show plan and sectional view of Talbot plant with central rotating furnaces of the Talbot type.

In the new plant at Witkowitz, Austria, which is now in course of erection, there will be four large tilting furnaces for the Talbot process, which will follow largely the lines of the Skinningrove furnace, but which will be arranged to be electrically tilted, as most of the furnaces in America are, whereas in Great Britain all the furnaces are tilted by hydraulic power.

As regards the quality of steel produced when working hematite iron, the product is exceptionally pure, and when the usual basic pig-iron with, say, 1·7 per cent. of Phosphorus is used steel is obtained in every respect equal to basic Siemens from the same class of pig-iron. The removal of Sulphur and Phosphorus takes place under conditions similar to those in the ordinary basic Siemens, the Talbot process having the advantage that the temperature of the bath and the composition of the slag can be more readily controlled and modified to suit the conditions of working.

The great possibility of the Talbot process, however, in the opinion of the author, lies in the facilities it offers for extremely rapid work with ordinary hematite iron as at present used in Siemens and Bessemer acid practice. In working metal of this kind, especially if it is first passed through a mixer to insure fairly average composition, the output should be very large indeed, as the Silicon, under basic conditions of work, is oxidised almost immediately, and it only remains to reduce the Carbon to the required extent, which can be done very rapidly, and the steel is ready to teem into the ingot moulds.

The Twynam Process.—A process of direct reduction of iron ore to steel has been patented by Mr. Twynam in several countries. In some early experiments carried out at Brymbo some years back, Mr. Twynam found that the reduction of iron, from iron ore and Carbon briquettes, thrown into the bath of metal in a basic-lined open hearth furnace, was very rapid and complete; thus in one experiment, in which 30 cwts. of such briquettes were added, the slag, ten minutes after the last of the briquettes had been thrown in, contained only 4·08 per cent. **Fe**, with 19·3 per cent. Phosphoric acid. The comparatively small quantity of such briquettes which can be added to a charge in a fixed furnace and the growth of the banks and bottoms which was found to result, caused the abandonment of the experiments. These difficulties would appear to be overcome by effecting the direct reduction of a mixture of ore or Oxide and Carbon (preferably briquetted), in conjunction with the continuous working of a basic-lined open hearth furnace, preferably of large dimensions and of the tipping type, such as those now used for the Talbot process. The addition of such briquettes would be made continuously throughout the week, the excess of slag would be poured off from one side of the furnace, and the metal, either as finished steel, or metal for further treatment in a second furnace, would be teemed from time to time as the capacity of the furnace demanded. There should be no trouble with the bottom or side growing, as there is with a fixed furnace worked in the ordinary discontinuous way, as the large reservoir of metal always present in the continuous method of working, would, it is claimed, wholly prevent this.

The Monell Process.—In this process, instead of charging iron ore, limestone, and cold pig-iron, the ore and limestone are first charged, heated to a high temperature near to insipient fusion, and then molten iron poured into the furnace. The process is described as follows, by Mr. Monell*:—

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* *Iron and Steel Inst. Journ.*, 1900, vol. i., p. 75.

“The process consists in charging in a basic open hearth furnace limestone and a relatively large quantity of ore, heating these, and then charging molten pig metal taken from a mixer or direct from the blast furnace. The temperature of the resulting mixture must be sufficiently high to produce a rapid slag formation, and yet low enough to ensure the rapid oxidation of the Phosphorus. The slag formed rises in a foam and is drawn off at a cinder notch. One hour after charging the molten pig the bath is practically free from Phosphorus, Silicon, and Manganese, and the bulk of the slag containing the impurities has been removed. The bath is then in the best possible condition to be acted on by the flame and remaining ore which has not yet been reduced. The steel may be tapped when the Carbon has reached the desired point. Either mill scale or tap cinder may be substituted for the ore, and the proportion of Oxide may be varied according to the percentage of Carbon desired in the finished product.”

The only difference between this and the ordinary basic Siemens process consists in preheating the limestone and relatively large quantities of ore in the furnace, charging molten metal instead of cold pig-iron, and removing the bulk of the slag through a cinder notch at an early period of the working of the charge. The process is stated to have given good results at the Homestead Works; it has been tried experimentally at one works in England, but the results were not sufficiently promising to lead to the process being adopted.

There is no doubt that any process which brings highly heated Oxides under basic conditions into intimate contact with fluid iron, will lead to rapid purification of the iron, but the semi-fusion of Oxides on a basic hearth must inevitably soften the bottom of the furnace, entail very heavy repairs, and generally cause considerable trouble in working, especially when dealing with Phosphoric and more or less silicious irons, such as are usually used in this country. Further, the removal of the slag at an early stage of the operation must inevitably lead to considerable waste of Oxide of Iron, as the slag at this period must of necessity contain a very high percentage of iron.

Duplex Process.—Various attempts have been made at different works to combine the Bessemer and basic open hearth processes by partially blowing the metal in an acid or basic converter and then finishing in the basic open hearth, but, so far, they have not been attended with great success. One of the latest developments in this direction is to desiliconise in an active mixer, blow down in basic converter, to remove the greater part of the Phosphorus, and then finish in a basic open hearth, using about two-thirds blown metal and one-third molten mixer metal for the open hearth charge. By this means the output of the open hearth plant has been more than doubled, and the gain in this direction is so great that it alone seems almost to justify its adoption. Important, however, as output is, it is not everything, and the costs of Bessemerising, together with the decrease in yield, are very serious drawbacks, and it is doubtful if the advantages are not more apparent than real. Under special circumstances, where pig-iron is very cheap, fuel dear, and labour costs high it might pay to waste a considerable percentage of iron in return for a great increase of output, but even under these conditions most careful investigations would be necessary before a definite opinion as to the economy of this method of working could be given. Although in some special cases a modification of the duplex process may be found to be economical, the fact remains that in most cases the extra costs of working two processes, and the low yield of ingots, has been found as the result of experience, to more than counterbalance any gain due to the increase in output, &c. At present the use of molten mixer metal, refined as far as possible in an active mixer, so that Silicon is reduced to 0·5 per cent. or less, and taken direct to an open hearth Talbot or similar furnace, must be considered the most economic method of working.

Heat Developed by Oxidation of Metalloids in Siemens and Allied Processes.—It has already been mentioned in Chapter v., when considering the thermo-chemistry of the Bessemer process, that the heat units evolved by the oxidation of the impurities in the open hearth process are the same as in the Bessemer, less the heat absorbed in the reduction of the Oxide of Iron to supply the necessary Oxygen. In the ordinary acid process, when the pig-iron and scrap are charged cold, about 40 per cent. of the impurities present are oxidised by the flame during melting, and consequently it is only the metalloids remaining in the metal when melted which are oxidised by the Oxygen from the ore added. In the basic Siemens, when Oxides are added with the cold charge, these react during the melting period, and it is impossible to say how much oxidation is due to these, and how much to the direct action of the flame. We shall, therefore, consider the case where the metal is charged into the furnace in the molten state.

Assuming that *molten pig*-iron and *fluid Oxides* are brought together at such a temperature that they can react, the net result of the oxidation of the Silicon to SiO_2, of Phosphorus to P_2O_5, and of Manganese to MnO, after allowing for heat absorbed by the reduction of the Oxide of Iron, is a gain, and the net result of the oxidation of Carbon to CO by Oxide of Iron is a loss.

If all the Oxide is added in the form of Fe_2O_3, some will be reduced to FeO, will unite with the Silica to form a slag, and some will be reduced to Fe. If a mixture of FeO and Fe_2O_3, such as Oxide cinder, roll scale, &c., is added, as is a common practice in basic Siemens working, there will be sufficient FeO to unite with the Silica, and no heat units will be necessary for its reduction. The Carbon is oxidised by the Oxide to CO, and this CO, as it escapes from the bath of metal, is burnt to CO_2 by the Oxygen in the gases with a further development of heat; but, in the ordinary process, this evolution of CO is very gradual, is spread over a long period, and it is not fair to assume that the heat is effective to any appreciable extent.

In the Talbot process the total heat units developed and absorbed are exactly the same as in the case of basic open hearth working with molten metal, but it is claimed that, although the heat developed is the same, it is *practically much more effective*, as the greater portion of the Silicon and Carbon is removed, during the first half hour, after charging the molten metal, and the heat units are concentrated in the bath; the loss by radiation is thus far less than if the reactions were spread over some hours, as in the ordinary Siemens. Again, although the Carbon, oxidised to CO in the bath, is attended with absorption of heat, the CO is evolved in such quantities that in burning to CO_2 it fills the entire furnace with flame, and during the reaction the gas is shut off from the furnace, the heat developed by the combustion of the evolved CO being sufficient to maintain the heat of the bath. It therefore seems reasonable to admit that both the rapid oxidation of the Silicon and the combustion of the CO to CO_2 by the hot air from the regenerators is attended with an effective gain in heat units.

The Talbot and the ordinary open hearth process may be compared respectively with two converters, one with an ample supply of air so that the oxidation of the impurities is completed in a short time, and one with a deficient supply of air, in which the oxidation of the same quantities of impurities takes three or four times as long. In both cases the total heat evolved is the same, but the temperature of the baths of metal at the end of the operation will be very different.

The heat units evolved in the Bertrand-Thiel process, for the same composition of metal, will be the same as in the basic Siemens.

As an example for calculating the heat developed by the oxidation of the impurities, we will take 1000 kilos. of metal, of the following composition:—Carbon, 3·5 per cent.; Silicon, 1·0 per cent.; Phosphorus, 1·0 per cent.; Manganese, 1·5 per cent.

The following figures will be required for the calculations :—

HEAT DEVELOPED BY COMBUSTION OF 1 KILOGRAM OF ELEMENT.

C to CO_2, ...	8,080 heat units or calories.
C ,, CO, ...	2,450 ,,
Si ,, SiO_2, ...	6,414 ,,
P ,, P_2O_5, ...	5,890 ,,
Mn ,, MnO, ...	1,654 ,,
Fe ,, FeO, ...	1,232 ,,
Fe ,, Fe_2O_3, ...	1,746 ,,

There are 700 grammes of Fe in every kilo. of Fe_2O_3, therefore tne heat absorbed by the reduction of 1 kilo. of Fe_2O_3 will be—

$$\frac{1,746 \times 700}{100} = 1,222·2 \text{ heat units.}$$

1,000 kilos. of metal of above composition will contain 35 kilos. of Carbon, 10 kilos. of Silicon, 10 kilos. of Phosphorus, and 15 kilos. of Manganese.

It is assumed that FeO is added in sufficient quantity to combine with the SiO_2, and no allowance is made for the reduction of the Fe_2O_3 found as FeO in the slag, it being assumed that the whole of Fe_2O_3 is reduced to metallic iron. As a matter of fact, this assumption does not appreciably affect the result, and only makes a difference of about 200 heat units. No allowance is made for the heat developed by the combination of SiO_2 and P_2O_5 with the bases in the slag, as the heat of formation of these is somewhat doubtful; on the other hand, no correction is made for the heat absorbed in the dissociation of the Silicides and Phosphides in the metal, but these may be fairly considered as balancing each other, and, if anything, probably the heat developed is greater than that absorbed.

As the Silicon, Phosphorus, and Manganese show a nett gain in heat units, we will consider these first.

SILICON.

	Heat Units.
10 kilos. of Si evolve on oxidation, ...	6,414 × 10 = 64,140
10 kilos. of Si require 38·1 kilos. Fe_2O_3, absorbing .	38·1 × 1222·2 = 46,564
Heat units evolved, ...	17,576

PHOSPHORUS.

	Heat Units.
10 kilos. of P evolve on oxidation, ...	5,890 × 10 = 58,900
10 kilos. of P require 43·0 kilos. Fe_2O_3, absorbing .	43 × 1222·2 = 52,554
Heat units evolved, ...	6,346

MANGANESE.

	Heat Units.
15 kilos Mn evolve on oxidation, ...	1,654 × 15 = 24,810
15 kilos. Mn require 14·5 kilos. Fe_2O_3, absorbing .	14·5 × 1222·2 = 17,722
Heat units evolved, ...	7,088

We thus see that in each of the above cases more heat is evolved than is absorbed, and the total heat units evolved equal

$$17,576 + 6,346 + 7,088 = 31,010 \text{ heat units.}$$

On the other hand, if we consider Carbon, we have

	Heat Units.
35 kilos. C evolve on oxidation to CO, . . .	35 × 2,454 = 85,890
35 kilos. C require 155·7 kilos. Fe_2O_3, absorbing	155·7 × 1,222 = 190,265
Heat units absorbed, ...	104,375

	Heat Units.
Thus by oxidation of Carbon we have an absorption of . . .	104,375
And by the oxidation of Si, P, and Mn an evolution of . . .	31,010
Showing a loss of	73,365

This is without making any allowance for heat units developed by the combustion of CO to CO_2 by the free Oxygen passing into the furnace, and if we take this we get

35 kilos. of C burnt from CO to CO_2 by Oxygen, 35 × 5,630 = 197,050 heat units evolved.

Assuming that all these heat units were utilised, the nett results would be—

	Heat Units.
Heat units generated by Si, P, and Mn, ...	31,010
Heat units generated by combustion of CO to CO_2, . . .	197,050
Total heat units evolved, ...	228,060
Less heat units absorbed by combustion of C to CO by means of Fe_2O_3,	104,375
Nett total of heat units generated, ...	123,685

Even in the Talbot process it is not reasonable to assume that all the heat generated by combustion of CO to CO_2 is effective, but if we assume that one-third is utilised in the furnace it will practically balance the loss entailed by the reduction of the Oxide necessary for the oxidation of Carbon to CO.

To sum up, we may say that Si, P, and Mn are heat producers in all open hearth processes, while the combustion of Carbon is attended with more or less loss of heat, varying with the conditions of working, so that the nett result is a loss, and extraneous heat has to be supplied not only to compensate for this, but to supply the heat necessary for fusing the Oxides and basic additions, and the heat lost by radiation, &c.

General Arrangement of Open Hearth Melting Shop.—The usual form of casting pit in a Siemens furnace plant is a long straight pit, about 6 feet deep, and running the entire length of the shop in front of the furnace, and in this the ingot moulds are placed. The casting ladle on a carriage (fig. 151, p. 165), is either run on rails over the pit, as shown in figs. 117 and 125, or suspended by an overhead crane capable of traversing the entire length of the shop. This arrangement of pit is still very common, but the tendency in modern works has been to move the casting pit further away from the furnaces when possible. The simplest way of doing this is to take the casting ladle away on a suitable railroad by means of a locomotive to a straight pit at a reasonable distance from the shop, or it may be taken away to a circular pit and the ladle transferred to a central casting crane. This last arrangement is in use in several works in England, and was formerly in use at the Homestead Works in America. Fig. 176 gives a general plan of the melting shop at the latter works in 1890, and shows the arrangement for removing the ladle, when full of steel to the casting pit. This plant is a very costly one, as there are ten large hydraulic cranes to eight furnaces. By raising the furnaces in the ordinary way to such a height above the ground level that the casting ladle can be run under the spout of the furnace for tapping, all the central cranes in front of the furnaces are dispensed with, and only those in the casting pits are required.

Both at Pencoyd and at the Phœnix Iron Works in America a semicircular pit is arranged in front of each furnace, with one hydraulic top-supported crane serving each furnace, as shown in fig. 177. This is distinctly an expensive installation, but less so than the Homestead arrangement.

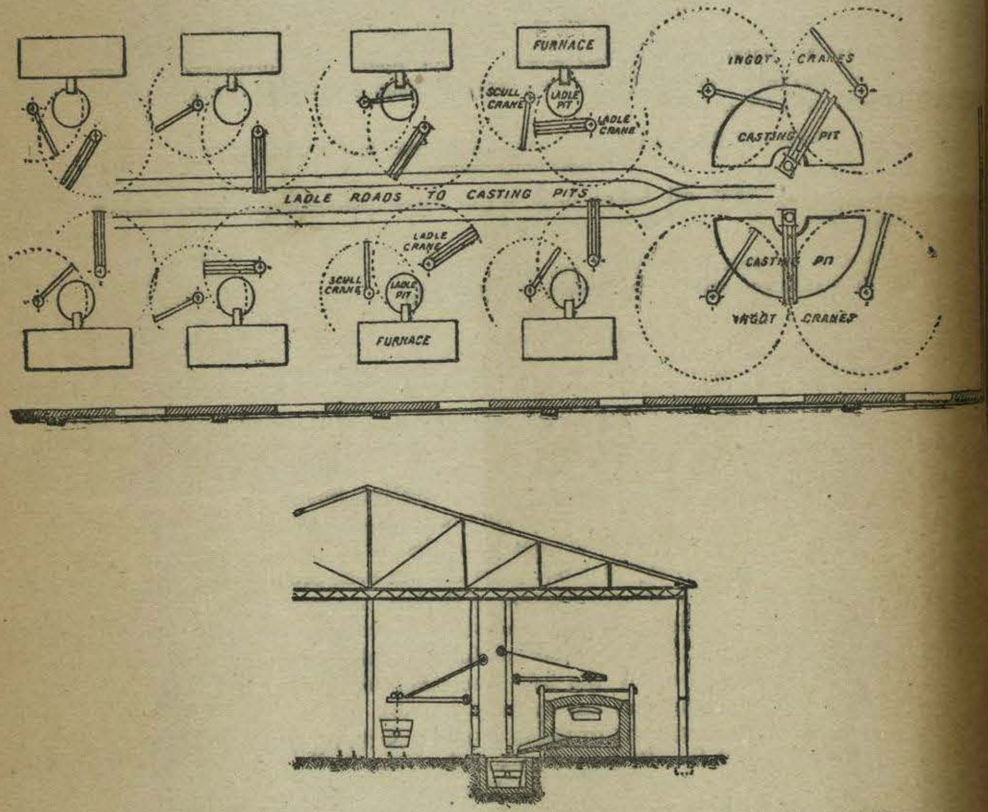
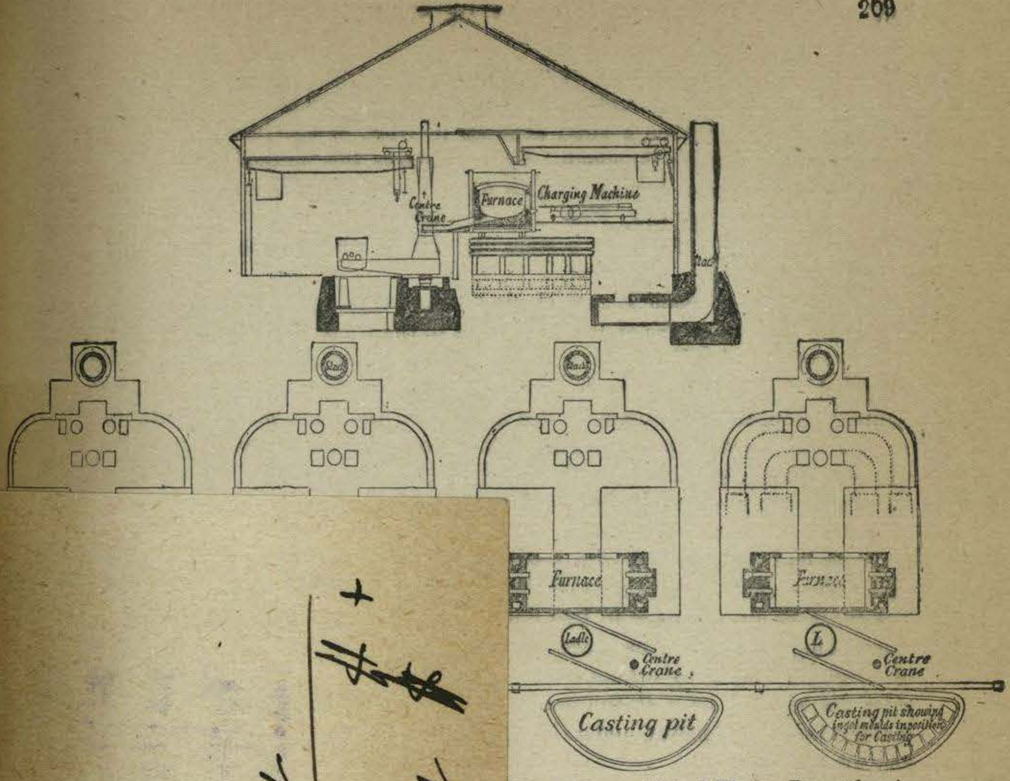


Fig. 176.—General Arrangement of the Homestead Siemens Melting Shop, 1890.

The furnaces stand in two rows, with two ladle roads between them. The furnaces, as shown in the sketch, are built so that the taphole is only just above the ground level, and the casting ladle is lowered into a pit in front to receive the charge of steel. In front of each is a 60 ton hydraulic ladle crane and a 5-ton slag and scull crane, both top-supported and built of H beams. After the metal is tapped into the ladle the latter is transferred to a four-wheeled bogie-car, run by a locomotive to one of the semicircular casting pits, where it is again transferred to one of the 60-ton central casting cranes and the metal teemed. There are two ingot cranes to each casting pit, as shown.

In view of the introduction of car-casting, the ladle suspended from an overhead crane running in front of the furnaces seems to be one of the best



hop at Pencoyd Steel Works, Pennsylvania.

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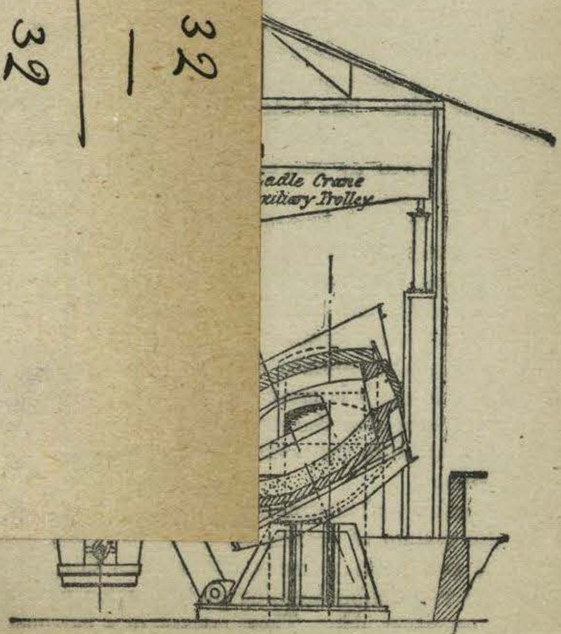

Fig. 178.—Wellman Furnace, with Casting Ladle carried on Overhead Ladle Crane.

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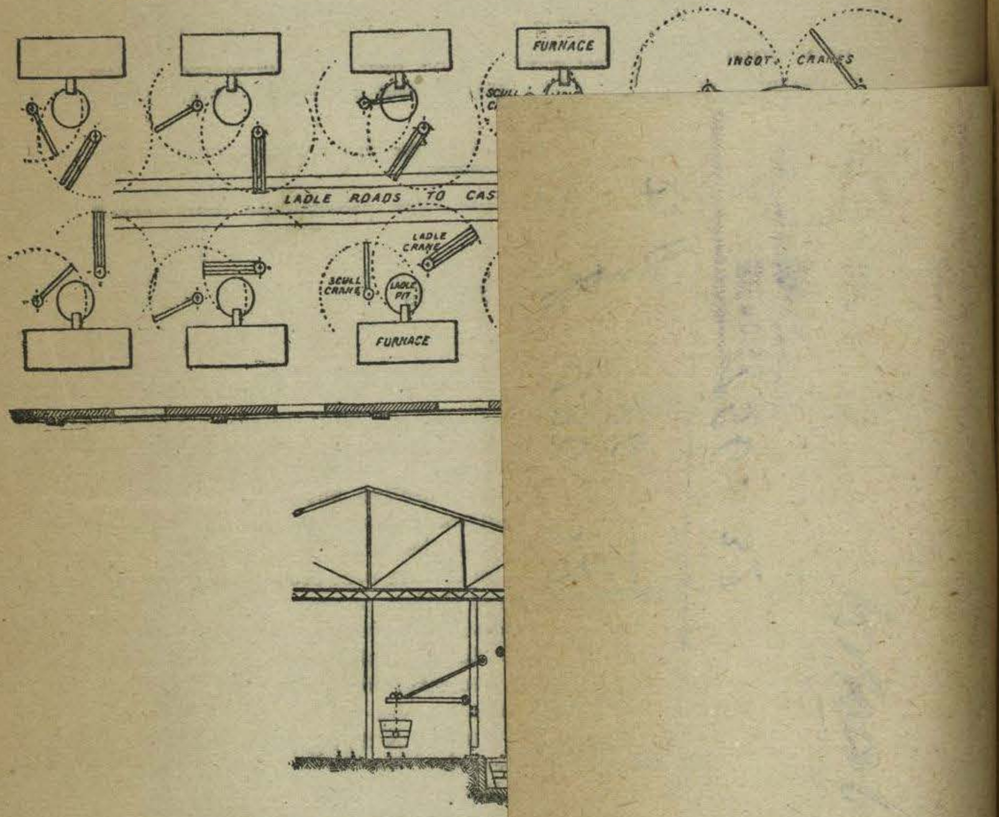

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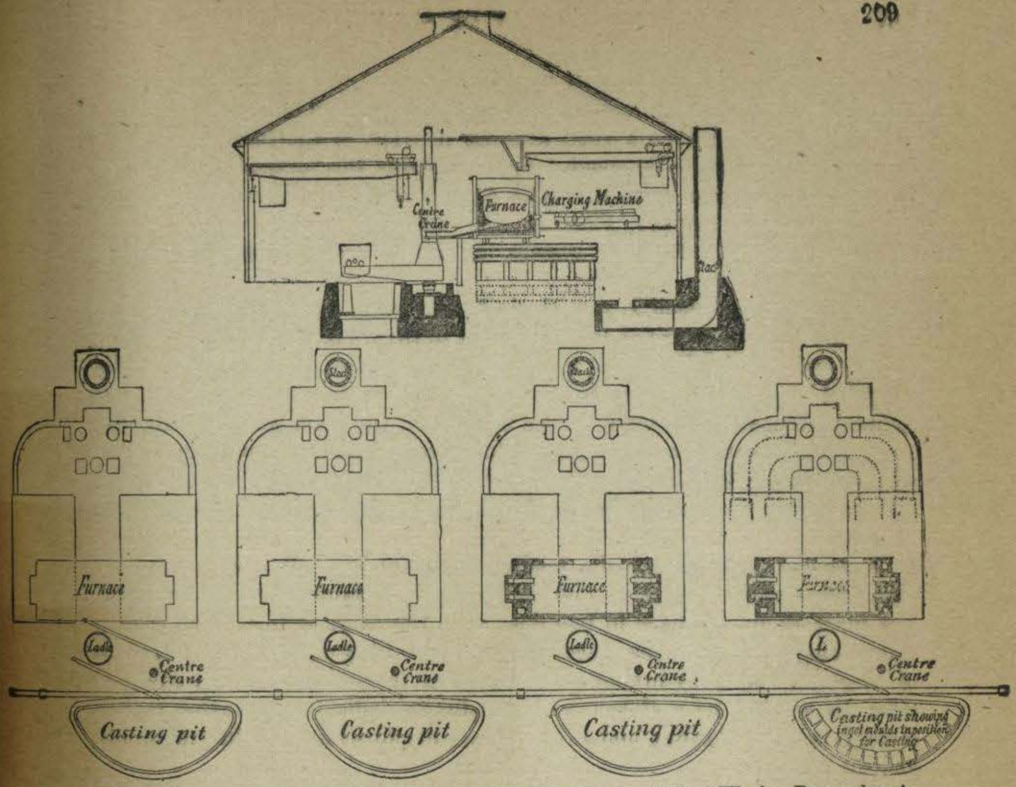

Fig. 177.—General Arrangement of Melting Shop at Pencoyd Steel Works, Pennsylvania.

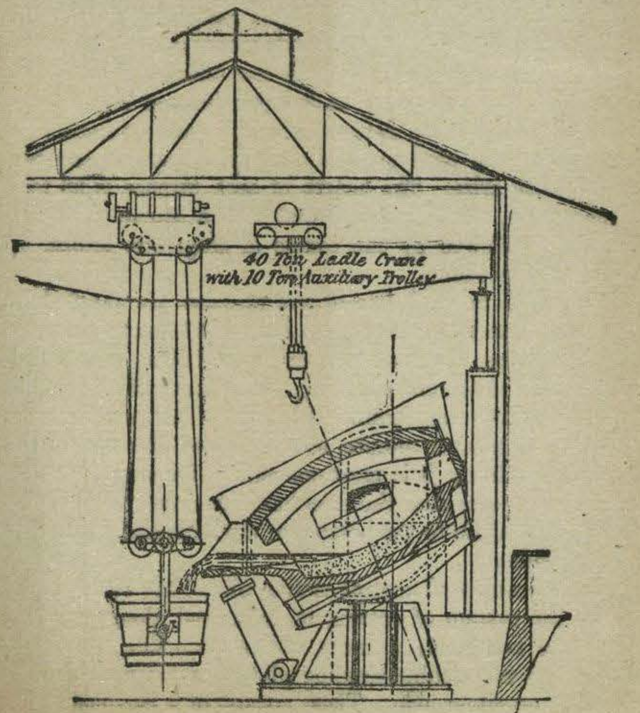

Fig. 178.—Wellman Furnace, with Casting Ladle carried on Overhead Ladle Crane.

arrangements, and is now largely used in America. The ladle can be readily raised or lowered, and, provided the span of the overhead crane is fairly large, the casting can be done a good distance in front of the furnace, and not necessarily right under its spout. Fig. 178 shows this method of casting as applied to a Wellman furnace. With a good type of modern crane, similar to that shown in fig. 153, Plate xi., the ladle can be easily manipulated, and it is probably the best system, especially when casting on cars is adopted.

Another modification in casting was some years ago introduced by Mr. Wellman, who, by means of an attachment to the front of the furnace known as the fore-hearth, dispensed with the casting ladle altogether. It really consisted of a ladle fixed on to the front of the furnace provided with two ordinary stoppers for teeming in the usual way, the ingot moulds being run on cars underneath the two nozzles, which are at such a distance apart that two moulds can be filled simultaneously. This arrangement, however, has not given such good results in practice as were anticipated, and has not been used to any extent.

A general arrangement of a modern open hearth plant is shown by the plan and elevation (Plate xv.) of the Homestead plant as erected in 1898.* The furnaces are arranged in two lines as in the plant of 1890, with casting sides facing each other, the space between them being covered by two groups of overhead travelling cranes. The furnaces themselves and the charging sides are covered by a 40-ton crane handling a ladle for conveying molten metal from a metal mixer, and a 15-ton crane employed for handling materials, and for repairs, &c.

The furnaces, of 45 tons, are built on solid brick bottoms on the ground level, and in front of each is a ladle pit for lowering the ladle beneath the metal spout during tapping. The air and gas regenerative chambers are exceptionally large, being 22 feet long inside measurement and 14 feet 2 inches high to the top of the arch, and the air 10 feet and the gas 6 feet wide. The air chambers thus have a capacity of 65 cubic feet per ton of charge. Each furnace is provided with a separate stack, and at present natural gas is used, but every provision has been made so that producer gas can be employed should the necessity arise. The hearth of each furnace is 28 feet long and 13 feet 8 inches wide, and is built up first with a course of firebrick, then a course of chrome, followed by one course of Magnesite bricks, upon which loose basic material is burnt.

The casting ladles for each line of five furnaces are handled by a 75-ton Morgan electrical travelling crane with a span of 37 feet 8 inches and a hoisting speed of 12 feet per minute. On the lower flanges of the girder, as will be seen by reference to the elevation (fig. 180), runs a 25-ton auxiliary crane, so that jointly the two can handle 100 tons. This auxiliary crane has a hoisting speed of 25 feet per minute, and the speed of travel of the bridge is 200 feet per minute, hence it is most convenient for emptying the slag from the ladle into a slag bogie after the steel has been cast. This is expeditiously done by attaching a chain to the bottom of the ladle and using this auxiliary crane to tilt the ladle.

The hydraulic cranes and central casting pits of the 1890 plant have been superseded by the system of casting on cars, and along the centre of the main building are two pouring tracks, one on each side, on which the ingot moulds travel, and two double teeming platforms are provided, with appliances for casting on either side. These consist of a car-pusher operated by

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* Taken from a sketch in the *Iron Age.*

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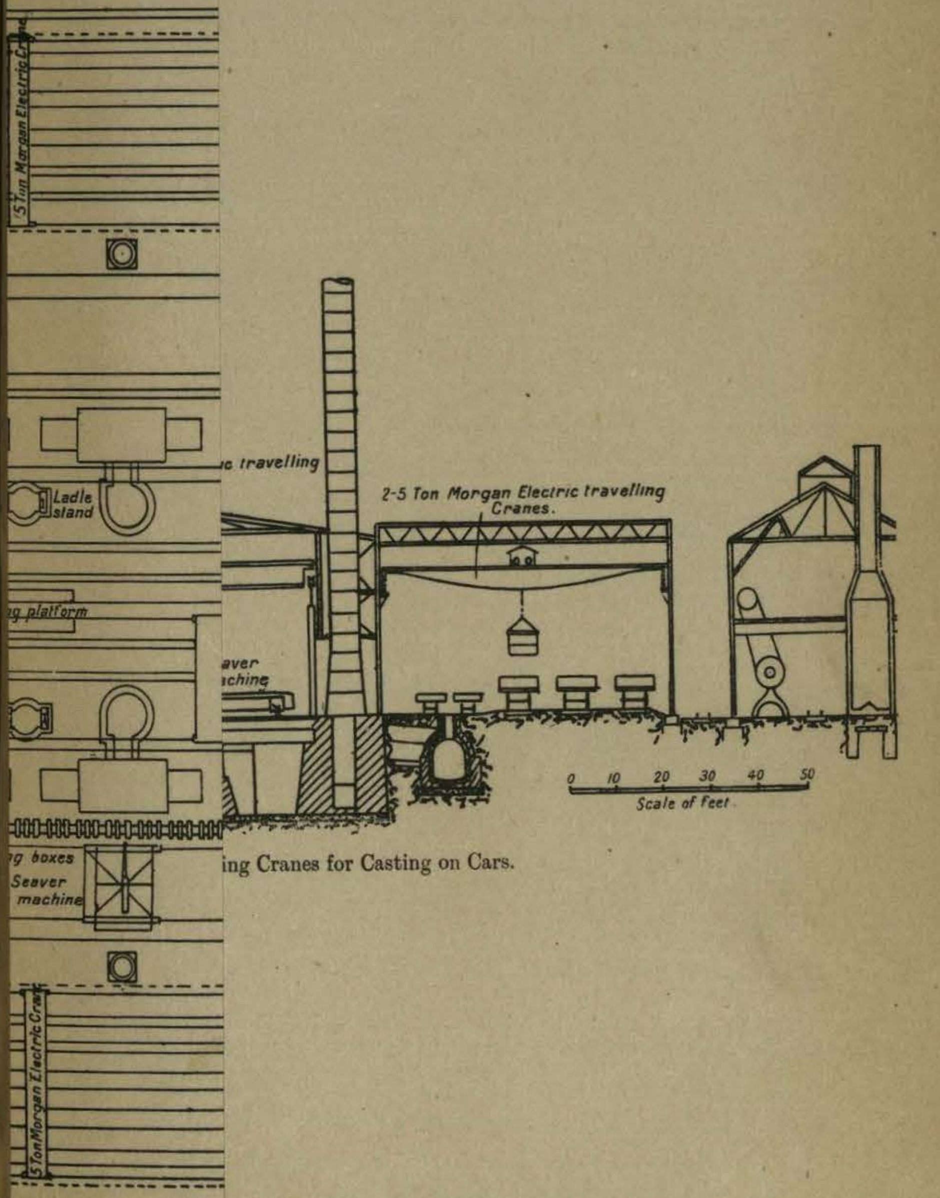

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PLATE XV.—Homestead Open Hearth Plant.

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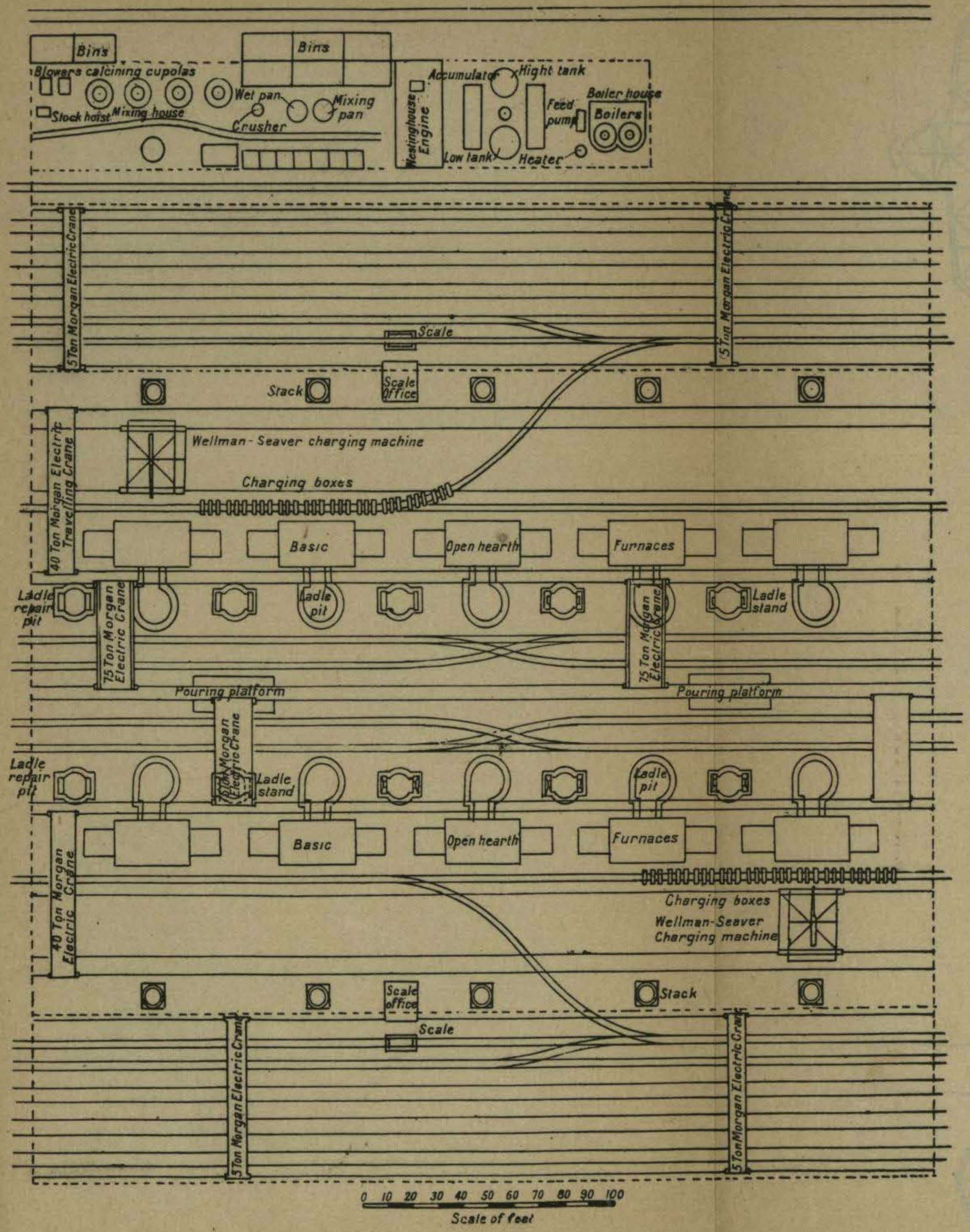

Fig. 179.—Plan of Homestead Open Hearth Plant.

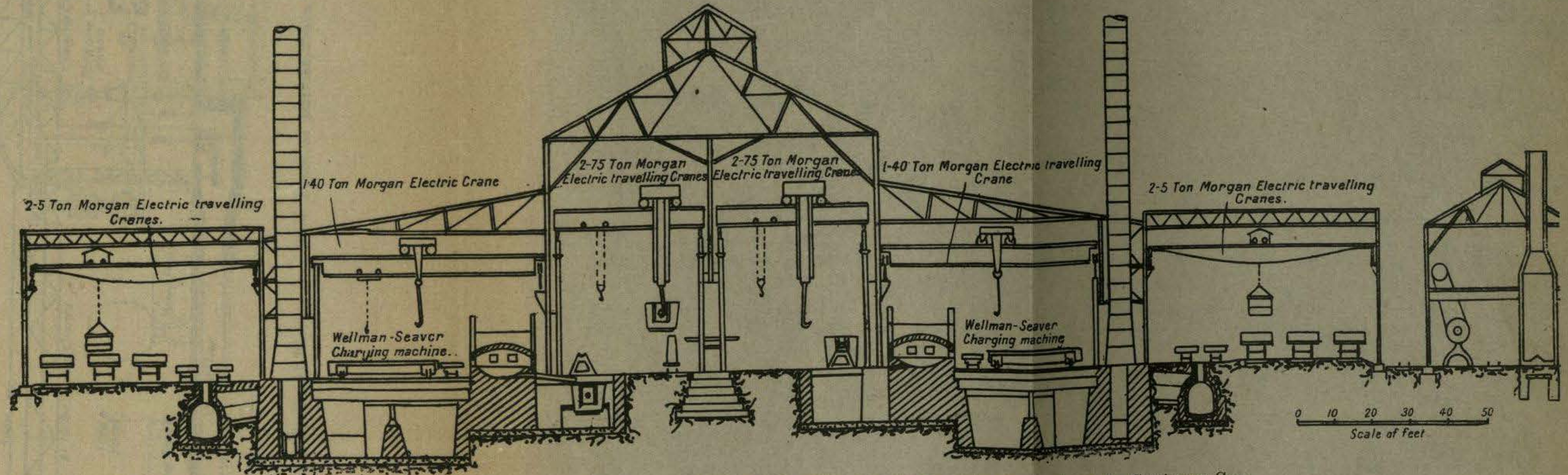

Fig. 180.—Transverse Section through Homestead Open Hearth Plant, showing Overhead Casting Cranes for Casting on Cars.

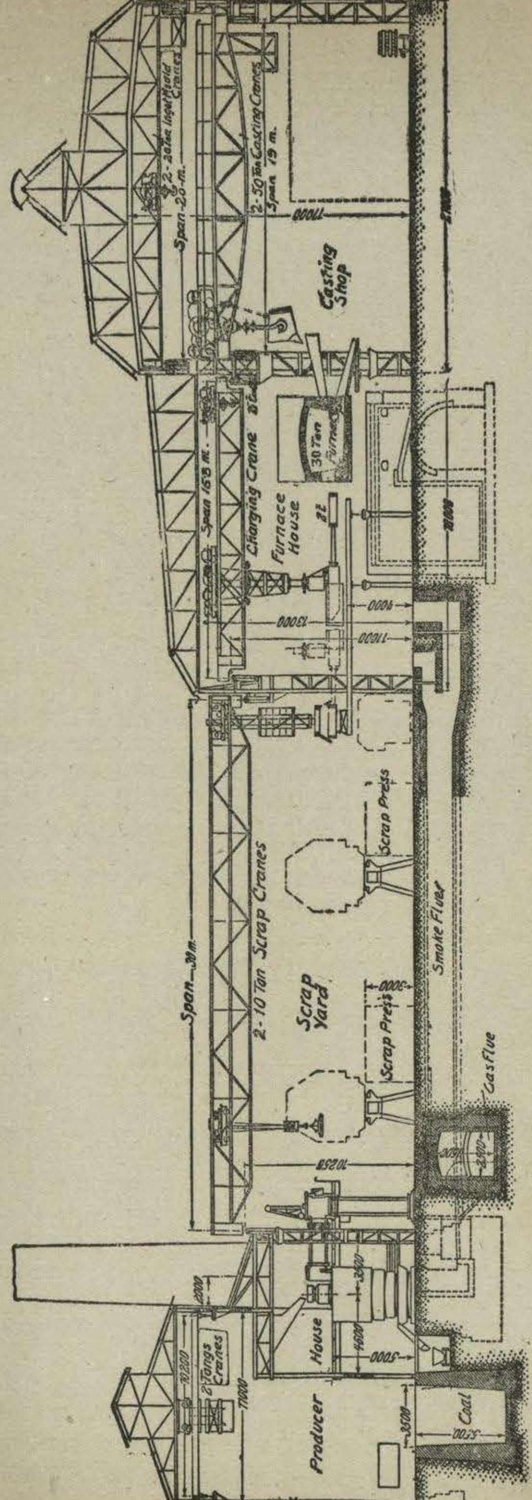

Fig. 181.—Sectional Elevation of New Plant at Bethlen-Falva Works.

a hydraulic cylinder with 14-feet stroke and 8 inches in diameter, with mechanism for engaging the dog which moves the car.

After teeming, the ladle is transferred to a ladle-stand, of which there are four to each group of five furnaces, for removing skulls and repairs.

The charging of the furnace is done by a Wellman charging crane running on a wide gauge track, and along the line of furnace in front of the charging machine runs a narrow gauge track upon which travel cars with the charging boxes. On both sides of the main building parallel to the line of furnaces is a storage yard with three wide gauge standard tracks and two narrow gauge tracks. This yard is commanded from end to end by a 5-ton travelling crane with 58 feet 3 inches span, a hoisting speed of 50 feet, and speed of travel of 600 feet per minute.

Running parallel to the storage yard on one side of the main building is the basic shop, as shown in the plan, where the basic material is burnt, crushed and mixed, ready for delivery to the steel works. For calcining the basic material four 10-feet cupolas, 20 feet high to the charging door, are used.

Fig. 181 is a transverse sectional elevation of the new basic open hearth plant at Bethlen-Falva Works arranged for molten mixer metal. At this works large quantities of scrap are used, which is compressed in scrap presses in a shop behind the melting shop previous to charging. The open hearth furnaces are 30 tons, and the mixer is a tilting furnace holding 150 tons.

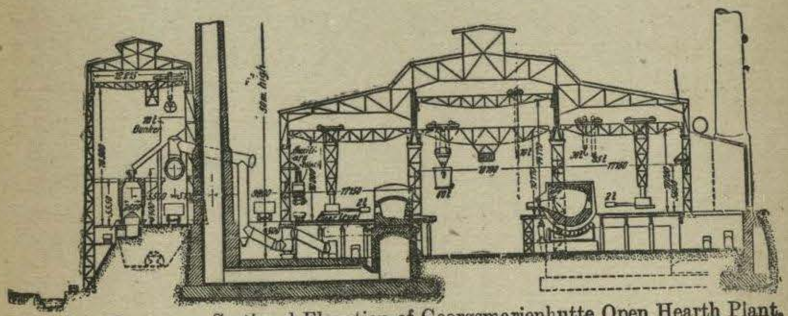

Fig. 182.—Transverse Sectional Elevation of Georgsmarienhutte Open Hearth Plant, showing Open Hearth Furnaces and Mixers.

Fig. 182 is a transverse sectional elevation of another basic open hearth plant, showing position of furnaces and mixer and general arrangement for charging both mixer and furnaces. This plant, Georgsmarienhutte, consists of five 40-ton open hearth furnaces and two 150-ton mixers. At this works the mixers are really worked as a Talbot furnace, the metal being completely desiliconised and the Phosphorus reduced from 0·6 per cent. to 0·10 per cent., and the metal then transferred to the open hearth furnace to complete the dephosphorisation and decarburisation to the required extent, when the metal is tapped.

Plate XV*a*. shows the general arrangement of the new melting shop at Witkowitz, at which a mixer, a Talbot furnace, fixed ordinary open hearth furnaces, and one ordinary tilting open hearth furnace have been erected—all in one shop. The general arrangement of this plant is exceptionally good, ample space being allowed on the charging floor, in the casting shop and between the furnaces. Every facility has been provided for most economic handling of all materials, both for charging and removal of the steel ingots, and the entire plant represents the latest design in modern practice.

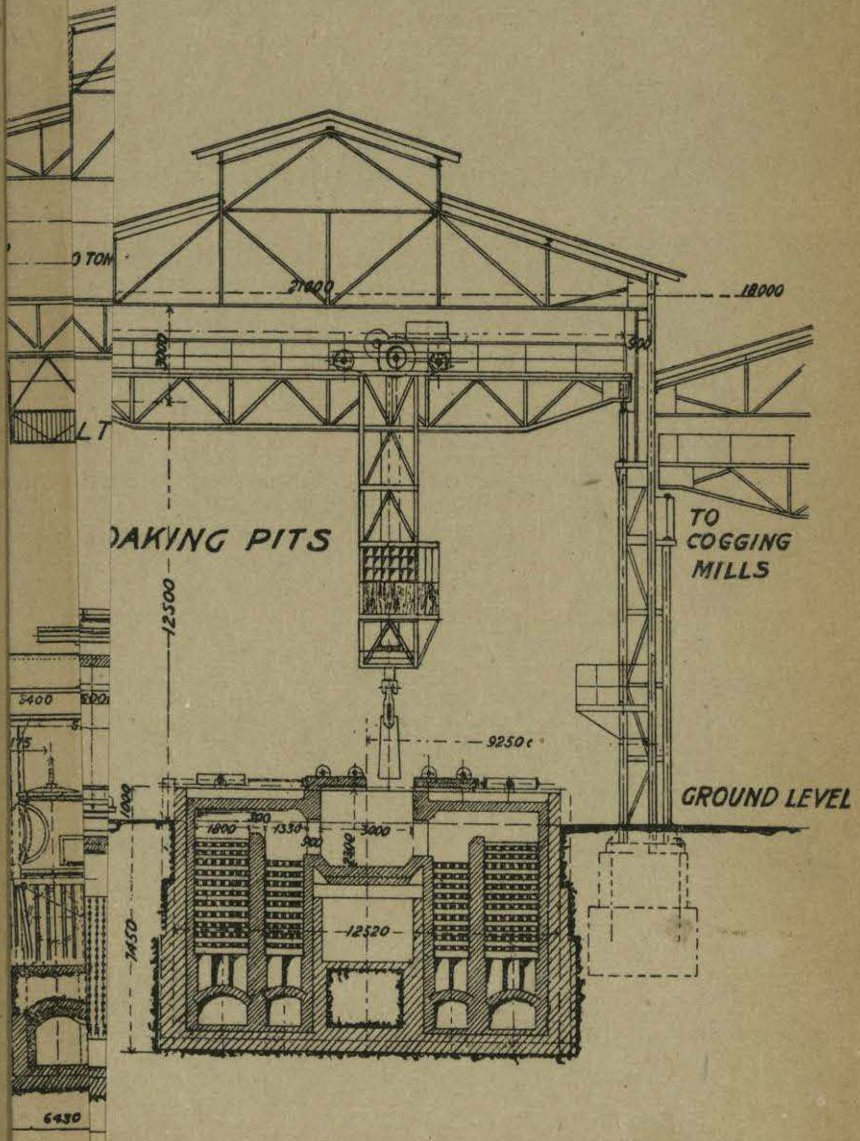

PLATE XVA.

Elevation of Scrap, Melting and Casting Shops, and Soaking Pits at the new works at Witkowitz.

This plant may be regarded as representative of the best modern practice in design of Open Hearth Steel Plants.

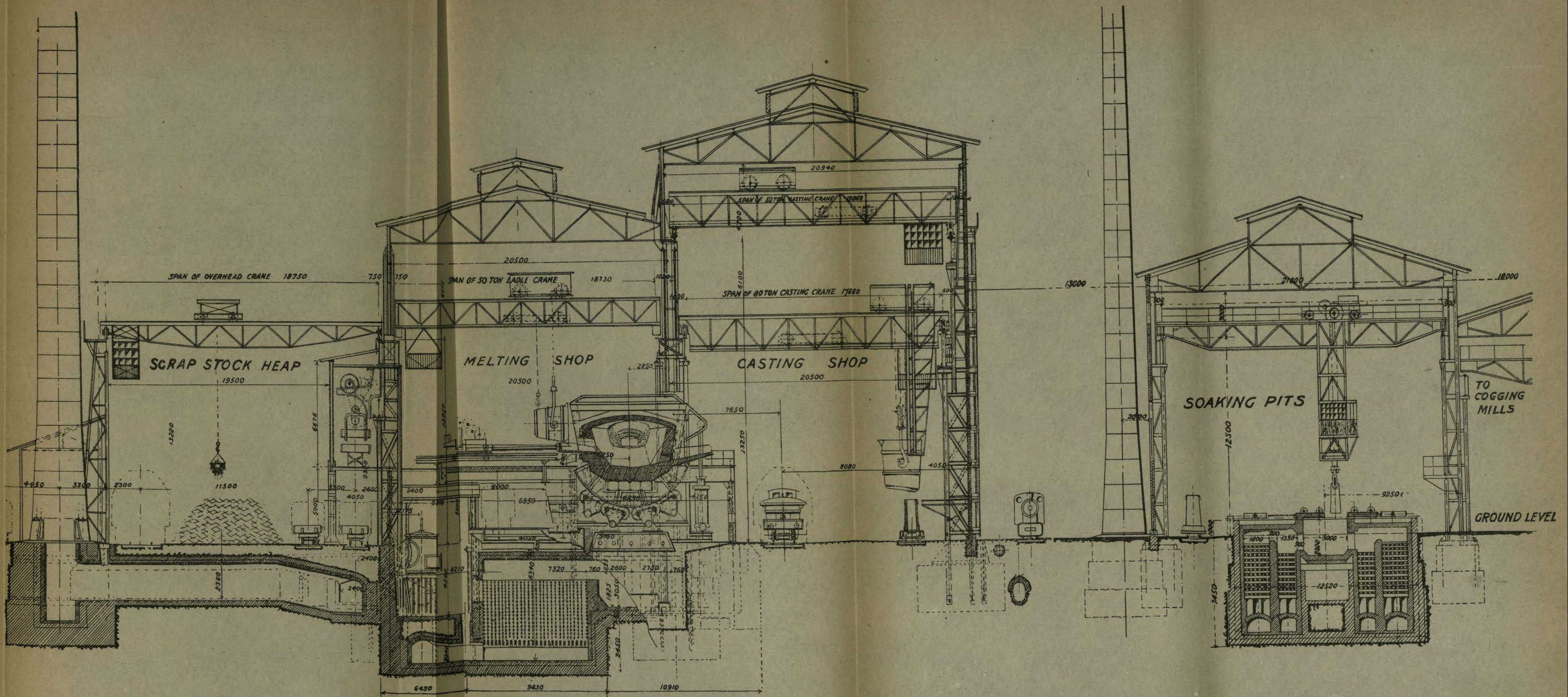

Fig. 182a.