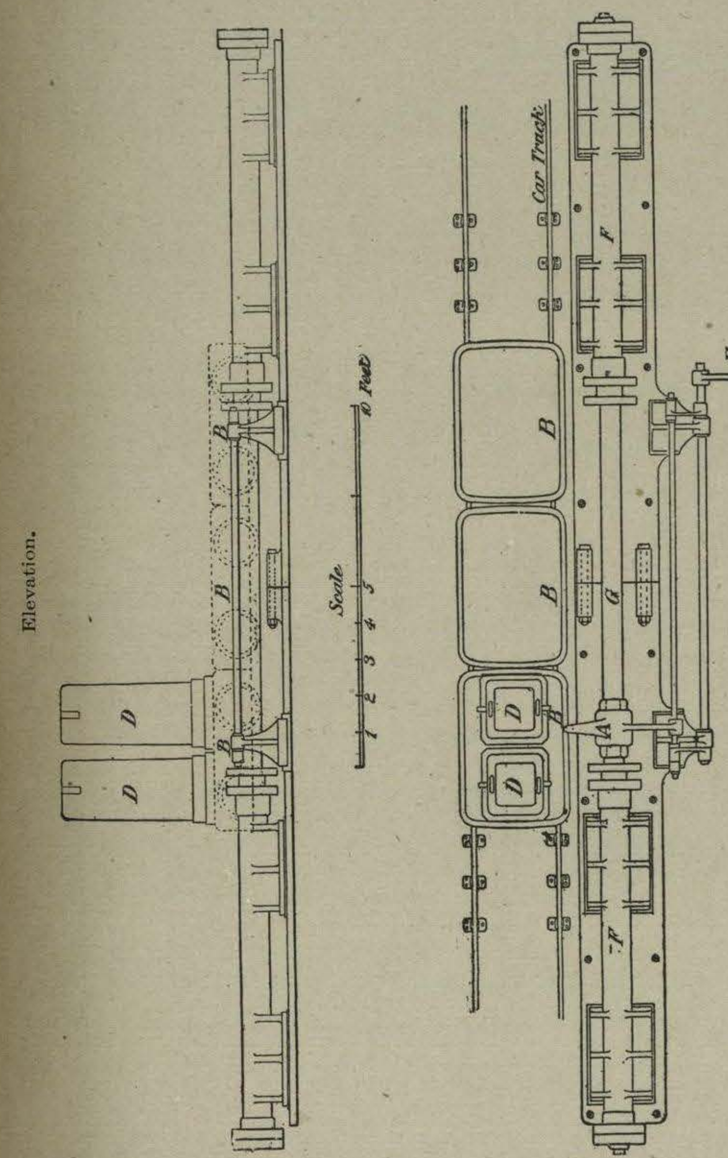


Fig. 65.—Plan and Elevation.

Car Pusher.—B, Ingot cars; D, ingot moulds; F, hydraulic cylinders; R, R, track for ingot car. By means of levers, E, E (fig 66), the finger, A, on ram, G, may be interlocked with ingot cars, B, at will, and the cars are then pushed along until the centre of the next mould is under the nozzle of the ladle, when A is released.

The immense advantage of removing the hot ingots directly they are set, and stripping them in a shed quite separate from the Bessemer shop will be apparent to anyone who visits a modern works where car casting is employed. Not only does it greatly increase the working space and facilitate mechanical operations of the Bessemer shop in every way, but the better conditions under which the men work enable them to do more work in a given time with less fatigue. The slow cooling of the moulds, so that all water-cooling becomes unnecessary, is also an important consideration, as their life is very appreciably prolonged.

## Detailed Description of Process.

The molten metal, having been tapped either from the cupola or direct from the blast furnace, or poured from the mixer into the metal ladle, is weighed, and then raised by means of a hoist, inclined railway, or other contrivance to the converter level, and brought in front of the nose of the converter. The converter is turned down into the horizontal position, the metal poured from the ladle into it, and the latter withdrawn and returned to the cupola or mixer for another charge of molten metal. The position of the converter must be such that when the whole charge has been poured in, the twyers are well above the bath of metal, otherwise the molten iron will run into the twyer-holes.

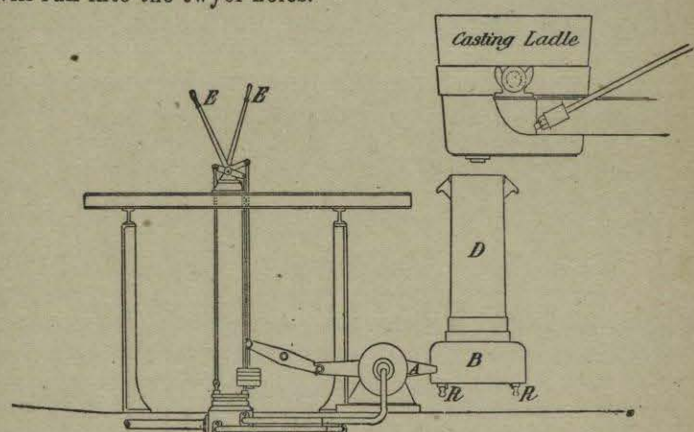


Fig. 66.—Car Pusher—End Elevation.

The blast is now turned on, and the converter turned up to the vertical position, the pressure of the blast being sufficient to keep the metal from running into the twyer-holes, and also to force its way through the molten metal. During the early stages of the blow a short flame, accompanied with showers of sparks, issues from the mouth of the converter, and gradually increases in size as the temperature of the bath is raised owing to the oxidation of the Silicon. The flame further increases in size and brightness, and evidence of very violent reaction inside the converter is given by large splashes of molten slag and some metal being ejected from the vessel. This is known as the "boil," and is due largely to the evolution of Carbonic Oxide from the oxidation of the Carbon.

**"Scrapping" the Charge.**—It is during this period that the "blower" decides by the appearance of the flame, &c., whether the charge requires "scrapping," and, if so, to what extent. If blowing "hot," scrap is either shot into the converter from an overhead shoot while the blow is going on, or in works where they have no arrangement of this kind, the vessel is "turned down," and scrap thrown in from the converter platform. It is very important that the metal should be regular in composition, and the Silicon should not exceed 2·5 per cent., or, for ordinary English practice, be less than 2·0 per cent. Metal much higher in Silicon is often used, but

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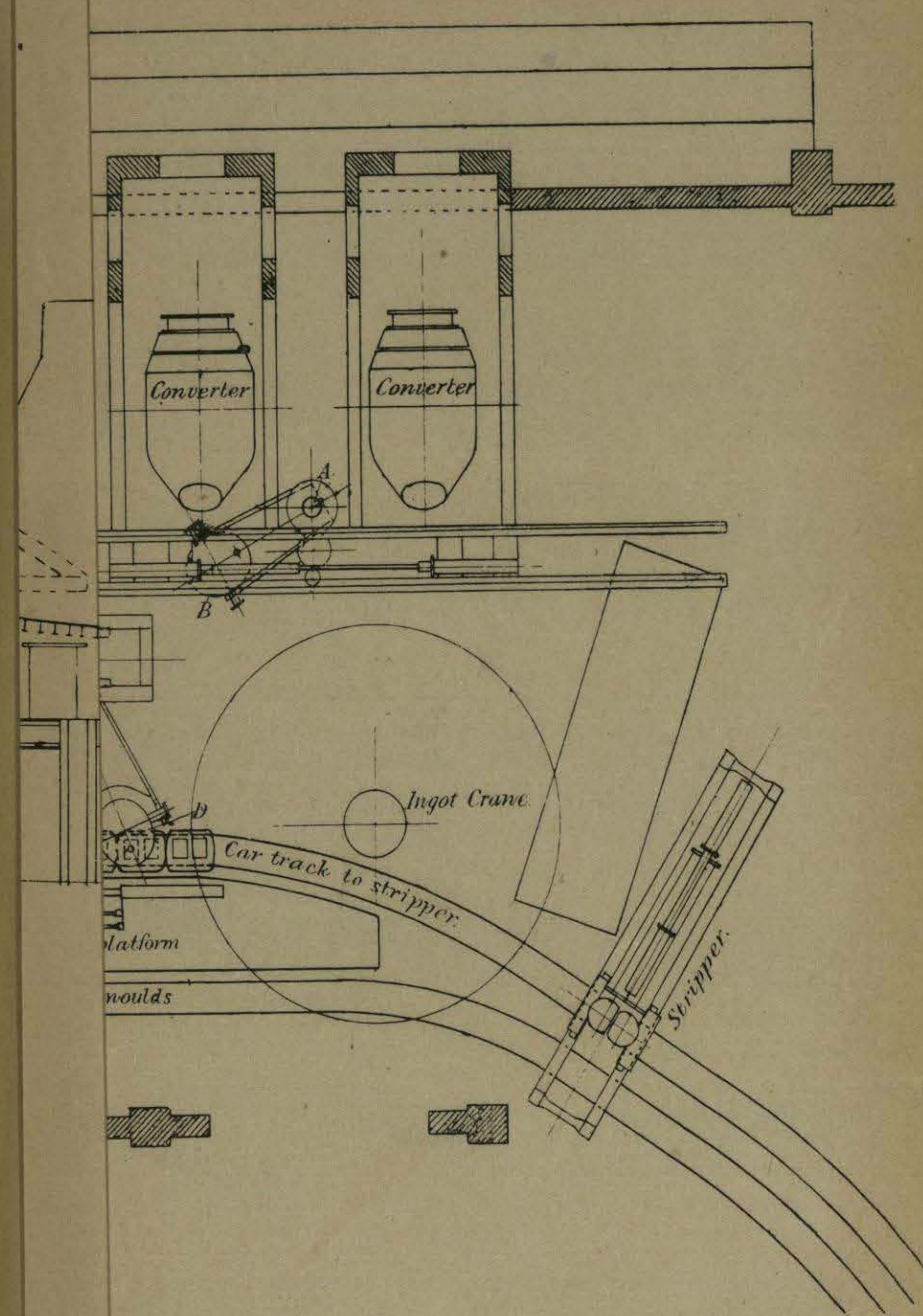

A B, Receiving or transfer crane.
C, Casting crane.
D, Casting ladle.
E E, Ram and rack for turning centre crane.
F, Hydraulic teeming cylinder.
H, Support to casting crane during teeming.

**The metal from the mixer or cupolas is brought up the inclined railway to the elevated track in front of the converters, and the metal poured by the hydraulic teeming cylinder, F (fig. 68). When the blow is finished, the steel is poured into ladle on the transfer crane, A B, the ladle transferred to centre casting crane, C, and teemed into the 2-ton ingot moulds on cars. After about ten minutes the ingots are sufficiently set to be taken to stripper, and thence to gas-heated soaking pits. About 100 moulds are kept in work, so that ample time is allowed for cooling without the use of water. At the back of converters is an inclined railway, with elevated track parallel to that in front, for the supply of refractories and scrap.**

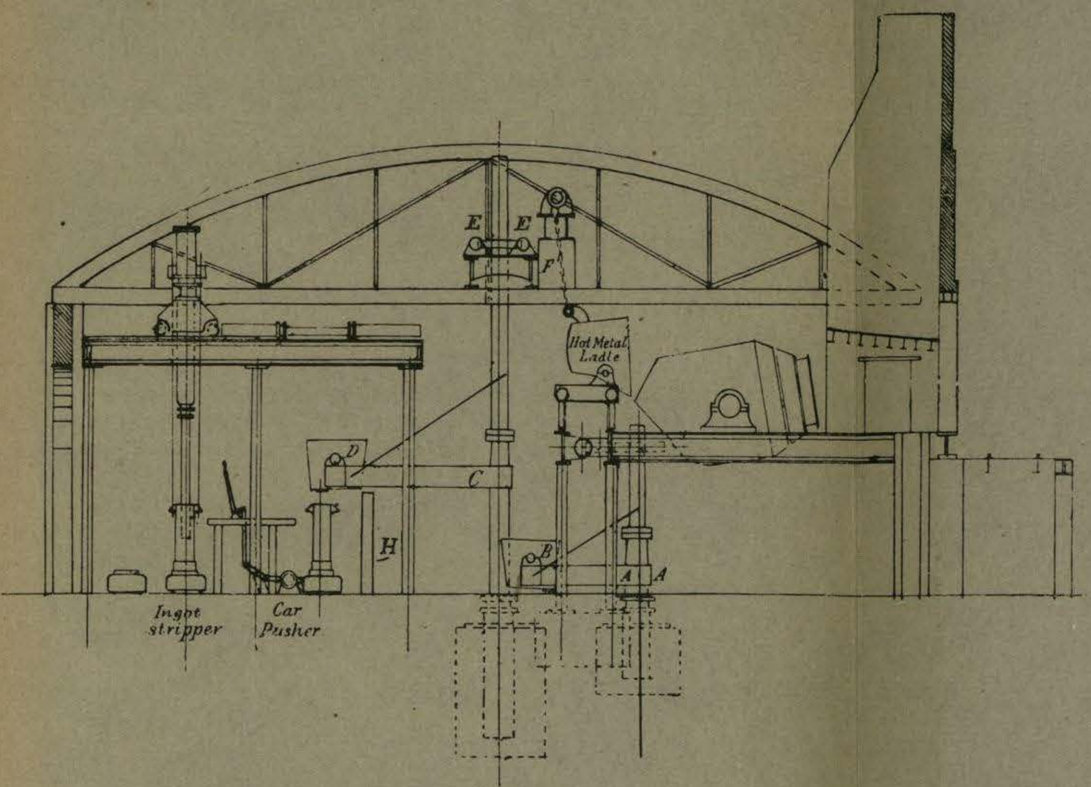


Fig. 68.

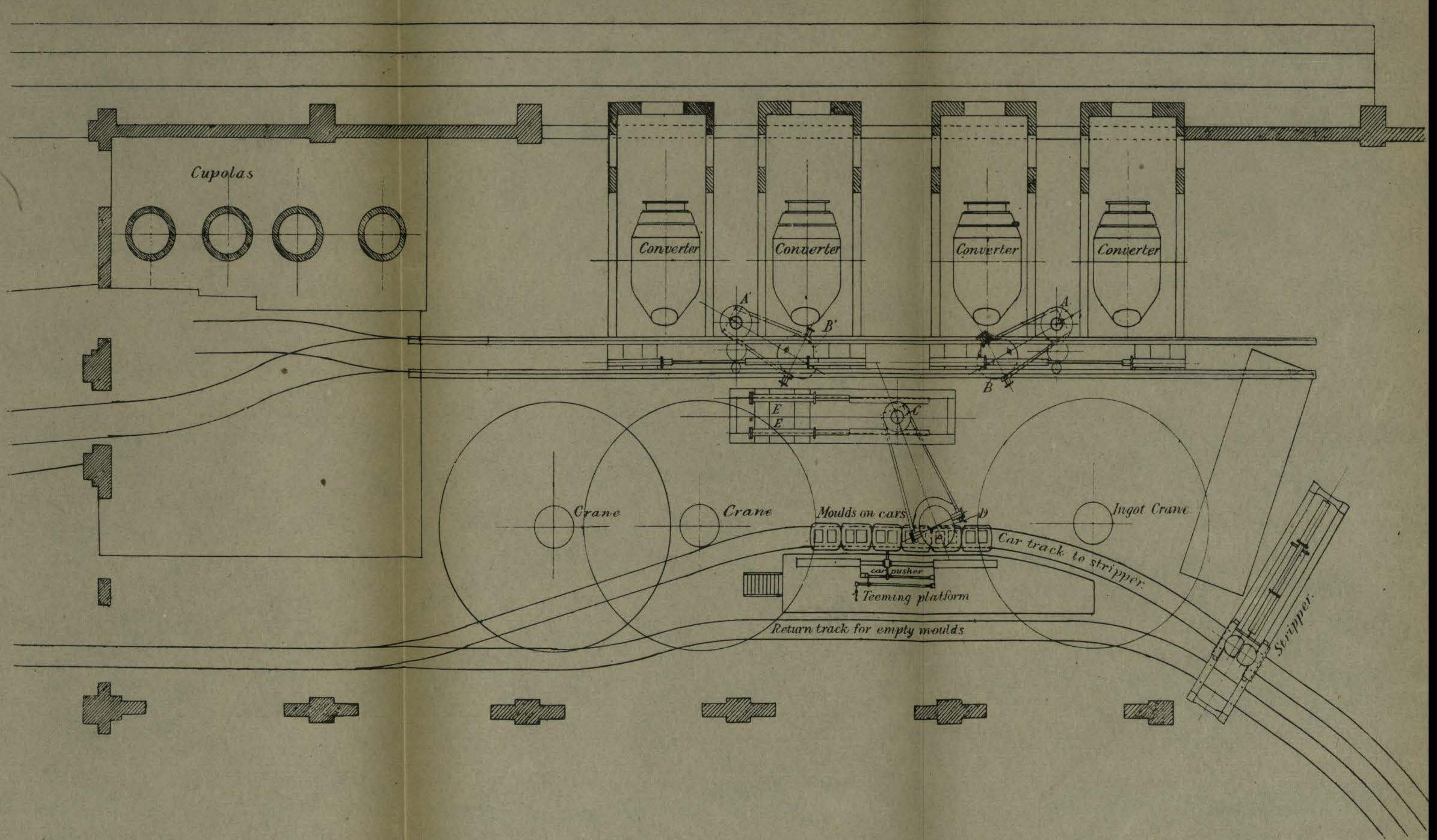


Fig. 67.

unless this is "scrapped" with great judgment "wild" metal, which produces unsound ingots, is likely to result. Gradually the action becomes less violent, the flame contracts and disappears almost entirely, this point being known as the "drop of the flame," and marking the almost complete removal of the Carbon. The converter is turned down immediately the flame drops, any further blowing tending to the production of over-blown metal, which is very liable to be red short.

**Finishing the Charge.**—The bath is now ready for the "additions" or "finishing metal," and the required amount of Ferro, in the case of mild or dead soft steel, and Spiegel, or Spiegel and Ferro and Hematite iron, in the case of rail or harder steels, is at once added, to give the content of Carbon and Manganese required in the finished product.

The addition of Manganese in some form to the blown metal is absolutely necessary in ordinary cases, as without it the steel is quite unworkable. When mild or dead soft steel is being made, Ferro-Manganese containing from 70 to 80 per cent. of Manganese is usually employed; this is either thrown into the converter cold, or, in some cases, first heated to redness. When higher Carbon steel is required, Spiegeleisen, which is a much poorer alloy of Manganese and iron, containing from 10 per cent. to 30 per cent. of the former, is used, and this is always melted in a cupola and added in a molten state, as the quantity required to give the right percentage of Manganese in the finished steel would often be more than the bath of molten metal would be able to melt, especially in the case of cold heats. Although Ferro-Manganese and Spiegel contain very different percentages of Manganese, the percentage of Carbon in each may be regarded for practical purposes as nearly the same, and consequently the addition of 100 lbs. Ferro containing 80 per cent. of Manganese, and 400 lbs. of Spiegel containing 20 per cent. of Manganese, although giving the same amount of Manganese, would give very different amounts of Carbon, the latter four times the quantity of the former; thus, when it is required to raise the Carbon without appreciably increasing the Manganese content, it can be done by using a large quantity of poor Spiegel low in Manganese instead of a rich Ferro-Manganese. The following may be taken as typical analyses of different percentages of Ferro-Manganeses and Spiegels, and it will be seen that the Carbon slightly decreases with the percentage of Manganese:—

| | Ferro-Manganese. | | Spiegels. | | |
|---|---|---|---|---|---|
| | (1) | (2) | (1) | (2) | (3) |
| Carbon, | 6·58 | 6·20 | 5·66 | 5·00 | 4·84 |
| Silicon, | 1·00 | 1·14 | 1·20 | 1·10 | 1·21 |
| Sulphur, | Trace | Trace | Trace | Trace | Trace |
| Phosphorus, | 0·12 | 0·09 | 0·07 | 0·06 | 0·06 |
| Manganese, | 82·00 | 70·00 | 40·50 | 20·40 | 10·21 |
| Arsenic, | 0·10 | 0·10 | 0·10 | 0·10 | 0·11 |
| Iron, | 9·90 | 22·20 | 52·30 | 73·20 | 83·40 |

The Phosphorus should not exceed 0·10 per cent., and if possible not 0·06, but in these days it is often very difficult to get Ferro-Manganese and Spiegel which are so low, and this is one of the difficulties with which steel makers have to contend in the manufacture of steel very low in Phosphorus.

After the addition of Ferro-Manganese or Spiegel, the metal is allowed to remain at rest in the converter for a few minutes to allow the "additions" to melt and mix, and is then poured into the casting ladle. Some blowers turn the vessel just up and down, allowing the blast to pass through for a few seconds before pouring, to mix the charge completely. There is of course a limit to the re-carburisation to be effected by Manganese additions, and molten Hematite pig-iron is sometimes added to increase the Carbon, but this too can be used only to a limited extent for the manufacture of high Carbon steels. Darby's re-carburising process, which is described in detail in connection with basic practice, may be used with excellent results, or the blow may be stopped before all the Carbon has been removed. In Sweden it has been the practice since the early Bessemer days to stop the blow when the required Carbon point has been reached, and in some of these works no Manganese additions are made. This stopping of the blow at any required point is possible only when very small charges are blown, and when pig-iron of great regularity is employed. The pig-iron used in such cases is usually very low in Silicon and Sulphur, and high in Manganese, the latter being absolutely essential if Manganese additions are not made.

**Casting.**—After pouring the finished steel into the casting ladle, the latter is transferred to the centre casting crane, and the ingots cast as quickly as possible, all delays being avoided. A good blower, who generally teems the heat himself, will always see that his pitmen have a set of sharp-pointed bars at hand in case of difficulties. Teeming, which looks a very simple operation, is really one requiring very considerable skill and judgment, if sound ingots and little scrap are to be made.

Ingot moulds must not be filled too rapidly, or they will rise and "pipe"; and, on the other hand, if teeming is done too slowly, there is a very fair chance of never filling them at all, as the metal will probably set round the nozzle of the casting ladle. Sometimes a small piece of metal setting in the edge of the nozzle outside will divert the stream from the vertical, and cause it to splash on the sides of the ingot moulds, but generally a sharp-pointed bar and a skilful man will remove this.

**Running Stoppers.**—In the event of a running stopper—*i.e.*, a stopper which refuses to shut close—little can be done except to move the ladle as rapidly as possible from mould to mould, and to see that the pitmen remove the scrap from the top edges of the moulds the moment they can get near. In the case of metal partially setting in the nozzle, it may often be removed by one man holding a sharp-pointed bar, with end bent up at right angles, under the nozzle, while another drives it into the nozzle with a sledge, and then rapidly knocks it out again. This is one of those practical things which must be done very quickly and skilfully if it is not to do more harm than good, and is a distinctly dangerous operation for a clumsy man to attempt. If this is not successful, the only thing to do is to remove the nozzle-box on the bottom of the ladle, and knock the nozzle out, when the steel must be caught in the moulds as best it can. This is rarely successful, and frequently ends in spoiling several moulds by covering them with molten steel, and it is generally better to tip the ladle and pour the steel into one corner of the pit. These accidents rarely occur in a well-managed works, but even under the best management they will sometimes happen, and appliances must always be at hand to clear the pit rapidly as soon as the steel has set. When the steel is once in the ingot moulds, if it shows any sign of rising in the moulds, as it frequently does in the case of "dead soft" steel, the sooner the moulds are "stoppered down" the better. Sand and a steel plate held down by a bar through the "lugs" on the mould, secured by wedges, will do this very effectually, and this is the usual plan in most works. If the steel is



quiet in the moulds, there is no necessity to "stopper down" at all, a piece of steel sheet or thin plate placed on the top of the molten metal to cool the surface being quite sufficient. Directly the ingots have set, which will take from three to ten minutes, according to their size and the grade of the steel (whether high or low Carbon), the wedging down plates are removed, and the ingot moulds are stripped off the ingots by lifting them with the ingot crane. Where casting on cars is in use, the bogies are taken away direct to the "stripper." In cases where the ingot refuses to leave the mould after a few blows with the sledge-hammer, and where there is no stripper, it should be put on a bogie and taken to the sticker press. This is simply a powerful hydraulic machine, which is really a primitive form of "stripper," by which it has been replaced at all modern works. During the teeming of the heat, a small sample is usually caught in a hand ladle and poured into a cast-iron mould, and is known as the "pit sample." This is taken to the smiths' shop and drawn down to a bar about 0·75 square inch, a piece cut off one end and welded to the other. To make sure that the weld is sound, a hole is often punched in the weld, and this is enlarged by drifting. If the steel stands this test (see p. 328), it may be considered satisfactory as regards welding. The other end of the bar, after cooling, is bent over an angle block with a radius one and a-half times the thickness of the bar, and for dead soft steel it should bend through an angle of 180°. The sample is then sent to the laboratory for analysis.

The pit is now reset with ingot moulds to be ready for another charge. Before replacing the moulds it is usual in most works to dip them in a deep bosh or tank containing a thin wash of fireclay and blacklead, which protects them to some extent from the cutting action of the molten metal, and also largely prevents the ingots from sticking. Before "boshing," the moulds should be as cool as possible, as if plunged into the wash hot, they are liable to crack, and anything approaching rapid water-cooling should be avoided.

The ingots, on removal from the moulds, are either transferred direct by one of the ingot cranes to a soaking pit, or vertical re-heating furnace near the casting pit, or placed on a bogie and taken to vertical or horizontal re-heating furnaces nearer the mill, according to the arrangements for re-heating at the particular works.