means for the recovery of by-products to the beehive oven. The Aitken coke-oven, as shown in fig. 124, is a beehive oven fitted with two pipes, *a a′*, for conveying the blast and gas from the condensers through small openings in the roof distributed equally round the circumference, whilst channels, *b b′ b″*, in the floor of the oven conduct the collected by-products to an external pipe, *c*, which leads them to the condensers. The main body of the oven measures 5 feet from the opening in the roof for filling in coal to the floor, and has a diameter of 9 feet.

The Jameson coke-oven[1] is another improvement on the beehive oven. It is shown in cross section and in sectional plan in fig. 125. In the bottom of the ordinary beehive oven, *a*, channels are formed, covered with perforated tiles, *b b′ b″*, connected out-

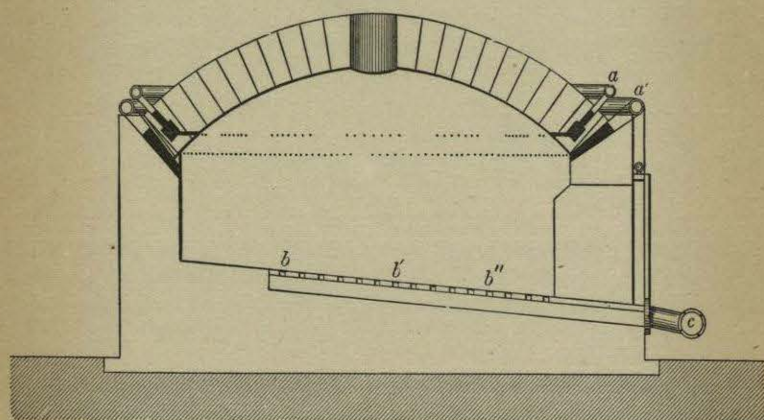


FIG. 124.—Aitken Coke-oven. *a a′*, gas and air inlets; *b b′ b″*, by-product collectors; *c*, gas and by-product pipe to condensers.

side the oven with pipes leading to apparatus, C C′, for producing a slight suction, and for discharging the by-products when required. The cost of applying this process is small, and the results of a series of trials show that the average yield of coke is 65·49 per cent., the average yield of ammonium sulphate and of oil being 4·6 lbs. and 6·1 lbs. per ton respectively.

The use of beehive and modified beehive ovens is now, however, somewhat limited. The waste entailed by employing the beehive oven prohibits its use, except for small quantities of coke or for special purposes; whereas, if any attempt is made to recover the products of distillation, the usual practice is now to adopt one of the more modern ovens.

In the improved forms of coke-ovens air is not admitted into the coking space, but into side flues, so as to mix with the

[1] *Journ. Soc. Chem. Ind.*, vol. ii. (1883), p. 114; *Journ. Iron and Steel Inst.*, 1883, p. 504.

gaseous products passing through openings in the oven walls into the side flues. In this way use is made of the heat afforded by the ignited gases, which are, in the older forms of oven, allowed to pass directly into the chimney or into the open air; there is complete combustion of all the gaseous products, and the ovens are heated without any coke being actually burnt.

All ovens for coking without access of air have a rectangular

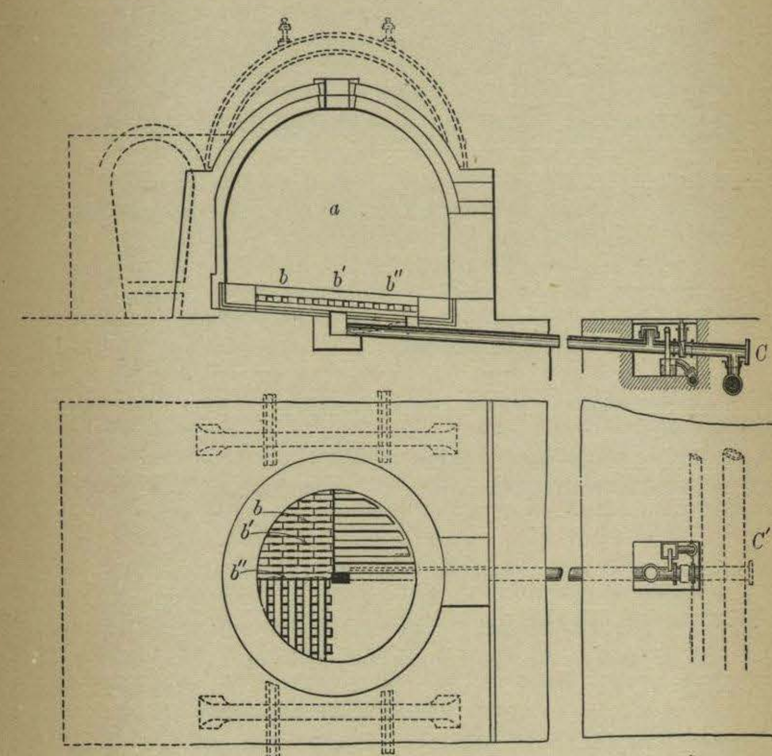


FIG. 125.—Jameson Coke-oven. *a*, coking chamber; *b b′ b″*, perforated tiles; C C′, suction apparatus.

section, and in most cases the major axis is horizontal. The Appolt oven, however, is an exception, its principal axis being vertical. It was invented in 1856 by the brothers Appolt,[1] and consists of twelve or more vertical coking chambers of brickwork, arranged in rows, the series being surrounded by walls of brickwork. The ovens are rectangular in plan; they are tapered, measuring, at Saarbrücken, 4 feet 1 inch by 1 foot 7 inches at the lower, and 3 feet 8 inches by 1 foot 2 inches at the upper end, and 16 feet in height. Each oven is surrounded by an air

[1] *Annales des Mines*, 5th Series, vol. xiii. (1858), p. 417.

space 10 inches in width, and is provided above with a lid, and below with a door opening downwards into a vault where the coke may be received in an iron waggon. As the charging is also effected by waggons on the top of the furnace, the working is extremely simple. The brickwork of the ovens is separated by air spaces which communicate with one another and with the interior of the ovens themselves. The products of combustion are carried off to the chimney by means of flues, which have fire-brick dampers for regulating the draught, and in which there are openings to allow of their being cleaned out. The gases from the coal pass into the air spaces surrounding the retort, where they mix with air introduced through flues in the wide sides of the ovens. As in all coke-ovens, the process is conducted by first heating the ovens to redness. They are then filled, and the process may be carried on uninterruptedly. The charge in each chamber is 1 ton 4 cwt. to 1 ton 8 cwt., so that the whole oven cokes about 17 tons of coal in twenty-four hours, the work being so arranged that one retort is discharged and recharged every hour. The Appolt coke-oven presents the advantage of a very great heating surface in proportion to its capacity, which is easily explained by the fact that each chamber is completely surrounded, with the exception of the two end planes, by fire. Thus much less heat is lost by cooling from without. Dürre estimates the internal area of the walls at 50 to 58 square feet per cubic yard of capacity, and Kerpely states that the heating surface is more than 1 square foot per 20·5 lbs. of charge. The average yield of coke is 70 to 80 per cent. with caking coal, and very good results have been obtained with a mixture of caking and non-caking coals. The vertical position of the compartments presents the advantages of occupying less space than other ovens; the coke in dropping down exerts no injurious amount of wear on the sides, and the pressure of the column of coal produces a coke of greater density than that obtained in other ovens. On the other hand, the Appolt coke-oven has the disadvantage of high initial cost, and repairs are effected with much difficulty.

Numerous varieties of ovens with horizontal axes have been introduced, and worked with more or less success. In all these ovens the object sought is to utilise the gases to the highest possible degree by effecting the coking by their combustion. At first this led to the adoption of complicated constructions, which have recently been greatly simplified, and the main differences in the system of heating and in the arrangement of flues depend on whether the heating flues are horizontal or vertical in position. This naturally divides ovens into two classes.

To the class of ovens having horizontal flues belong, among others, the Simon-Carvès,[1] Semet-Solvay, and Hüssener; while to

[1] *Journ. Iron and Steel Inst.*, 1883, p. 494; 1885, p. 108.

the class having vertical flues belong the Coppée, Otto-Hoffman, Otto-Hilgenstock, von Bauer, Brunck, and others.

The Simon-Carvès oven resulted from the investigations of Carvès and Henry Simon. The former studied the regulation and distribution of the temperature in coke-ovens by burning the waste gases in flues around the coking chamber, and found that with the coal he had to do with—a poor, non-caking coal—a high temperature rapidly and evenly distributed throughout the coal in conjunction with closed carbonising chambers were the conditions for obtaining good coke, and at the same time a good yield of ammonia and tar rich in aromatic substances.[1] He improved the arrangement of the horizontal side flues in which the washed gases were burnt to heat the coking chamber, and insisted on the narrow chamber to ensure the desirable rapidity of carbonisation. Simon introduced his arrangement, in which, by allowing the air for combustion, on its way to the oven, to pass through passages running between the underground waste gas mains, the heat from these gases passed to the air, which became heated. In the early form of oven the residual gases, returned from the washers, were burnt over a solid fuel fire on a grate built for the purpose in the lower part of the walls separating the coking chambers. The heated and burning gases then circulated in two side flues, ascended to the uppermost of the three horizontal flues in the wall, and thence descended these in succession on their way to the waste flue leading to the chimney.

In the later forms of this oven the grate and fireplace are dispensed with, the heat for the coking being derived wholly from the combustion of the gases, air being admitted under pressure to support the combustion.

The construction of a modern Simon-Carvès oven is shown in fig. 126. There are charging holes, $a\,a'$, in the top of the oven, and the gases are drawn off through a pipe, $b\,b'$, which is provided with a regulating valve. From here the gases pass into a system of pipes common to 30–50 ovens, and kept cool by jets of water, so that the tar and ammoniacal liquors are condensed. The lower open ends of the pipes dip into a collector for the products of condensation, similar to that employed in many gas-works. The gases from the condenser are then passed through scrubbers filled with moistened coke, where the last traces of ammonia are removed. The uncondensed gases pass onwards to the oven for heating purposes, entering through an aperture, c, in the basal flue of the oven, whilst the air for combustion enters at several points as shown in the figure. Under the base of the oven the burning gases pass, then rise between two adjacent ovens to the bottom one of the side flues, e, and pass gradually upwards through e', e'' and e''' to the flue, which conveys them

[1] These historical details are copied from a paper by D. A. Louis, *Journ. Iron and Steel Inst.*, 1903, No. 2, p. 293.

to the chimney or under steam boilers. The ovens are 30 feet long, 2 feet broad, and 6½ feet high. The yield is about 75 per cent. The coke produced possesses sufficient resistance to render it suitable for blast-furnace use.

The air introduced receives a previous heating to some 500° or 600° by its being brought into contact with the hot flues conveying away the spent fire-gases from the ovens. At the part of the bottom flue where the greatest heat is sustained, the walls are lined with the best silica bricks. The heated air admitted into the bottom flue is purposely insufficient for complete combustion of the gas introduced there, the further supply of hot air being admitted into the side flues of the oven. The arrangement

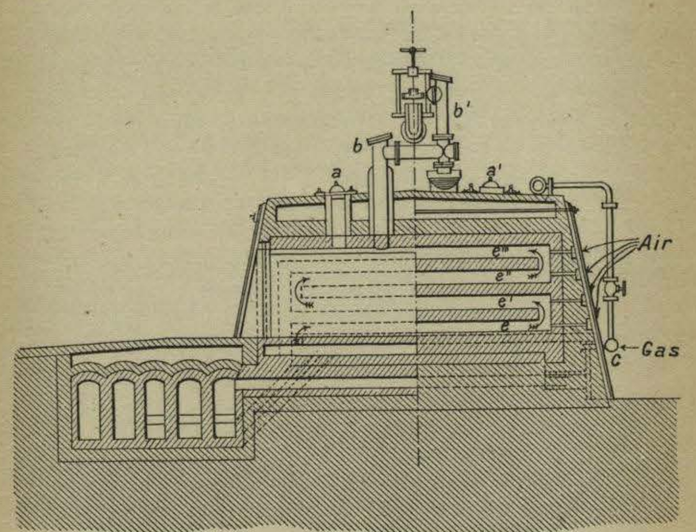


Fig. 126.—Simon-Carvès Coke-oven. *a a'*, charging-hoppers; *b b'*, gas outlet; *e e' e'' e'''*, combustion flues.

for thus admitting the air is completely controlled by dampers. Each oven is charged with 4½ tons of coal, the time for coking being a little over forty-eight hours.

After coking is complete, the product is discharged by means of a ram carried on a truck which runs on rails behind the ovens; this ram is introduced at the end of the oven with the smaller sectional area, and as the coke emerges from the larger end it is quenched with water. The ram is propelled by a cogged driving-wheel, worked by a small portable engine.

The Semet-Solvay oven (figs. 127, 128) has horizontal flues on the Carvès principle, but instead of the flues constituting the wall between two ovens this is made solid, and the flues are composed of hollow tiles on either side of it. This renders the

flues of each oven independent of adjoining ovens; and since the weight is entirely borne by the solid walls between the ovens, these flues can be made much thinner, and consequently more efficient.

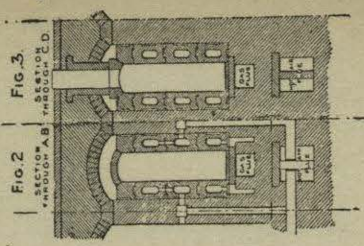


Fig. 128.

In this case only so much pre-heating of the air takes place as is acquired during the passage of the air through cooling flues in the structure, and great care is taken to equally distribute the heat in the flues. For this latter purpose part of the gas and air enter the uppermost flue in the front of the ovens; more gas is admitted from the back of the ovens into the middle horizontal flue, whilst still more is admitted into the lowest flue from the front.

The coal is charged in through hoppers in the roof, and the coke is discharged in exactly the same manner as is used in the Simon-Carvès oven.

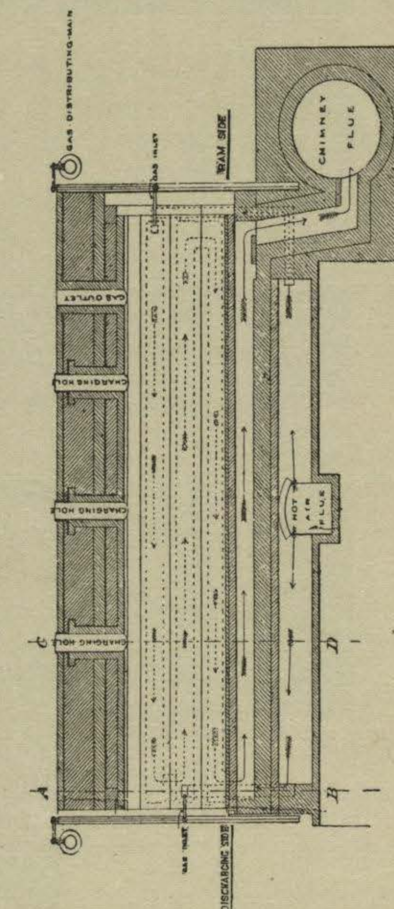


Fig. 127. Semet-Solvay Coke-oven.

The Hüssener[1] oven was introduced into this country from Germany in 1901, a plant of 60 ovens being built at the Clarence Works, a further 60 being added in 1904. This oven resembles the Semet-Solvay in several particulars; for instance, in both ovens there is a solid brick wall between each coking chamber which carries the top arch of the oven and the

[1] *Journ. Iron and Steel Inst.*, 1904, No. 1, p. 188.

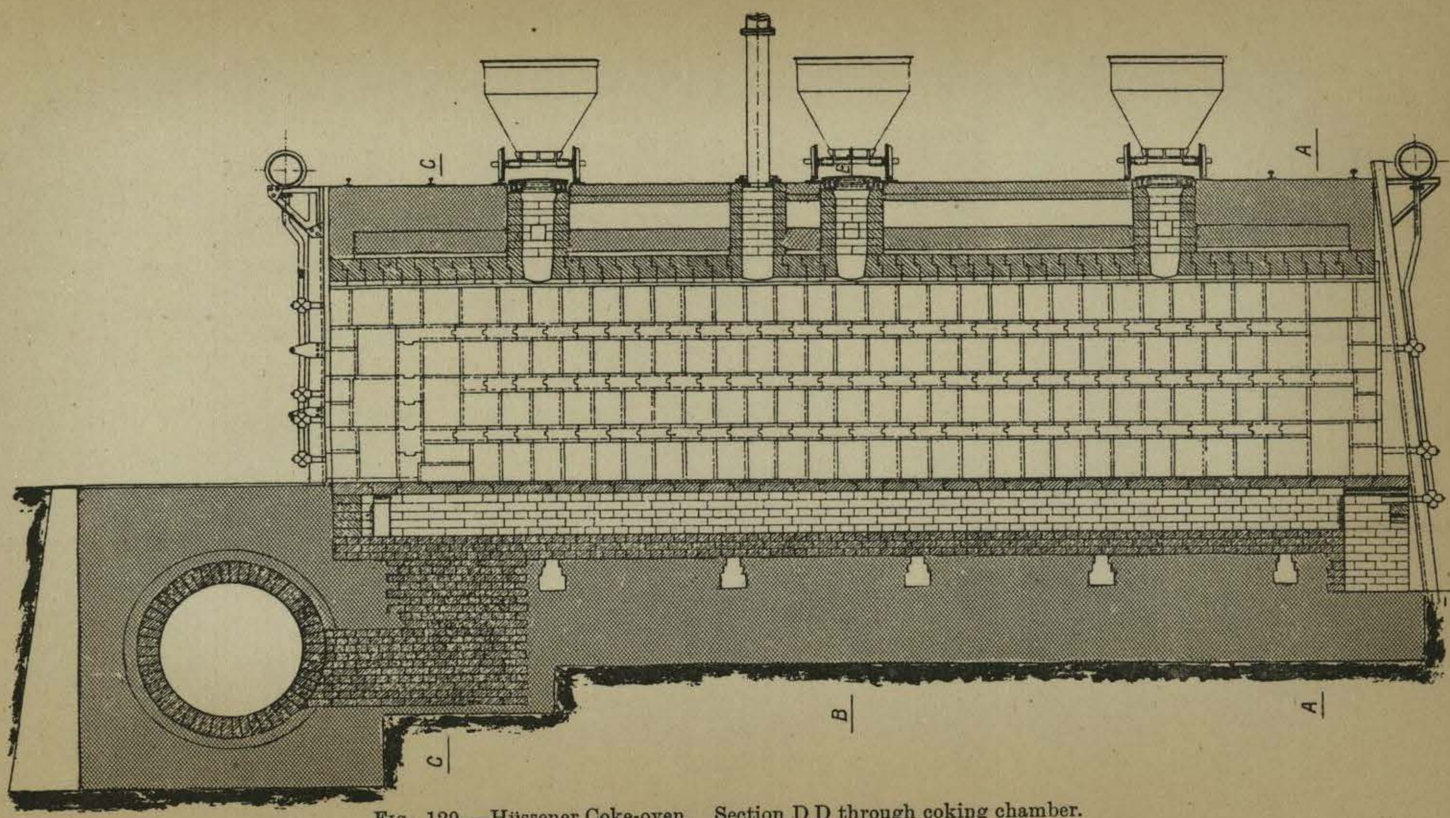
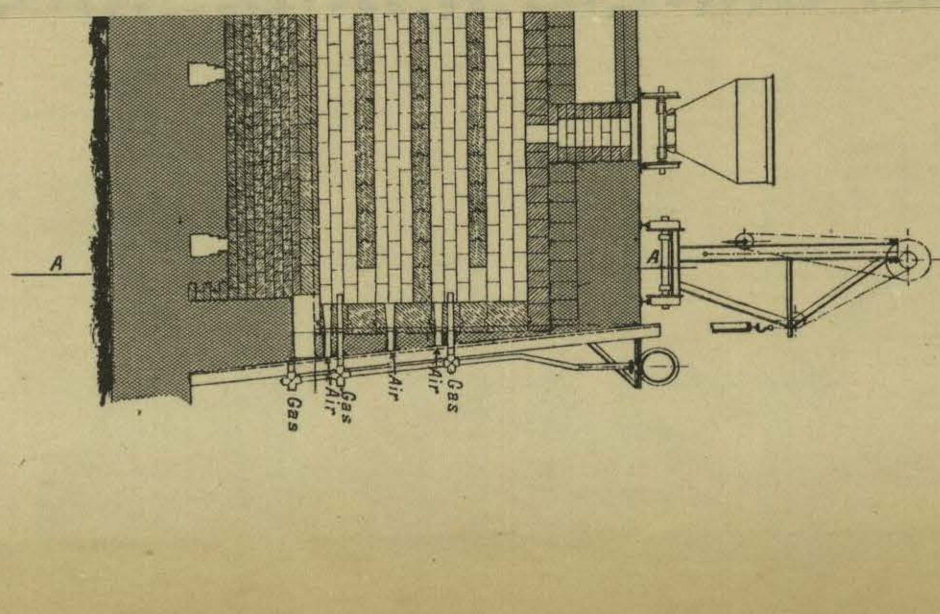


FIG. 129.—Hüssener Coke-oven. Section D D through coking chamber.



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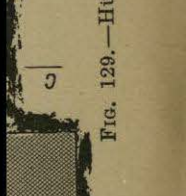

FIG. 129.—Hüssener Coke-oven. Section D D through coking chamber.

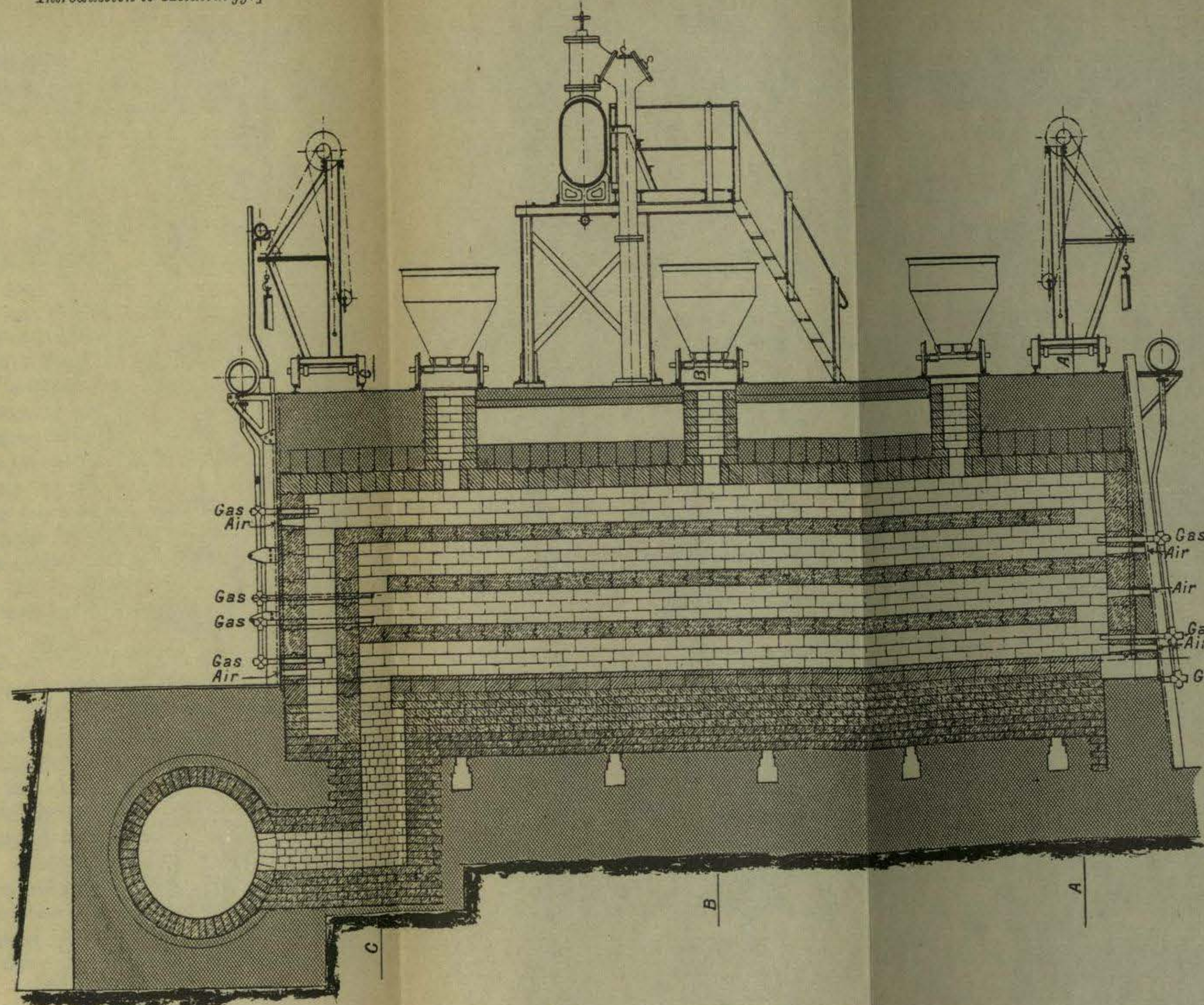

FIG. 130.—Hüssener Coke-oven. Section through heating flues.

superstructure, leaving little or nothing to be carried by the side walls of the coking chamber, which can consequently be made much thinner than usual, and so allow the heat to pass more rapidly through them with less consumption of gas. This arrangement also permits any single oven to be laid off for repairs without interfering with the working of its neighbours, and also allows the vertical walls of the oven to be removed and rebuilt without disturbing the top of the oven in any way. The construction of the oven is shown in figs. 129, 130, and 131; fig. 129 being a horizontal section through the coking chamber, fig. 130 a horizontal section through the heating flues, and fig. 131 containing three vertical sections at A, B, and C.

The coking chambers are about 33 feet long, 7 feet high to the crown of the roof, and are slightly tapered to assist the removal of the coke by means of a ram, being 1 foot 6 inches wide at the narrow or ram end, and 1 foot 9 inches wide at the wide or quenching end. Each oven is fitted with three charging holes, and one opening for the removal of the gases. At the ram side the oven is fitted with ordinary fire-doors in order to get up heat on starting, and on each side of the charging holes there are two loose bricks (marked *a* and *b* in the section on B B, fig. 131); by taking these out, gas from the ovens is allowed to pass into the flues without going through the washing apparatus. This arrangement also permits the ovens to be used for the manufacture of coke alone without the by-products. As soon as the oven is in work, and when making by-products, these holes are permanently bricked up. In regular working, the gas coming back from the various washers, etc., enters on the ram side underneath the floor of the oven into two parallel flues, between which is a solid brick wall. Each of these flues is connected with the upper flues of the oven on the same side. The great advantage of this is that the heat can be the more easily regulated on each side of the oven. The gas, having passed through the bottom flues, rises up to the top of the oven, receiving on its upward course a second, and on turning into the top flue a third, supply of fresh gas. After passing back in the upper flue, the gas falls to the second one, being enriched by a fourth supply of gas, and then passes along the third flue, enriched as before, down into the fourth flue, where it is found unnecessary, as a rule, to add more gas, and so into the waste flue leading to the boilers and chimney.

It will be seen that the flues are in two separate divisions, each heating one half of the oven, both bottom and side. All the gas is forced to pass through every part of the flue; and as it is enriched in so many places with fresh gas, the heating of the coking chamber is very regular, and is entirely under the control of the burner. A large proportion of the air necessary to burn all the gas is admitted in the bottom flues; any further supply

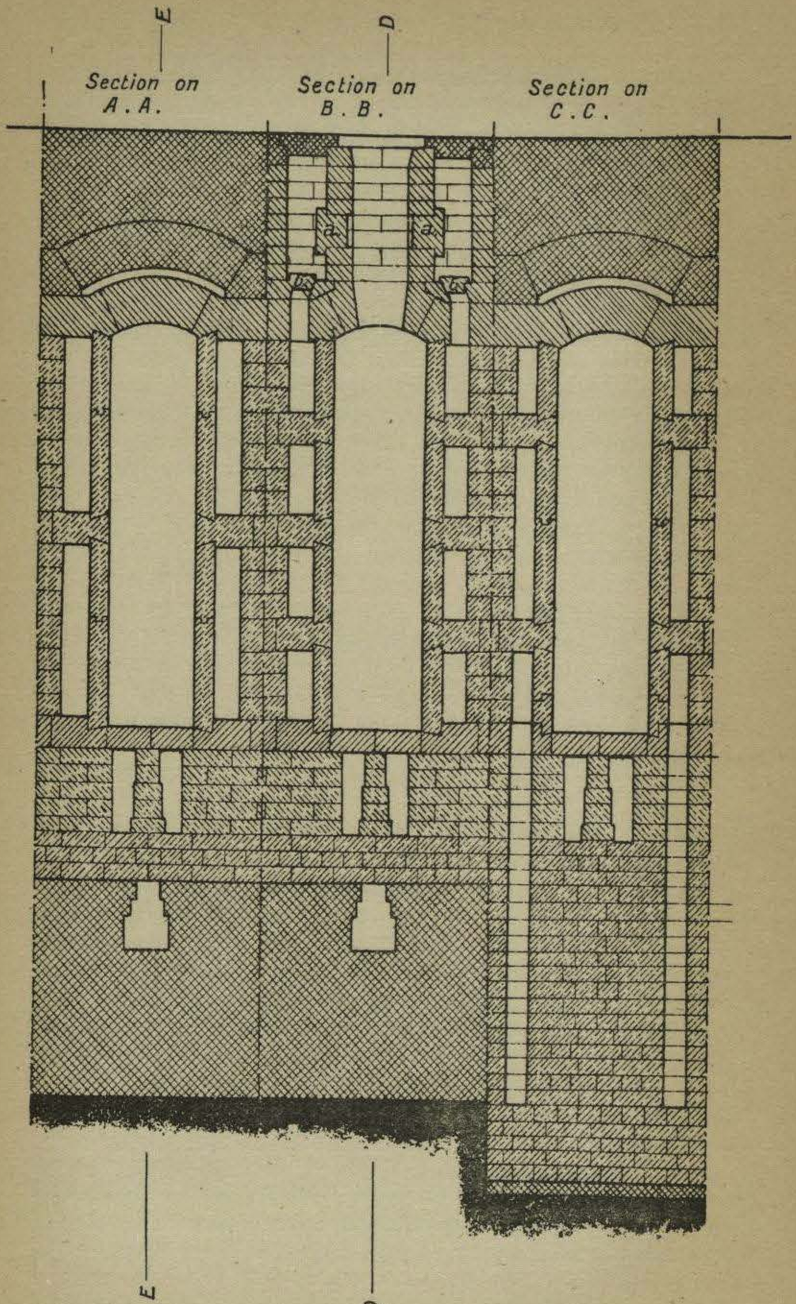

FIG. 131.—Hüssener Coke-oven. Showing vertical sections.

can easily be regulated by means of the sight-holes, which are fixed close to the inlets. About 70 per cent. of the total gas from the coking process is used in heating the ovens, and having done this, passes under the boilers at a temperature of 825° C., raising sufficient steam for the exhausters of the ovens themselves, for the by-product plant, and for other purposes. The time required for coking is thirty-two hours, using wet coal containing 10·5 per cent. of water. The production of each oven is about 22 tons of coke per week, each charge consisting of 6·5 tons of wet coal, giving 4·36 tons of coke.

Of ovens with vertical heating flues, the Coppée was the first, and this method for distributing the heat round the coking chamber has been very largely and successfully adopted in modern ovens. The Coppée ovens are usually built in series of thirty or forty, and are worked in pairs. The ovens, which are 30 feet long, 18 inches wide, and 4 feet high, have each twenty-eight vertical flues leading from the top through the partition-wall common to two ovens, to the horizontal flues that pass underneath the chambers in the direction of their length. In these horizontal flues the gases from a freshly charged oven mix with those from one in which the coking is nearly complete, and combustion is effected by air admitted through three small openings. At each end of an oven are two metal doors. The coke is removed from the oven by means of a ram, as previously described. When the coking is complete, the engine and ram are placed opposite the end of the oven, and the coke is pushed out, the operation lasting about two minutes. A jet of water is then applied to the coke. At the same time the lower doors of the oven are closed, and coal is fed in through three openings in the roof, the openings being then covered by sliding doors. The coal is then levelled by means of rakes, and the upper doors are closed. The whole operation, from the opening to the closing of the doors, lasts only eight minutes. When working thirty of these ovens, numbered consecutively, those with odd numbers are drawn in the morning, and those with even numbers twelve hours later, the coking occupying twenty-four hours.

The various Otto ovens belong to the vertical flue group, and have shown a gradual change in construction and method of regulating the heat of the chambers. In the earlier forms of Otto-Hoffman ovens both the gas and air necessary for the combustion were pre-heated before being used, but in the later forms the air only is pre-heated.

The Otto-Hoffman[1] oven itself has undergone some modification, for the earlier forms were encumbered underneath with regenerating checkerwork chambers, which alternately conducted the heated waste gases away from, and the air supply to, the ovens. Later on, the regenerators were put under the ends of

[1] See D. A. Louis, *Journ. Iron and Steel Inst.*, 1903, No. 2, p. 293.

the ovens, there being regenerators at each end, and connection with them was made through the flue beneath the coking chambers, which was divided transverely across at the middle. In working this form of oven, gas and then heated air were admitted at one end of the sole flue; combustion immediately ensued, and the burning gases passed up the flues on one side into the upper flue, and then down the vertical flues on the other side of the central division, along the other half of the sole flue, to the regenerative chamber. In a further stage of development, the regenerators were reduced considerably in size, and placed underground in front of the ends of the ovens, leaving the arches under the ovens entirely unencumbered; moreover, the gas was supplied at the top as well as the bottom, so distributing the area of combustion. A further modification has now been adopted, the Hoffman element—the regenerator—being dispensed with, and the gases for combustion, instead of being admitted unburnt into the flues, are led by piping beneath the wall between each oven, and from Bunsen jets rising from the piping are burnt in orifices opening into the side horizontal bottom flue, and rise through the vertical flues to the horizontal top flue, whence they descend a narrow vertical flue at the end leading to a flue under the bottom of the coking chamber, along which they sweep, ultimately passing as waste gases through an opening, controlled by a damper, into the waste gas main. The Otto-Hilgenstock coke oven, which is shown in fig. 132, illustrates this modification.

The standard oven is 33 feet 7 inches long, 6 feet 6 inches high, and 1 foot 9 inches wide at the middle. The gases given off from the coal in the oven chamber A pass through the opening B into the gas main C, whence they are drawn to the by-product plant by means of exhaust fans. The washed gases are returned by the main D, and from this main pipe a number of smaller pipes E branch out into the arches which support the ovens, and from these smaller pipes are led lateral branches which rise up to nozzles to which Bunsen burners are fitted, and by their action sufficient air is drawn in for combustion, this air being sufficiently heated on its way through the arches of the ovens. The flame rises vertically into the horizontal bottom flue, and ascends through the vertical heating flues F into the horizontal top flue G. From this flue the gases are led into the centre through the vertical flues H, under the bottom of the oven I, through opening K, to waste gas main M, thence to the boilers and chimney.

The Brunck[1] ovens resemble others in having long chambers supported on a substructure, but this substructure is of some complexity, as it contains an elaborate series of connecting ducts, cooling channels, checkerwork chambers, and vaulted conduits. These arrangements serve for the removal of the waste gases and for pre-heating the air supplied for combustion, as well as for con-

[1] *Journ. Iron and Steel Inst.*, 1903, No. 2, p. 298.

ducting it to the points where it is required. Again, to ensure a

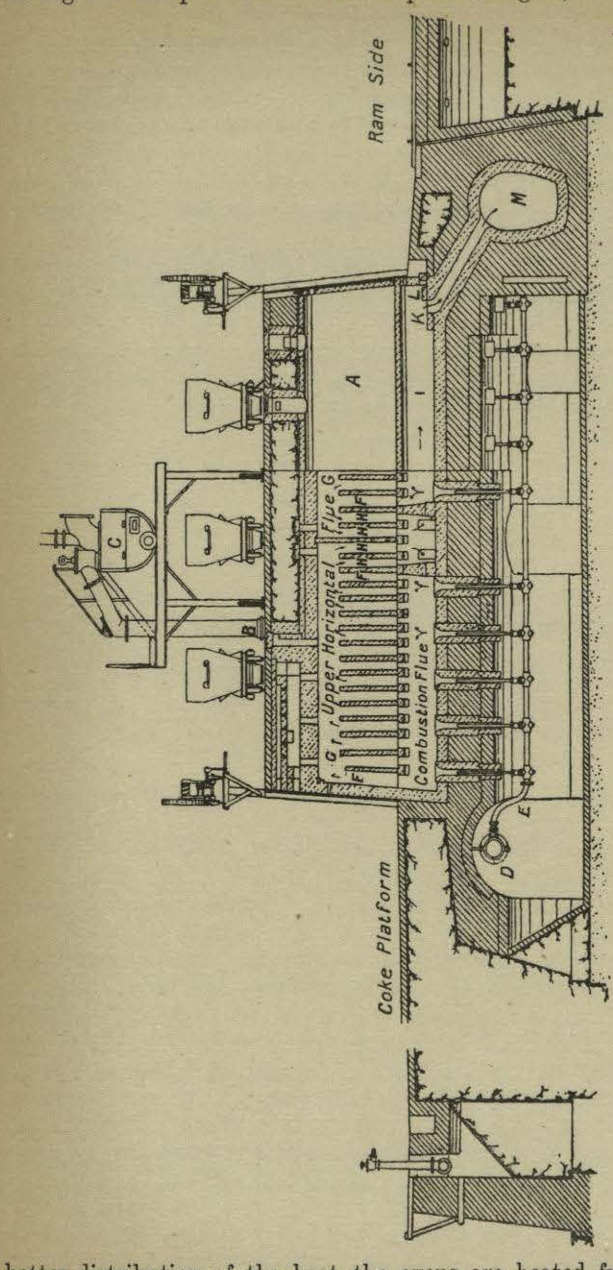

FIG. 132.—Otto-Hilgenstock Coke-oven. A, coking chamber; B, gas outlet; C, gas main; D, return gas main; E, branch gas pipes; F H, heating flues; G, top horizontal flue; I, waste gas flue; M, waste gas main.

better distribution of the heat, the ovens are heated from each end independently; hence all the substructural arrangements are