

in duplicate. The coking chambers are built on the top of an upper row of cooling passages, arched chambers being first constructed, separated by solid walls, and within these the coking chambers proper are built, with a longitudinal flue below each one, whilst vertical flues, arranged on each side of each chamber, connect this lower longitudinal flue with a longitudinal flue above. The lower flue is divided into four sections by parting-walls, and a parting-wall extends all round the outside of the coking chamber at the centre, completely shutting off one side of the heating spaces from the other.

The firing of the ovens is effected by six gas-jets, three at each end, of which one is set in the sole flue and one in each side, while the air forced along by a fan traverses various passages below, and is delivered by ducts and ports to the scene of action. The burning gases ascend the end flues and descend the flues at the centre, passing into the waste mains which run below the

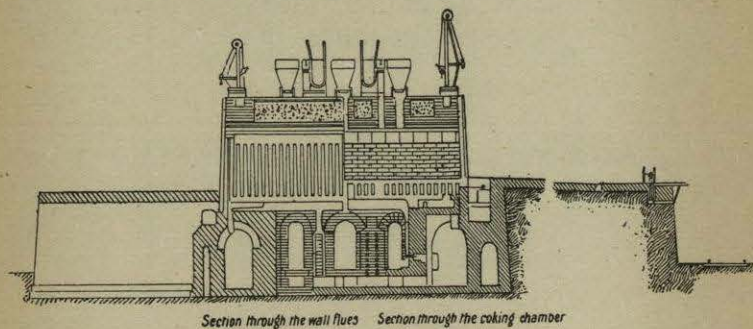


Fig. 133.—Brunck Coke-oven.

centre, and at right angles to the direction of the ovens. There are two of these mains, and between them is built the two sets of checkerwork, through which part of the air supply passes on its way to the combustion chamber and becomes highly heated. The rest of the air supply passes through a special conduit and through various cooling passages, taking up heat on the way.

Further, the air supply is used to cool the products of distillation, and thus takes back to the ovens some of the heat that would otherwise be wasted, and in addition economises water required for cooling. The Brunck oven is built  $33\frac{3}{4}$  feet long, from 6 feet  $6\frac{3}{4}$  inches to 7 feet  $4\frac{3}{4}$  inches in height, and from about 17 to 22 inches in width, and has a capacity of from 5 to  $7\frac{1}{2}$  tons of coal, containing from 10 to 15 per cent. of water. Figs. 133, 134, and 135 illustrate the design of the Brunck system.

Fig. 133 is a longitudinal section partly through the wall flues and partly through the coking chamber; below the latter is shown the lower longitudinal flue, with the openings into the side

flues; beneath these are shown the air-admission flue, cooling passages, and checkerwork. In this figure are also shown three filling trucks and openings, gas take-off, and winches for lifting doors, etc. Fig. 134 illustrates various cross sections and elevations, and the special features of the substructure are set forth. Fig. 135 is a sketch of the path traversed by the gases and the

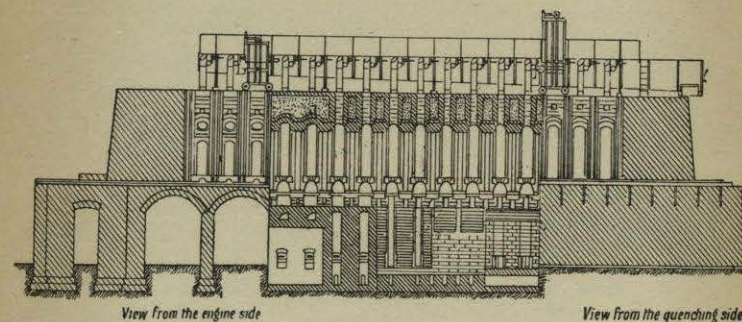


Fig. 134.—Brunck Coke-oven. Cross section.

simultaneous pre-heating of the air, showing the by-product recovery plant.

The von Bauer<sup>1</sup> oven resembles the Brunck oven in one particular, that is, in having the heating system of one end separated by a parting-wall from the heating system at the other end.

The von Bauer oven has a simple vaulted substructure with a

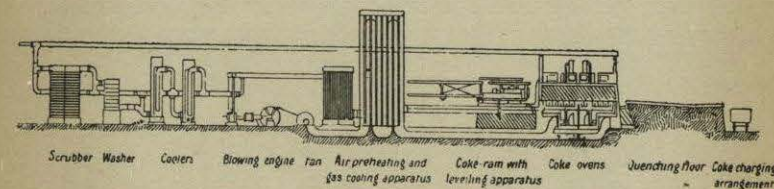


Fig. 135.—Sketch of the path traversed by the gases of a coking installation with the recovery of by-products of the Brunck system.

simple set of alternately wide and narrow longitudinal cooling channels, separated by thick walls, but connected by transverse ducts. Upon these walls are built the walls of the coking chambers, which are constructed with three sets of vertical flues or passages, the outer ones serving for combustion chambers, the central set for the air supply; under the coking chamber and over the wider cooling channels there is the usual longitudinal vaulted combustion chamber (G, fig. 136), but divided transversely by a wall at the centre, and it only connects with the group of

<sup>1</sup> D. A. Louis, *Journ. Iron and Steel Inst.*, 1903, No. 2, p. 300.

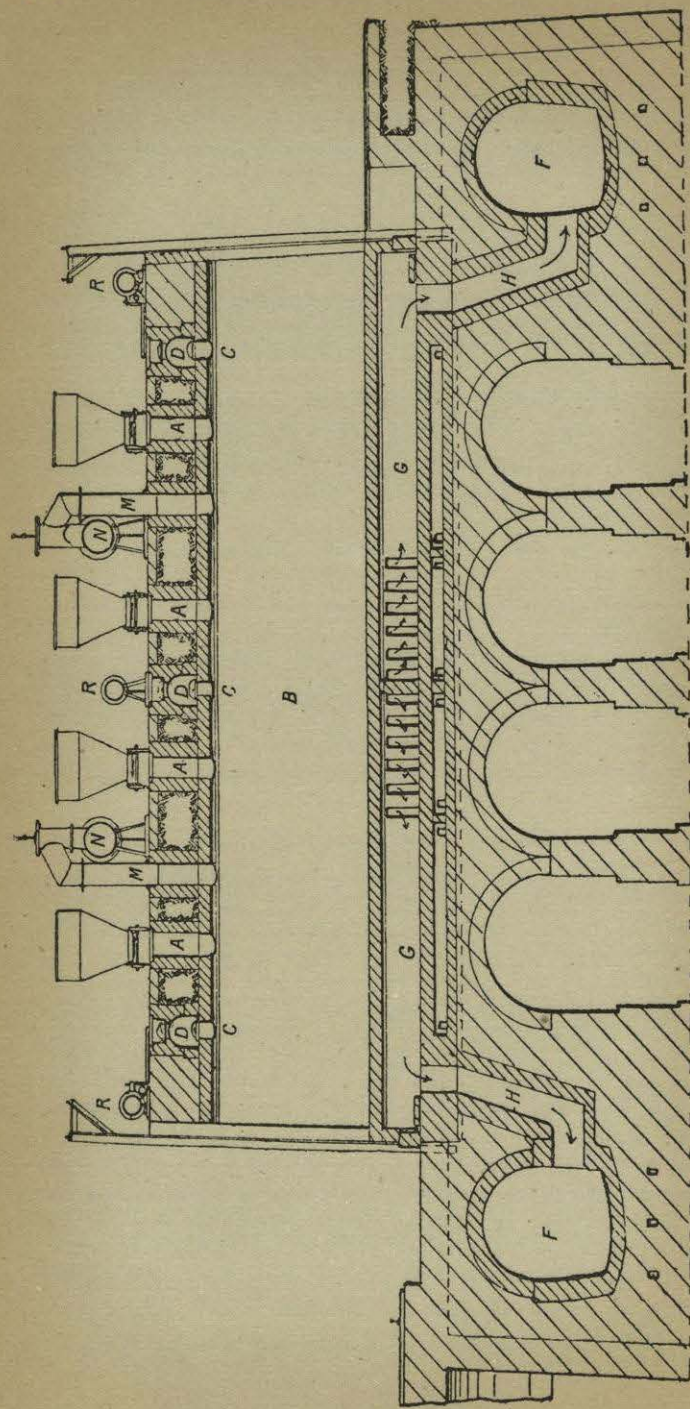


FIG. 136.—Von Bauer Coke-oven. Section through coking chamber, B; A A A, charging openings; M M, gas outlets; G G, combustion chamber; H H, waste gas flue; F F, waste gas mains.

side flues near the centre, there being no connection between this bottom chamber and the three groups of flues nearer the ends. This chamber, however, is in direct communication with the waste gas main at either end (H H, fig. 136). The air passages communicate with the combustion flues in such a manner that air is admitted exactly where required. The combustion flues unite in an upper longitudinal flue, divided into two portions by a central wall, and each of these portions is further subdivided into two groups of four flues and a larger central group of eleven flues (fig. 137). There is also a lower longitudinal flue, in which the first eight flues and the first five central flues unite, all the other flues being separated by walls from one another, and it is at these points that the six central flues on each side of the middle wall connect with the chamber under the coking oven.

Each group of flues receives its own supply of air, which is delivered at the desired spot to properly assist combustion, but before entering the combustion flues it traverses either the cooling channels below, or, when entering from above, some length of the air flue, and so becomes heated. It is, however, the upper part of the oven which differs essentially from ovens previously described. The roof of the oven is pierced by nine openings (fig. 136); four of these are spaced at equal intervals, and serve for charging the ovens when loose coal is used, the charging taking place through the end door when compressed coal is used (see p. 280). Two of these openings serve for the removal of products of distillation; the remaining three are in connection with three chambers or conduits (D, fig. 137), running at right angles to the direction of the coking chambers, across the whole battery of ovens, one being at the middle, the other two near the ends. These conduits, where they pass over the combustion flues, connect with them by vertical ducts, there being a duct for each of the two end groups and for each of the six-flued central groups; moreover, by means of piping above, these conduits can be connected with the return gas from the by-product works.

These conduits serve to supply the gas, either from the coking chambers direct or from the by-product works, the gas passes into them, and through the ducts into the combustion flues, where it is burnt with the air supply, passing down the first two groups of flues into the lower longitudinal flue, where it meets a further supply of air at the bottom of the next group of flues, up which it passes into the upper longitudinal flue, where it encounters a fresh supply of gas from the duct leading from the central gas-conduit, and another supply of air at the top of the last group of flues, down which it passes into the big flue under the coking chamber, and thence into the waste main.

By this arrangement of conduits the by-products may be collected during any stage of the coking operation from any of the ovens. The von Bauer oven is built from 26 to 39 feet long,

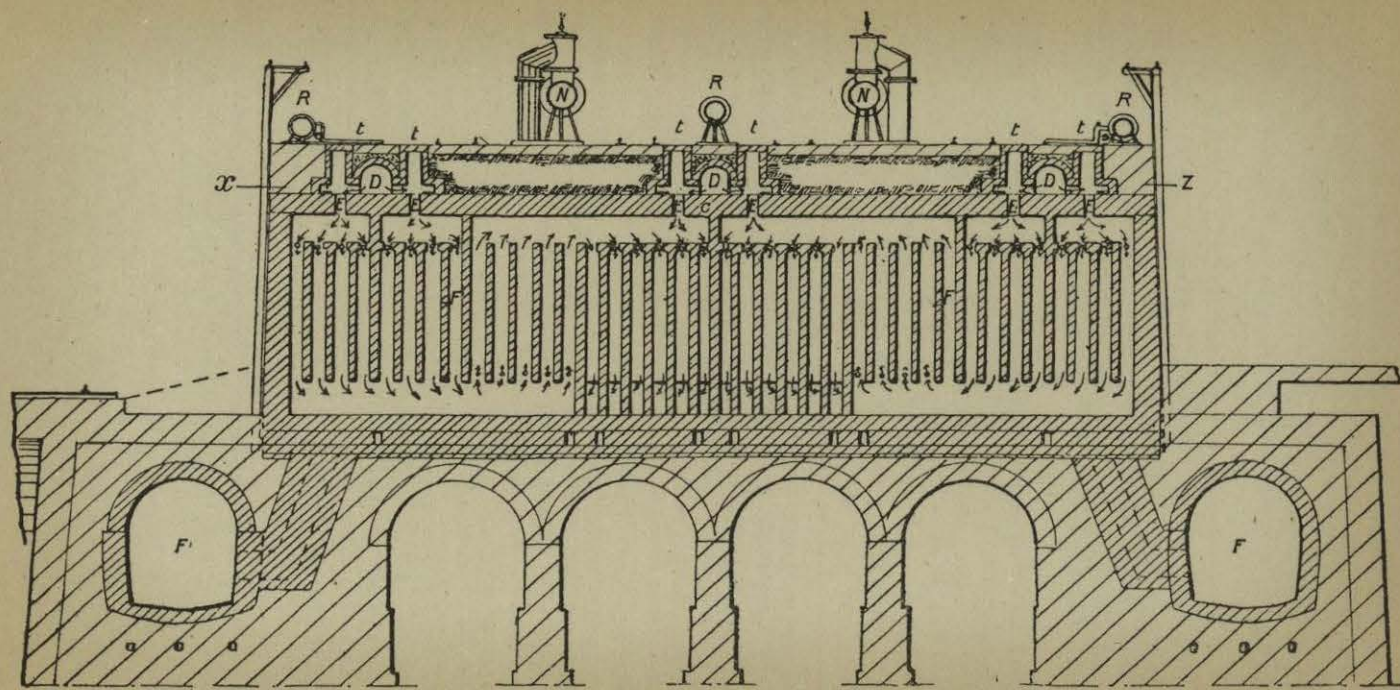


FIG. 137.—Von Bauer Coke-oven. Section through the combustion flues. R R R, gas supply ; D D D, gas conduits ; E E E, gas inlets.

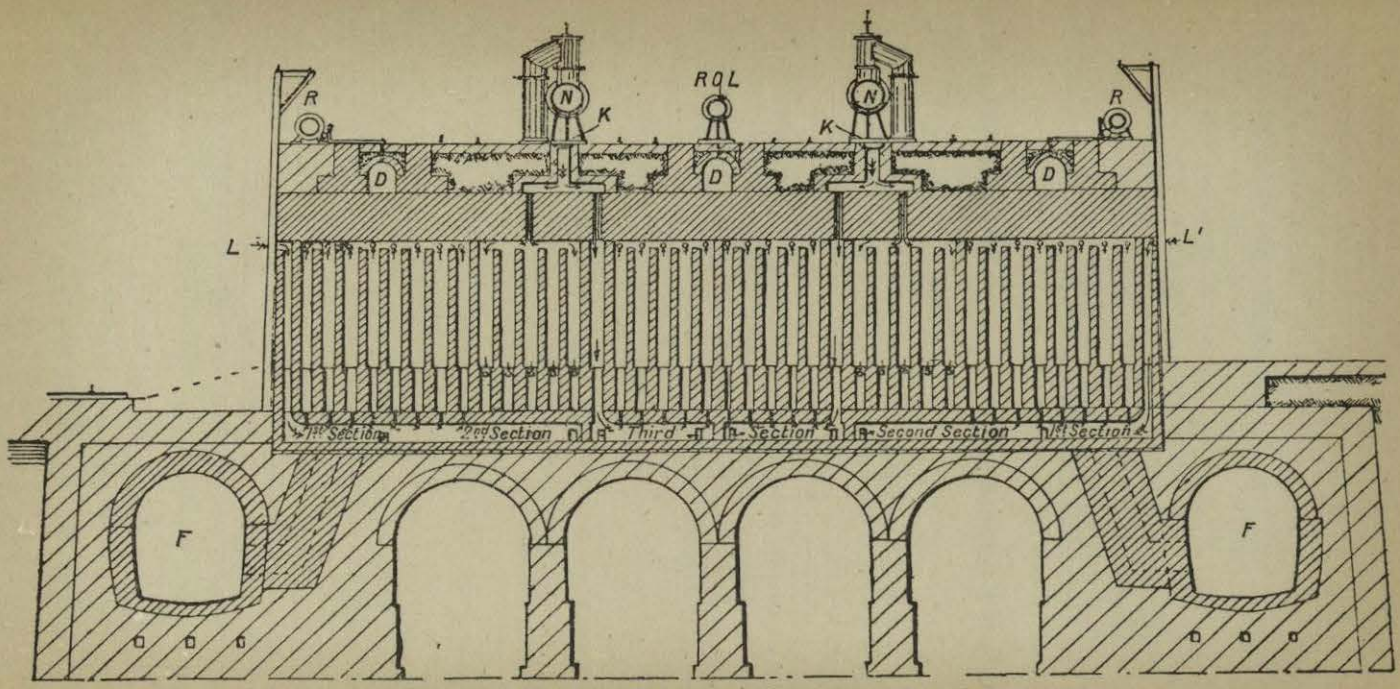


FIG. 138.—Von Bauer Coke-oven. Section through air flues.

7 feet high, and  $21\frac{1}{2}$  inches wide at one end, tapering to  $19\frac{1}{2}$  inches at the other end; the capacity of the larger being about 10 tons of loose coal, or  $12\frac{1}{2}$  tons compressed coal.

Fig. 136 is a sectional view of von Bauer's oven through the coking chamber B; fig. 137 is a longitudinal section through the combustion flues F; fig. 138 is a longitudinal section through the air flues; figs. 139 and 140 are cross sections showing the arrangements of flues, passages, and chambers.

Considerable progress has been made during the last few years in the successful coking of inferior or poorly-caking coals by compressing<sup>1</sup> the material before charging into the ovens, and it may be here stated that coals high in ash and sulphur contents are subjected to a washing process in order to eliminate a portion of

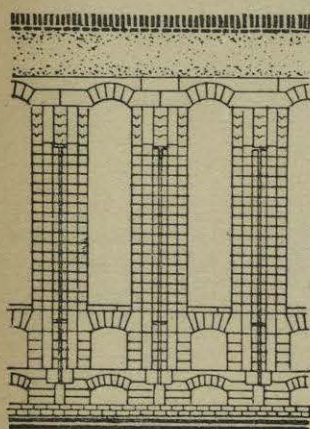


FIG. 139.—Von Baur Coke-oven.  
Cross section.

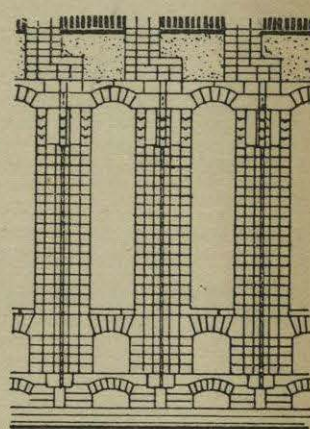


FIG. 140.—Von Baur Coke-oven.  
Cross section.

the ash and sulphur-bearing constituents. The idea of compressing fuel for coking purposes originated on the Continent, where it was observed that with coals of indifferently-caking properties the coke produced from the bottom portions of the retort ovens, compressed by the weight of the superincumbent fuel, was superior to that produced from the upper portions of the charge.

The method of compression first adopted was merely to stamp the charge in the oven by hand or by weighting the charge, and from this has gradually evolved the method now in general use of compressing the coal in a box outside the oven, the stamped cake being afterwards moved out of the box into the oven by mechanical means.

The degree to which fine coal may be compressed varies with its character, state of division, contents of moisture, etc., and the

<sup>1</sup> *Journ. Iron and Steel Inst.*, 1902, No. 1, p. 26.

advantages to be gained by using compressed coal in coke ovens are a considerably denser coke, less breeze or small coke, quicker charging of ovens, and a diminution in the amount of hand-labour required.

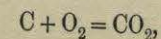
4. **Liquid Fuel.**—The prepared liquid fuels used in practical work include oils obtained by distillation of crude oils, shales, tars, and similar materials. During recent years the burners adapted for the burning of liquid fuels have been greatly improved, and very good burners have been devised for the consumption of crude tar by means of compressed air or steam.

There is little doubt that in the near future the use of liquid fuel for metallurgical purposes will be much more common than it is at the present time.

5. **Gaseous Fuel.**—The use of gaseous fuel in metallurgical operations has effected a great saving in coal. Besides this advantage, there are two circumstances that must lead to its more general adoption; these are the possibility of employing inferior fuels and waste products, and the high temperatures attainable by the use of such fuel. The method of gas-firing is, however, still far short of a universal adoption, but it may be predicted that, except in some special cases, it will gradually supersede other methods of heating.

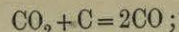
The use of gas as fuel is based on the principle that at one place all the fuel is converted into combustible gas, which is consumed by admixture with the necessary amount of air at another. These gases are produced by burning the fuel in a long column, whereby most of the carbon is burnt to carbonic oxide, whilst the hydrogen either remains free or is converted into carburetted hydrogen.

In ordinary gas-producer practice,<sup>1</sup> when a charge of bituminous coal is dropped into the producer, it first undergoes a process of destructive distillation similar to that carried out in the manufacture of coal-gas. The products of distillation are chiefly hydrogen, methane, tarry hydrocarbons, and carbonic acid, together with small quantities of ammonia, compounds of sulphur, and a large residue of coke. This incandescent coke is in turn gasified by the combined action of oxygen (air) and steam. The air is heated somewhat during its passage through the layer of hot ashes at the bottom of the producer. The process depends for its success on the chemical action of air and steam upon incandescent carbon. With regard to the method of combustion of solid carbon, the commonly accepted view has been that carbon burns directly to carbon dioxide, thus,

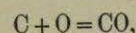


<sup>1</sup> These details are taken from the paper by Bone and Wheeler, *Journ. Iron and Steel Inst.*, 1907, No. 1, p. 126.

which reacts with the excess of incandescent carbon, forming carbon monoxide, thus,

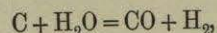


but in view of Mr H. B. Baker's work<sup>1</sup> on the combustion of solid carbon, and the work of Prof. Dixon<sup>2</sup> on the rates of explosion of cyanogen and oxygen, it is very probable that solid carbon burns directly to carbon monoxide, thus,



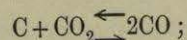
and that carbon dioxide is only formed by the secondary combustion of this monoxide. Whichever of the above views be adopted will make no difference to the thermo-chemical results obtained. When solid carbon is burnt to CO, practically 30 per cent. of its total heat of combustion is generated in the producer, and a large amount of this heat would, if not partly absorbed in decomposing steam, be lost, give rise to high temperatures in the producer, and consequently troubles with clinkers, etc.

The use of steam in the blast allows part of this heat to be utilised in doing chemical work, with the formation of hydrogen and a further quantity of carbon monoxide, according to the equation



thus raising the potential energy of the resulting gas at the expense of some of the sensible heat of the incandescent fuel.

The relative proportions of CO and CO<sub>2</sub> in the resulting gas are influenced by the reversible reaction,



and, according to Boudouard's<sup>3</sup> figures, the following mixtures of CO and CO<sub>2</sub> are in equilibrium with solid carbon, under atmospheric pressure at the temperatures given:—

Temperature. C°.	Percentages of	
	CO.	CO <sub>2</sub> .
650	39	61
800	93	7
925	96	4

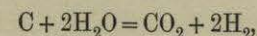
<sup>1</sup> *Journ. Chem. Soc.*, 1885, vol. xlv. p. 349; also *Phil. Trans.*, 1888, vol. clxxix. A. p. 571.

<sup>2</sup> *Journ. Chem. Soc. (Trans.)*, 1896, vol. lxxix. pp. 759, 774; also *ibid.*, 1899, vol. lxxv. p. 630.

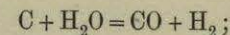
<sup>3</sup> *Annales de Chimie et de Physique*, 1901, Series vii., vol. xxiv. pp. 28-34.

From these figures it will be readily seen that when the temperature of the zone of reaction of the producer is lowered, the proportion of CO<sub>2</sub> to CO will be increased.

The composition of the gas obtained when steam reacts with solid carbon depends mainly upon the temperature. At comparatively low temperatures (500°-600° C.) the chief products are CO<sub>2</sub> and H<sub>2</sub>, according to the equation



whereas at temperatures of 1000° and upwards the products consist for the most part of equal volumes of CO and H<sub>2</sub>, according to the equation



at temperatures between 600° and 1000° the products correspond to a simultaneous occurrence of the two reactions. Both reactions are endothermic (that is, use up heat), and consequently reduce the temperature of the producer, but at the same time they raise the thermal efficiency of the gas. It must be remembered that there is also a reversible reaction represented by the equation



which may have a considerable effect on the composition of the gas. The direction in which this reaction will take place depends on the temperature of the system and on the relative masses of the reacting gases. O. Hahn<sup>1</sup> has recently determined the equilibrium ratios for varying temperatures as follows:—

Temperature. C°.	$\frac{\text{CO} \times \text{H}_2\text{O}}{\text{CO}_2 \times \text{H}_2} = \text{K}.$	Temperature. C°.	$\frac{\text{CO} \times \text{H}_2\text{O}}{\text{CO}_2 \times \text{H}_2} = \text{K}.$
786	0.81	1086	1.95
886	1.19	1205	2.10
986	1.54	1405	2.49

From these figures it is possible to predict the direction in which any change will take place in a system containing oxides of carbon, hydrogen, and steam at any temperature, provided their relative concentrations are known. Also it is obvious that in the case of a given mixture which is in equilibrium at a low temperature, change will take place in the direction  $\text{CO}_2 + \text{H}_2 = \text{CO} + \text{H}_2\text{O}$  as the temperature is raised, and *vice versa*, and also that the addition of steam at any temperature will tend to cause a change in the direction  $\text{CO} + \text{H}_2\text{O} = \text{CO}_2 + \text{H}_2$ .

<sup>1</sup> *Zeit. für Phys. Chemie*, 1903, vol. xliii. p. 705; vol. xlv. p. 513.

Bone and Wheeler<sup>1</sup> have done some very valuable work on the use of steam in producer practice, and in a series of systematic experiments they included—

1. The weighing of the whole of the coal used.
2. The continuous sampling of the gas over eight hours in the day shift.
3. The daily estimation of ammonia, tar vapour, and sulphur compounds in the gas.
4. The weekly collection and weighing of tar deposited throughout the plant.
5. The weighing of the ashes, clinker, and coke withdrawn from the bottom.
6. The estimation of soot and fine ash carried over by the gas.

The samples of coal-tar, ashes, soot, gas, etc. thus collected were afterwards analysed, and from the results the following data were obtained:—

1. The total carbon in a ton of dry coal charged into the producer.
2. The proportion of this carbon lost in the tar, ashes, and soot.
3. The proportion of the carbon actually gasified.
4. The weight of carbon in a cubic foot of the gas.
5. The yield of gas per ton of coal gasified.
6. The calorific value of the gas per cubic foot at 0° C. and 760 millimetres pressure.

From the figures actually obtained by experiment in a Mond producer, the efficiency of the producer was determined under various conditions as to the supply of steam. By efficiency should be understood the ratio of the available energy of the gas as supplied from the producer, to the energy of the coal required to produce it.

From the work mentioned the following conclusions were drawn:—

(a) *Quality and Composition of the Gas.*—The quality of the gas steadily deteriorated as the steam saturation temperature was raised beyond 65°. Thus, whereas at 60° and 65° the average percentage of combustibles exceeded 47 per cent., it dropped to about 42 per cent. as the steam saturation temperature was raised to 80°. This falling off in quality was partly counter-balanced by an increase in the quantity produced per ton of coal, but the general efficiency fell off as more steam was used. As the steam saturation temperature was raised the gas became richer in hydrogen and carbon dioxide, but much poorer in carbon monoxide; at the same time the net calorific value of the gas fell from 43·6 to 38·69 kilogrammes C. per cubic foot.

<sup>1</sup> *Journ. Iron and Steel Inst.*, 1907, No. 1, p. 126.

(b) *Thermal Efficiency of the Plant.*—On raising the steam saturation temperature from 60° to 80°, using live steam for the blast, the efficiency of the plant fell from 68·7 to 57·8 per cent.

(c) *Yield of Ammonia.*—As far as ammonia recovery was concerned, for high yields the plant should be run with the highest steam saturation temperature consistent with the production of combustible gas.

The ammonium sulphate equivalent of the ammonia in the gas was found to increase from 39 to 72 lbs. per ton of coal gasified as the steam saturation temperature of the blast was raised from 66° to 80°.

At a saturation temperature of 60°, 27 per cent. of the nitrogen in the coal was recovered as ammonia; at a temperature of 65°, 30 per cent., and at 80°, 50 per cent., was recovered.

The gas-producer first assumed importance in 1856, on the introduction of the Siemens regenerative system. In 1861 the well-known Siemens gas-producer was patented, and is illustrated by fig. 141. It consisted of a chamber lined with fire-brick, with one side sloping at an angle of 45° to 60°, with the grate at the bottom. The grate thus resembled the step-grate largely used on the Continent. The fuel was charged in at the top of the incline, and fell in a thick bed upon the grate, where air was admitted. Passing from the top of a brick shaft or up-take, 8 to 10 feet high, placed above the producer at the back, there was a cooling tube, having not less than 60 square feet of surface per producer. Its object was to cool the gases issuing from the producer, thus giving them increased density, causing an onward movement towards the furnace, and rendering it unnecessary to place the producer at a much lower level than that of the furnace. This cooling, however, resulted in a condensation of tar, and, to overcome this annoyance, modifications were adopted in the producer and its working. In one modification of Siemens producer the volatile products of distillation are obliged to descend through highly heated fuel, thus causing the tar to undergo decomposition.

The modern Siemens producer is one of the best-known types of grate producers.

This producer is illustrated in fig. 142, and it will be seen that the chief differences between this and the early form consist of the elimination of the cooling tube, the closing of the grate portion, and the alteration in the slope of the front wall and grate.

In fig. 142, D is the hopper by which the fuel is introduced into the rectangular chamber C, F are the firebars, and E the gas-flue through which the gases pass on their way to the furnace. Air is injected by means of the steam jet A, through two openings on each side shown at B.

The ashpit is cooled by water in an iron tray, the water being kept at practically a constant level. The ashes and

clinkers which accumulate on the grate are removed at regular intervals.

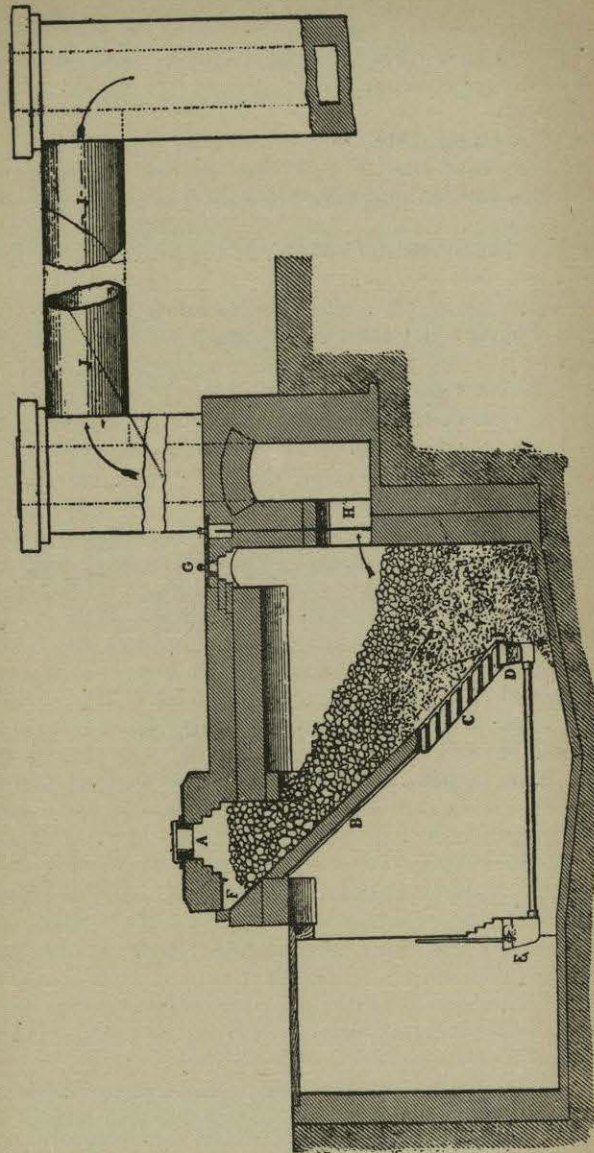


FIG. 141. - Siemens Producer, 1862.

The Wilson gas-producer (fig. 143) represents a type of solid bottom producers, the fuel resting on the bottom, the air and steam being injected through a central passage called the dis-

tributor, supported by a fire-brick arch. The producers are cylindrical, and consist of an outside shell of boiler plate, lined with fire-brick. They vary from 8 to 12 feet in diameter, and gasify about 30 lbs. of coal per square foot of bottom area per hour. The fuel is charged through a central hopper C H, and the gas is drawn off through a series of openings *aaa*, arranged symmetrically round the circumference of the producer to the downcomer B. To remove the ashes in this form of Wilson, the producer has to be stopped at regular intervals, and iron bars are pushed through small openings and allowed to rest on the central

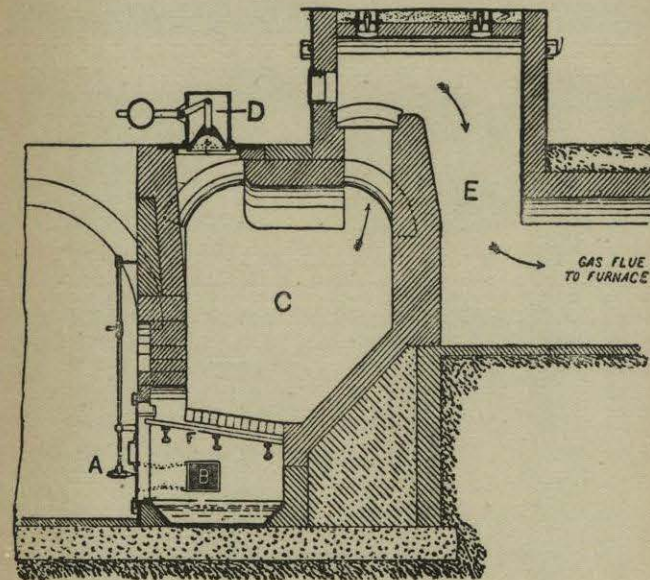


FIG. 142. - Modern Siemens Producer. A, steam injector; B opening through which steam injected; C, body of producer; D, charging hopper; E, gas flue; F, firebars.

fire-brick arch in order to support the fuel. The cleaning doors C are opened and the ashes raked out.

After closing the doors, the temporary firebars are withdrawn, the charge allowed to sink, and the blast turned on.

To avoid this necessary stoppage, later forms are used with a water-sealed bottom, from which the ashes and clinkers can be removed without interfering with the working of the producer, and in one type an Archimedean screw is used, which rotates under the water, and thus removes the ashes.

The Mond producer is one of the latest developments of the gas producer, and was specially designed for the collection and recovery of as large an amount of ammonia as possible as a by-

product. In this form very large quantities of steam are used, about 2 tons for every ton of coal gasified, thus preventing the temperature from rising to such a degree as to bring about the formation of much clinker in the ash, or to decompose the ammonia products from the coal. The greater portion of this steam passes out of the producer undecomposed, but during its condensation its sensible and latent heat are utilised to produce fresh steam for use in the producer. The fuel is mechanically fed into the producers, and is charged in large quantities of 8 to

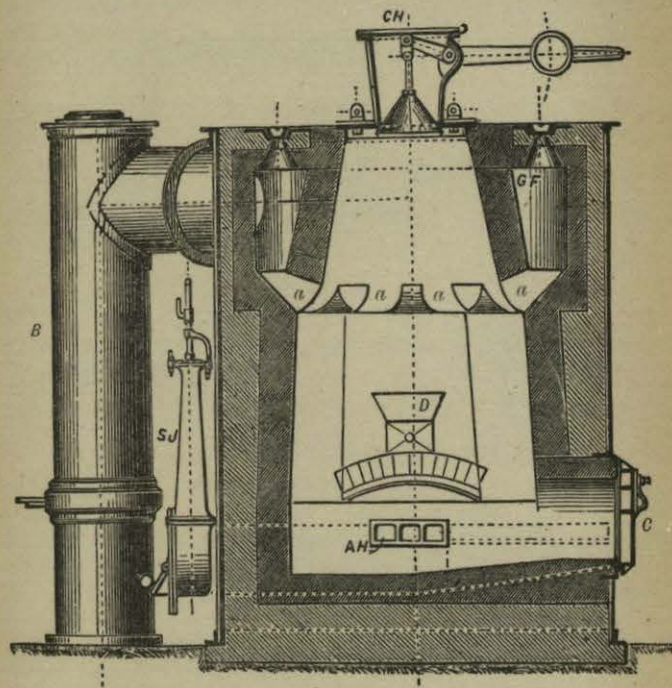


FIG. 143.—The Wilson Producer. *aaa*, openings round circumference of producer through which gas is withdrawn; *B*, downcomer or gas-flue; *C*, door for raking out ashes; *D*, air distributor.

10 cwts. at a time, and the ashes are withdrawn without interfering with the working of the plant. The gas generated is uniform in quality, and on leaving the producer is cooled by passing through the superheaters, round which the air and steam forming the blast travel and become heated.

From the superheaters the gas passes through washers, and thence passes to gas-cooling towers. An exchange of heat between the hot gas and cold water cooling towers is thus effected, and the hot water, leaving the bottom of the tower, is pumped up to the top of an air-heating tower, down which it is allowed

to fall. During its descent it meets the ascending air-blast forced in at the bottom by the blower, whereby another heat exchange is effected and the blast is both heated and charged with steam.

Fig. 144 is a sketch of the producer, which consists of an inner and outer wrought-iron cylindrical shell, the former lined with fire-brick for a portion of its height. The top is arched and is lined with fire-brick, while the bottom portion consists of an inverted truncated cone. The whole producer is supported by cast-iron brackets, and a water-bosh at the bottom forms a seal. The fuel is delivered direct from the railway waggons into a large hopper over the producers, and is charged into the hoppers of the different producers by a creeper. When the hopper is filled, the hood valve is opened, and the fuel falls into the bell-shaped casting suspended from the top of the inside of the producer. This internal bell being surrounded by the hot producer gas, the coal undergoes partial distillation, and the products of distillation having necessarily to pass downwards through some of the hot fuel before they can escape, a portion of the tarry matter is destroyed and converted into gas. At the bottom of the producer are two cast-iron rings on which sloping bars are fixed, but as these do not reach the centre, part of the weight of the superincumbent fuel rests upon the ashes, which form a reversed cone, filling the centre space down into the water.

The air and steam forming the blast having passed round the superheater *A*, pass between the outer and inner iron casings of the producer, and thence to the fire-bars.

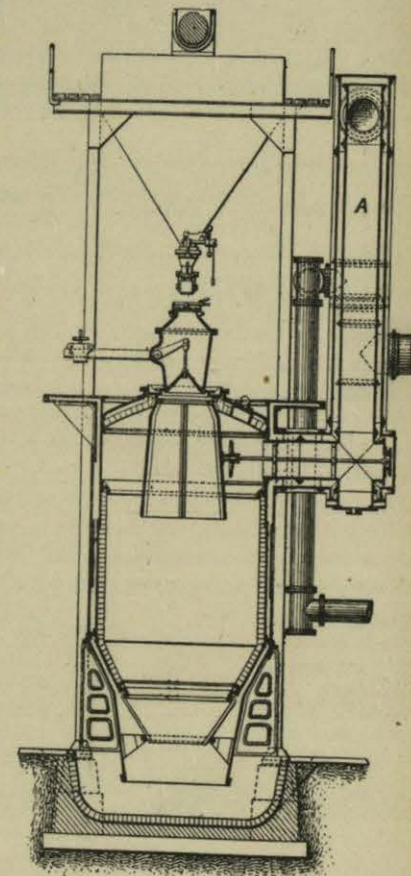


FIG. 144.