CHAPTER VI.

GAS PRODUCERS.

THERE is probably no factor of more importance to the successful working of Siemens and other gas-fired furnaces than the economical production of good gas, and a great amount of attention has been given by many metallurgists and engineers to this subject, with the result that we have numerous gas producers very similar in general construction, but differing from each other in many little details, designed to give greater efficiency and economy.

Theory of the Gas Producer.—In all metallurgical operations which depend upon high temperatures the problem is to do the work with the least expenditure of fuel, and, theoretically, far greater efficiency should be obtained by the use of solid Carbon than by an equivalent weight of Carbon converted into gas. Thus, a kilogram of pure Carbon on complete combustion to Carbon Dioxide would evolve 8,080 heat units, but if first gasified to Carbon Monoxide, assuming there were no loss by radiation, &c., and then burnt to Carbon Dioxide, would only evolve 5,630 units, showing a difference of 2,450 heat units, or nearly one-third of the whole. So far as the final result is concerned, one-third of the total available heat energy of the Carbon is actually developed in the producer, and is lost in respect to subsequent metallurgical operations in outside furnaces, except such portion as may be utilised in dissociating injected steam. In other words, the total combustion of Carbon gives 8,080 heat units, the combustion of Carbon to Carbon Monoxide, which is the final product as it leaves the producer, evolves 2,450 heat units in the producer, leaving 5,630 units of heat to be evolved on combustion to CO_2 outside for every unit of Carbon gasified. The superiority of solid Carbon over gaseous fuel is based on the assumption that the conditions are such that perfect combustion of the solid Carbon in intimate contact with the materials under treatment is possible; a state of things scarcely, if ever, attained in practice, and consequently the loss due to incomplete combustion, and other causes, frequently more than neutralises any theoretical gain over gaseous fuel. The ease with which perfect combustion of a gas can be obtained by regulating the supply of gas and air, the readiness with which it can be conducted to any required point, superheated or burnt under pressure, made to give an oxidising or a reducing flame at pleasure, and the general control that can be exercised over the size and temperature of the flame, in most cases more than compensate for the smaller number of heat units evolved as compared with solid Carbon. A certain amount of energy has thus to be sacrificed in order to gain in convenience, and to carry out certain operations which can only be done efficiently with gaseous fuel. The necessity for superheating the fuel and for keeping solid fuel out of contact with the bath of metal, makes gaseous fuel a *sine qua non* in the case of the open hearth furnace, and until Siemens solved the problem of cheap gasification of coal, this process of steel making was impossible.

Description of Producer.—The ordinary gas producer is a fire-brick lined receptacle in which air and steam are drawn or forced through a bed of incandescent fuel, the essential condition being to provide a sufficiently deep layer of incandescent fuel to insure that any Carbon Dioxide formed is, as far as possible, converted into Carbon Monoxide (CO) before it leaves the producer, and that the water vapour introduced is split up with the formation of Hydrogen and Carbon Monoxide. The resulting gas will

contain Carbon Monoxide, mixed with some Hydrogen and small quantities of olefiant gas, marsh gas, and Carbon Dioxide gas, and about 60 per cent. Nitrogen, which latter must always be present so long as we use air for the combustion of the Carbon.

Chemical Reactions in the Producer.—When coal is distilled in a closed retort only a small proportion is converted into gas—chiefly volatile Hydrocarbons—the greater part being left as coke. The object of the producer is to convert the whole of the Carbon in the coal into combustible gas so that nothing but ash is left, and this may be done by drawing air through a fairly thick bed of incandescent Carbon, the Carbon uniting with the Oxygen of the air to form Carbon Monoxide. Although the final result is Carbon Monoxide, the commonly-accepted view has been that Carbon burns directly to Carbon Dioxide, thus—

Carbon	+	Air	=	Carbon Dioxide.		
C	+	$O_2 + N_x$	=	CO_2	+	N_x,

and that this CO_2, in traversing a bed of red-hot Carbon, reacts with another atom of Carbon to form Carbon Monoxide, thus—

Carbon Dioxide	+	Incandescent Carbon	=	Carbon Monoxide.
CO_2	+	C	=	$2\,CO$.

In view, however, of Mr. H. B. Baker's work * on the combustion of solid Carbon, and the work of Professor Dixon † on the rates of explosion of Cyanogen and Oxygen, it is very probable that solid Carbon burns directly to Carbon Monoxide, thus—

Carbon	+	Air	=	Carbon Monoxide.		
C	+	$O + N_x$	=	CO	+	N_x,

and that Carbon Dioxide is only formed by a secondary combustion of this Carbon Monoxide. Whichever of the above views be adopted will make no difference to the thermo-chemical result obtained. Of the total heat available on the combustion of Carbon to Carbon Dioxide, 8,080 heat units for every unit of Carbon burnt, 2,450 will be developed in the producer itself by the formation of Carbon Monoxide, and the remaining 5,630 heat units will be available for the production of heat in the Siemens furnace or elsewhere when the CO is burnt to CO_2. As the air contains 79 per cent. of Nitrogen, which takes no part in the reaction, the resulting gas will be largely diluted with this, and a gas of the following percentage composition should, theoretically, be obtained:—

Carbon Monoxide, ...	34·7 per cent.
Nitrogen, ...	65·3 „

but, as will be seen later on, this is never obtained in practice.

Again, when steam is passed through a bed of incandescent Carbon, the water vapour is split up with the production of a gas containing equal volumes of Hydrogen and Carbon Monoxide, thus—

$$H_2O + C = H_2 + CO.$$

The decomposition of the water vapour, however, is attended with an absorption of heat which is greater than that given out by the combustion of the Carbon to Carbon Monoxide, so that the final result of this reaction is loss of heat, and a rapid cooling down of the incandescent fuel, when the reaction ceases. It is obvious, therefore, that the heat of the fuel cannot be maintained by water vapour alone, and what is usually done is to inject a

* *Journ. Chem. Soc.*, 1885, vol. xlv., p. 349; also, *Phil. Trans.*, 1888, vol. clxxix. A, p. 571.
† *Journ. Chem. Soc.* (*Trans.*), 1896, vol. lxix., pp. 759, 774; also, 1899, vol. lxxv., p. 630.

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mixture of air and steam together, so that the heat developed by the direct combustion of the Carbon by the Oxygen of the air more than compensates for the heat absorbed by the splitting up of the water vapour. The larger the amount of steam we can inject, subject to its being split up, the larger will be the percentage of combustible gases obtained, as the Nitrogen introduced with a smaller quantity of air will be less. We have thus to maintain a balance between the combustion of Carbon to CO, which produces heat, and the decomposition of steam, a reaction which absorbs heat; therefore the amount of air and steam admitted must always be so regulated that the heat produced shall be considerably in excess of that absorbed.

Theoretically, it is possible, starting with Carbon in a state of incandescence, to introduce sufficient steam (one of steam to five of air by weight) for the Oxygen from it to combine with half the Carbon, and thus to produce one-half the Carbon Monoxide in any given time, the other half of the Carbon being burnt by Oxygen from the air. The heat units evolved would then about balance each other, but practically so much heat is lost by radiation, and carried off from the producer by the gases and ashes as sensible heat, that only half this amount of steam can be used, and in practice it should never exceed $\frac{1}{10}$ of the weight of air introduced. Other things being equal, the amount of water vapour which can be admitted will depend greatly upon the depth of the bed of fuel which can be maintained in a state of incandescence. The depth of fuel which is found to give satisfactory results varies with the height of the producer and the quality of the fuel used; in steel works' producers this is about 5 feet, as, if deeper than this, it is impossible to keep it sufficiently well stirred to prevent clinkering, which leads to the formation of air channels and to irregular and incomplete combustion in different parts of the bed. As a matter of fact a comparatively small amount of steam is decomposed in the ordinary producer, the chief function of the steam injection being to cool the bed of fuel, lower the temperature, and thus prevent clinkering. In the case of some special producers, where precautions are taken to condense any undecomposed steam escaping with the gases, very much larger quantities can be employed. For many years, both in Siemens and in other producers, it has been the practice to inject steam under pressure, which enables the quantity to be better controlled, according as the producer is working hot or cold, than when relying upon evaporation from a trough under the grate as in the original Siemens. The pressure of the steam can also be used to inject air, and to maintain an outward pressure in the mains.

The heating value of the gas depends not only upon the ultimate number of heat units developed, but upon the intensity or temperature of the flame, and this will vary, for the same gas, with the conditions under which it is burnt. For example, Hydrogen when burnt in air gives a very much lower *temperature* than when burnt in Oxygen, although the total number of heat units developed is the same in each case; but when air is employed, for every part of Oxygen used there are 3·35 parts of Nitrogen, which have to be heated up at the expense of the flame, with consequent reduction of temperature. Again, assuming the combustible gas is not pure, but contains any appreciable quantity of Nitrogen or other inert gas, this obviously reduces its effective heating power, and it is consequently of the greatest importance to so regulate the production that the gas shall contain the maximum percentage of combustible gases. If we were able to draw Oxygen instead of air into our producer the calorific efficiency of the gas produced would be enormously increased, but as this is impossible we try to increase

the relative percentage of combustible gases by the injection of as large a quantity of steam as is possible without unduly cooling the producer.

As the fuel is charged in at the top, this part of the producer is always comparatively cool, and here the volatile products are driven off, whilst the CO is formed and steam is split up in the lower zone.

Producers may be divided into two main classes :—

(1) Those worked with natural draught.

(2) Those worked with forced draught.

And these may be again subdivided into—

Producers with firebar bottoms.
Producers with solid bottoms.
Producers with water bottoms.

The Siemens Producer.—The original Siemens producer, as introduced by the late Sir William Siemens and his brother in 1861-62, was an open producer, the fuel resting on firebars, and as it is the parent of all modern producers the following description is taken verbatim from a pamphlet published by Messrs. C. W. & F. Siemens, in 1862, and reprinted in the *Iron and Coal Trades Review* of March 4th, 1898.

"The producer is shown in fig. 88, and is a chamber lined with fire-bricks, into which fuel is introduced at intervals through the covered holes, A, and descends gradually on the inclined plane, B, which is set at an inclination of from 45° to 60°, according to the nature of the fuel used. The upper portion of the incline, B, is made solid, being formed of iron plates covered with fire-brick, but the lower portion, C, is an open grate formed of flat horizontal steps. At the foot of the grate, C, is a covered water trough, D, filled with water up to a constant level from the small feeding cistern, E. The large opening under the water trough is convenient for drawing out clinkers, which generally collect at that point. The small stoppered holes, F and G, at the top of the producer are provided to allow of putting in an iron bar occasionally, to break up the mass of fuel and detach clinkers from the side walls. Each producer is capable of converting daily about two tons of fuel into gas.

"The action of the gas producer in working is as follows :—The fuel, descending slowly on the solid portion, B, of the inclined plane, becomes heated, and parts with its volatile constituents. There now remains from 60 to 70 per cent. of purely carbonaceous matter to be disposed of, which is accomplished by the slow current of air entering through the grate, C. For every cubic foot of combustible Carbon Monoxide thus produced, taking the atmosphere to consist of one-fifth part by volume of Oxygen and four-fifths of Nitrogen, 2 cubic feet of incombustible Nitrogen pass also through the grate. Not all the carbonaceous portion of the fuel is, however, volatilised on such disadvantageous terms, for the water trough, D, at the foot of the grate emits steam through the small holes, I, under the lid, and each cubic foot of steam, in traversing the layer of from 2 to 3 feet of incandescent fuel, is decomposed into a mixture consisting of 1 cubic foot of Hydrogen and nearly an equal volume of Carbon Monoxide, with a variable small proportion of Carbon Dioxide. . . . The opening, H, leading from each producer into the main gas flue can be closed by inserting a damper from above, in case any one of the producers is required to be stopped for repairs.

"It is important that the main gas flue leading to the furnaces should contain an excess of pressure, however slight, above the atmosphere, in order to prevent inward draughts of air, which would produce a partial combustion of the gas. It is therefore necessary to deliver the gas into the furnace without depending upon a chimney draught for that purpose. This could easily be accomplished if the producers were placed at a lower level than the furnaces; but as that is generally impossible, the following plan has been adopted. The initial heat of the gas, which must in any case be sacrificed, is therefore made available for producing a plenum of pressure by making the gas rise about 20 feet above the producers, then carrying it horizontally 20 to 30 feet through the wrought iron tube, J, and letting it again descend to the furnace. The horizontal tube, J, being exposed to the atmosphere causes the temperature of the gas to drop, from 100° to 150°, which increases its density from 15 to 20 per cent., and gives a preponderating weight to that extent into the descending column, urging it forward into the furnace."

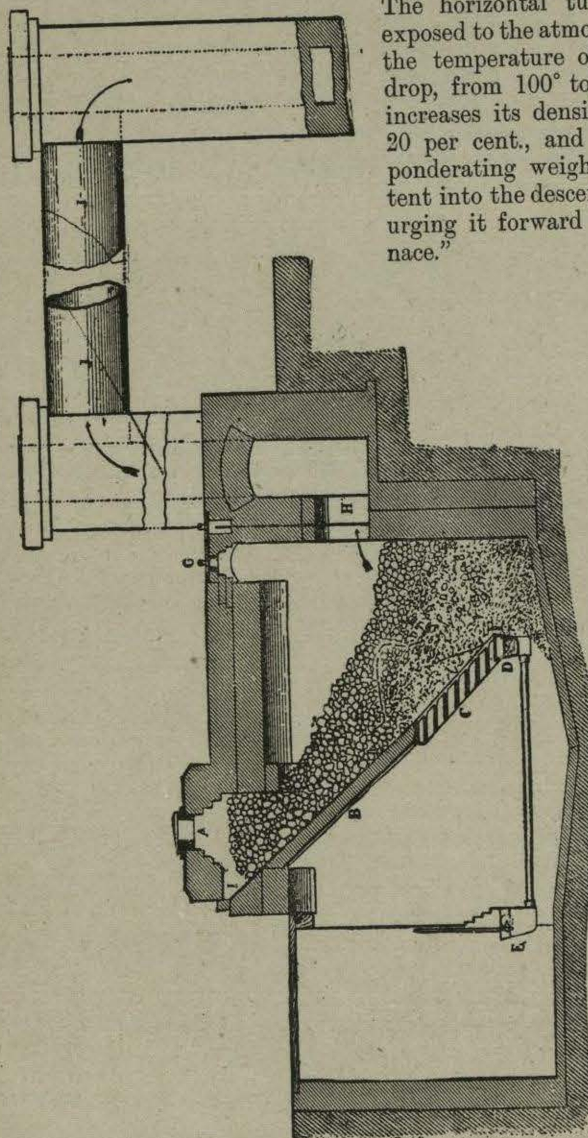


Fig. 88.—Siemens Producer, 1862.

In this producer we have all the essentials for the production of a highly combustible gas, and it is interesting to note the ingenious device to maintain an outward pressure in the gas flues by using some of the sensible heat

of the gas to do the work direct instead of employing mechanical means to force the gases into the furnace.

By lowering the temperature of the gases in the cooling tube their density is increased, and, consequently, they sink in the down-comer tube, which acts as a syphon, and enables an internal pressure equal to $\frac{1}{10}$ to $\frac{2}{10}$ of an inch of water above the atmospheric pressure to be maintained.

Modern Producers.—The following sketches illustrate various forms of modern producers, which differ from each other in detail, but are all capable of giving excellent results with good fuel:—

The Siemens Producer (*Modern Type*), fig. 89.—This is one of the best-known types of grate producer. D is the hopper by which the fuel is introduced into the rectangular chamber C, with firebars shown at F. The ashpit is closed by hinged doors in front, but air is injected with a 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, and the gases are drawn off at the top of the producer, and pass through the gas flue, E, on their way to the furnace.

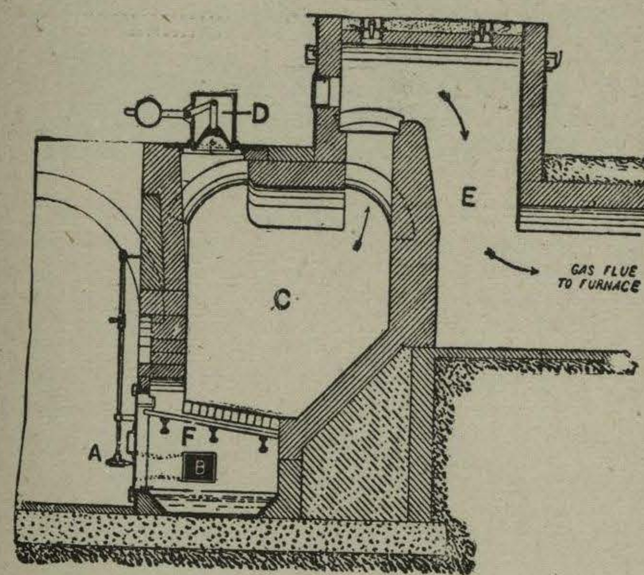


Fig. 89.—Modern Siemens Producer—A, Steam injector; B, opening through which steam injected; C, body of producer; D, charging hopper; E, gas flue.

Wilson Producer.—This producer (fig. 90) may be taken as the representative of solid bottom producers, the fuel resting on the bottom, and air and steam being injected through a central passage known as the distributer, supported by a fire-brick arch communicating with the body of the producer. The fuel is charged through a central hopper, CH, at the top, and the gas is drawn off through a series of openings, *a*, *a*, *a*, arranged symmetrically round the circumference of the producer to the downcomer, B. The producers are cylindrical, and vary from 8 to 12 feet in diameter, and gasify on an average from 25 to 30 lbs. of coal per square foot of bottom area per hour, although higher results can be obtained. To remove the ashes the producer has to be stopped at regular intervals, and iron bars are pushed through small openings and allowed to rest on the central fire-brick

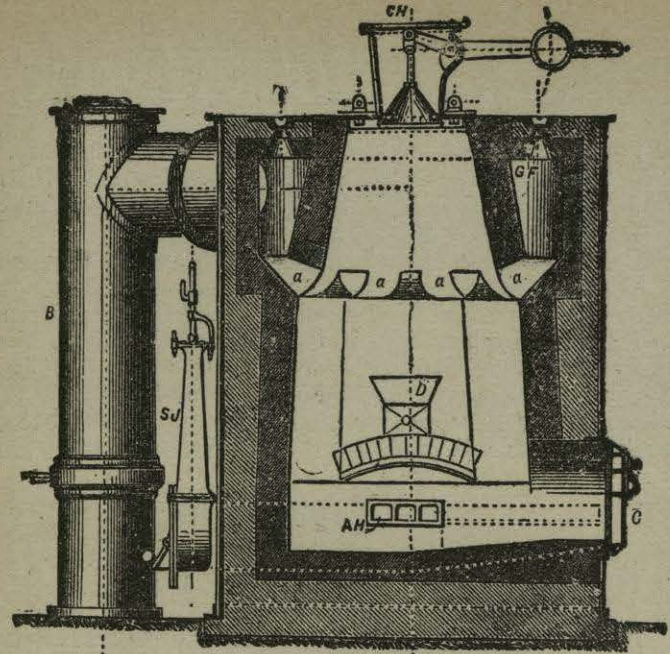


Fig. 90.—The Wilson Producer—*a*, *a*, *a*, Openings round circumference of producer through which gas is withdrawn; B, downcomer or gas flue; C, door for raking out ashes; D, air distributer.

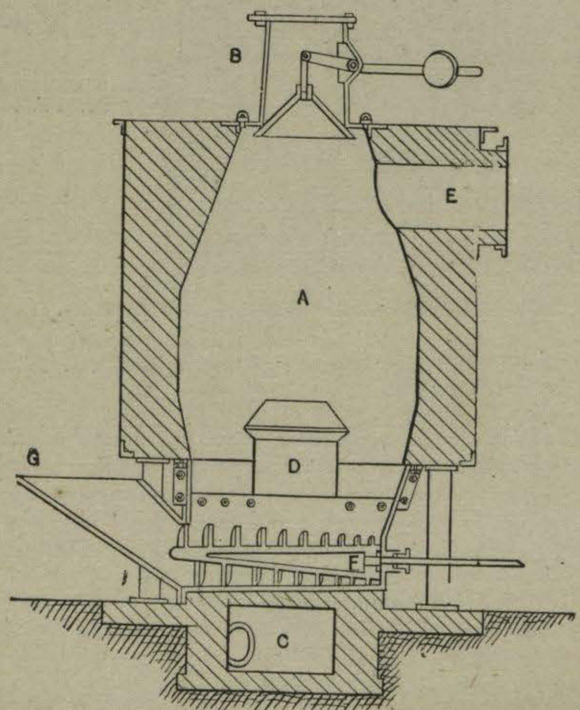


Fig. 91.—Wilson Producer—B, Charging hopper; C, air flue; D, air distributer; E, gas flue to furnace; F, screw for removing ashes; G, ash-pan filled with water.

arch to support the fuel. The cleaning doors, C, are opened and the ashes raked out. The bars are then withdrawn, the charge allowed to sink, and the blast turned on.

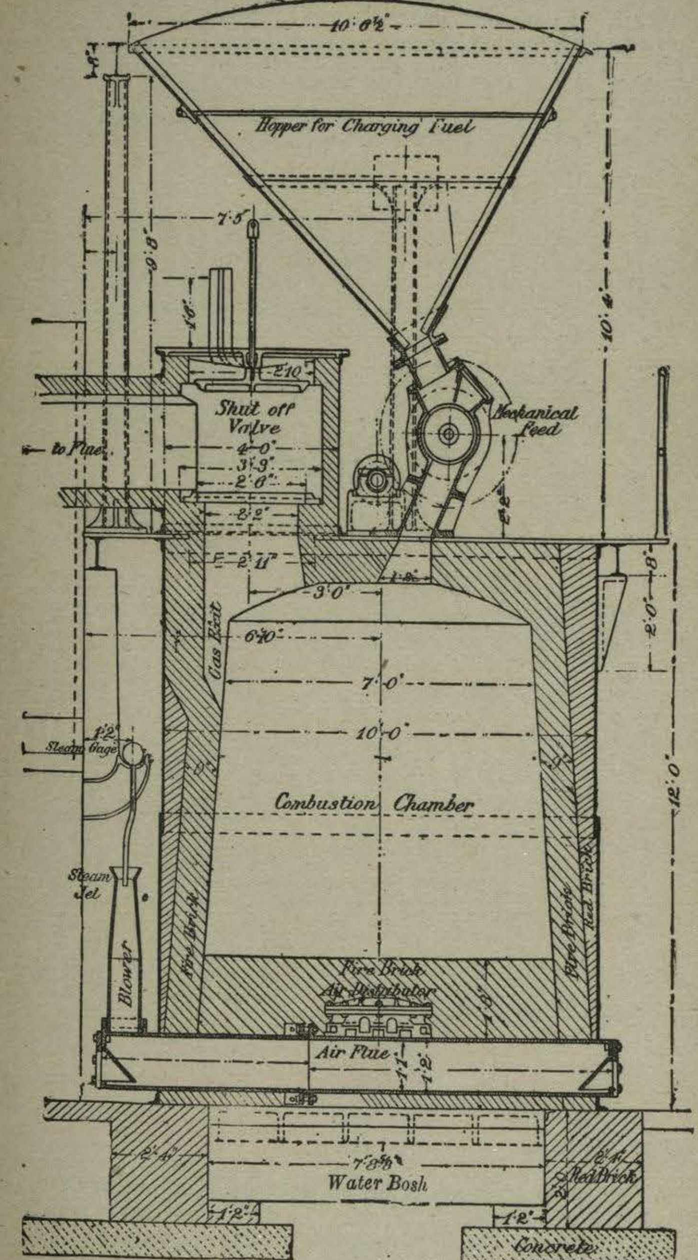


Fig. 92. - Wilson Gas Producer.

In a later design the ashes are removed by an Archimedean screw without stopping the producer, and this is shown in fig. 91.

This producer is charged and the gas drawn off as in the solid bottom producer, but the ashes and clinker are continuously forced out of the ash-pan, G, by the revolving screw, F, which rotates under water. This producer is therefore practically a water-bottom producer, as the water in G acts as a seal. The air is injected by a steam jet in the usual way.

In figs. 92 and 93 are sketches with leading dimensions of a large Wilson producer, fitted with mechanical feed and water bottom, the air distributer and other details being the same as in the closed bottom producers. The

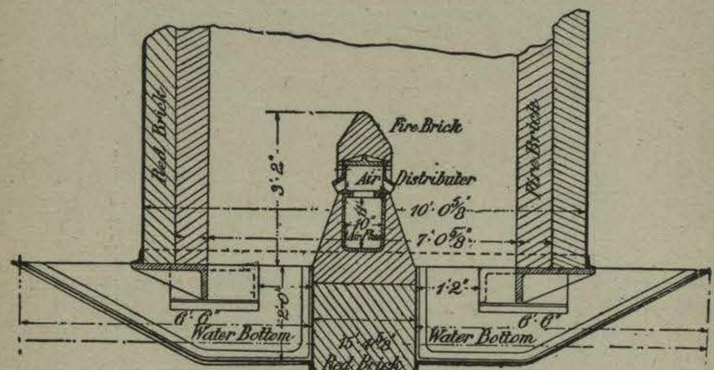
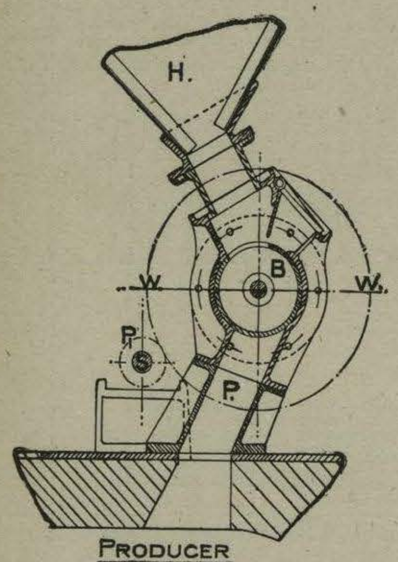


Fig. 93.—Section through Air Distributer and Water Bottom.



H, Hopper containing fuel which falls into the revolving barrel, B, through the opening shown. The barrel revolves until the opening is over the passage, P, when the fuel falls into the producer. The barrel is driven by shaft, S, on which spur pinion, P_1, is fixed, this latter gearing into W, which is keyed on the same shaft as the barrel.

Fig. 94.—Mechanical Feed for Producer.

mechanical feed is an important addition, as if carefully supervised, besides the saving in labour over hand-charging, the fuel is fed more regularly and can be better distributed over the producer. It is customary to have some form of mechanical feed now in all modern installations of producers, and that in the figure consists of a revolving barrel into which the fuel from the hopper falls when an opening in it comes underneath the bottom of the hopper. The barrel then revolves until the opening comes opposite the

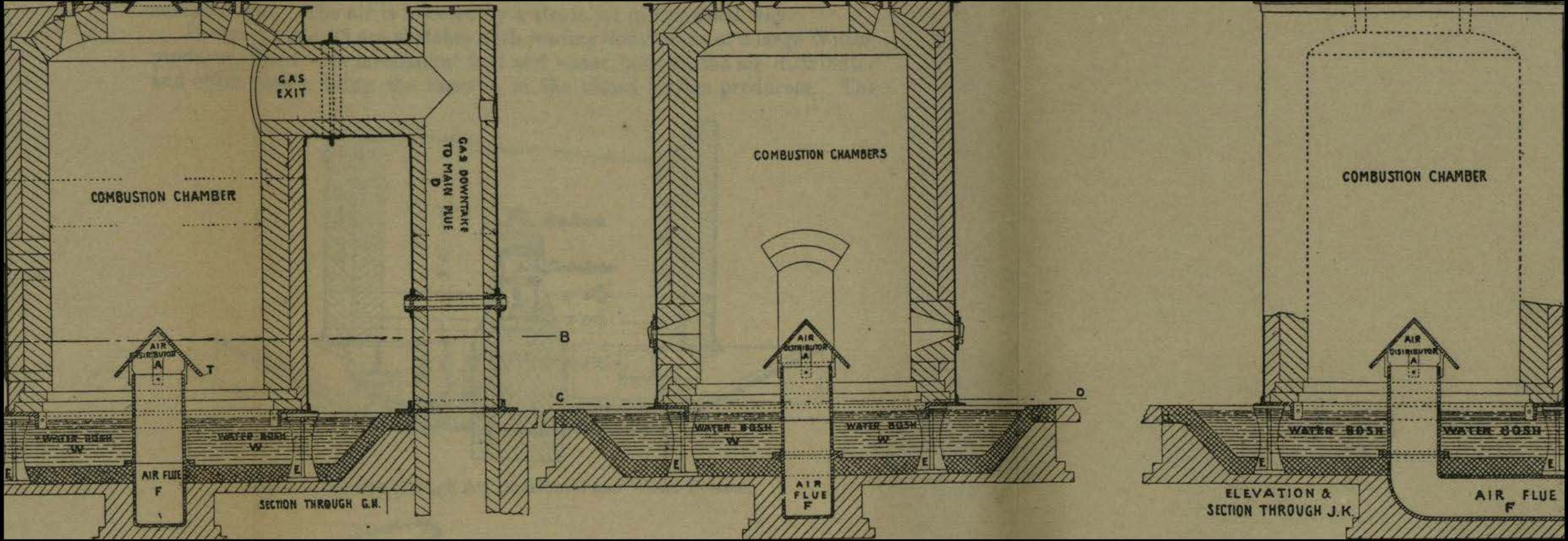

GAS EXIT
GAS DOWNTAKE TO MAIN FLUE D
COMBUSTION CHAMBER
AIR DISTRIBUTOR A
T
B
WATER BOSH W
WATER BOSH W
AIR FLUE F
E
E
SECTION THROUGH G.H.
COMBUSTION CHAMBERS
AIR DISTRIBUTOR A
C
D
WATER BOSH W
WATER BOSH W
AIR FLUE F
E
E
COMBUSTION CHAMBER
AIR DISTRIBUTOR A
WATER BOSH
WATER BOSH
E
E
ELEVATION & SECTION THROUGH J.K.
AIR FLUE F

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PLATE VI.—"Duff" Gas Producer, as used for Ammonia Recovery.

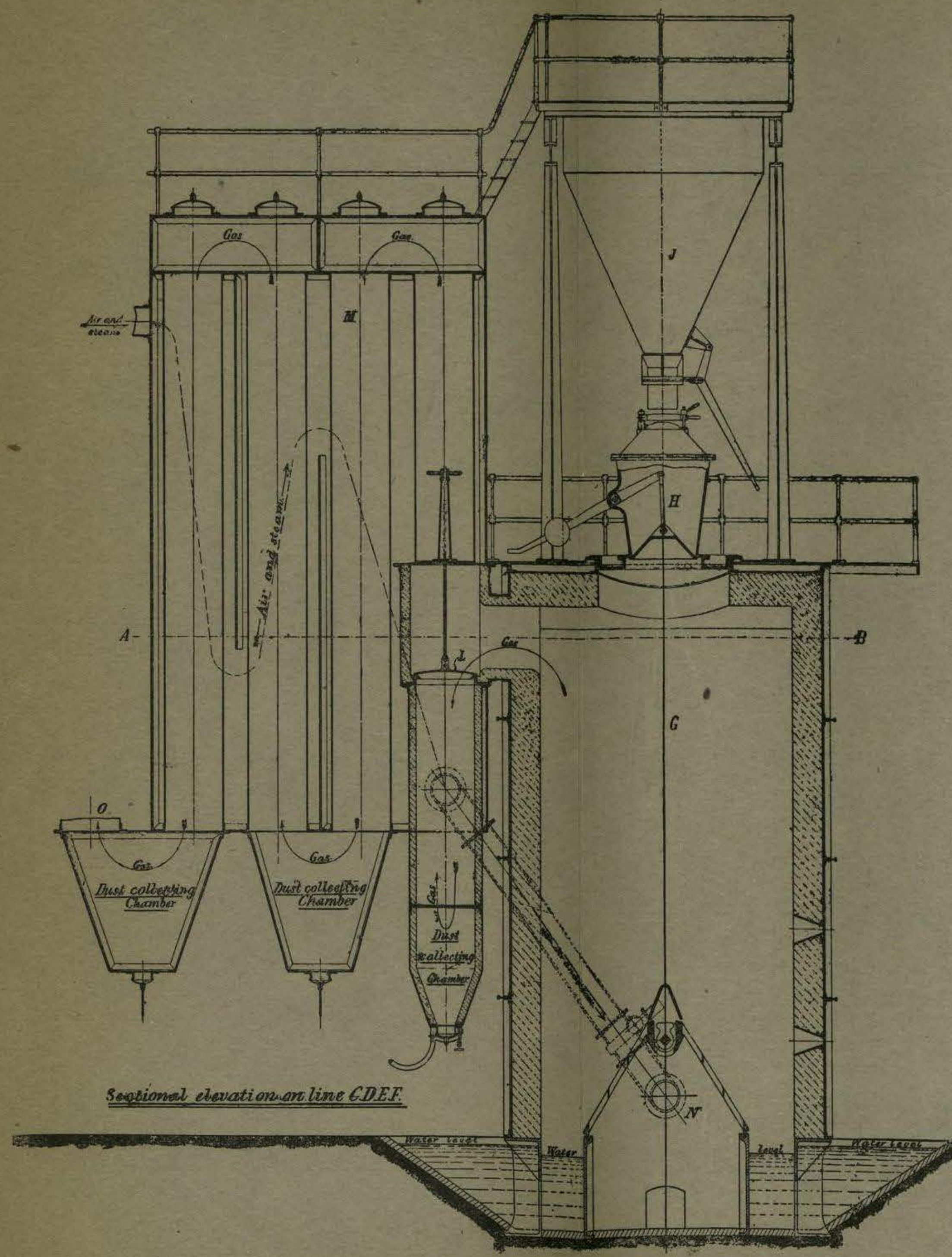

Fig. 101.

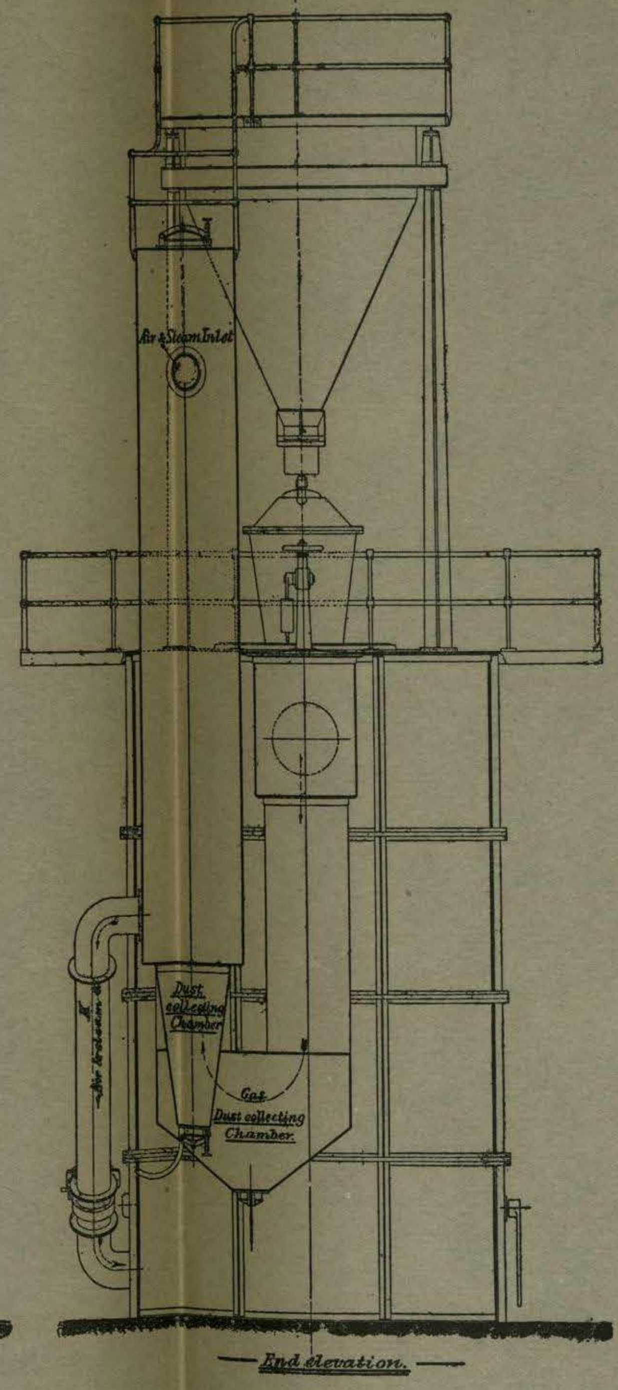

Fig. 102.

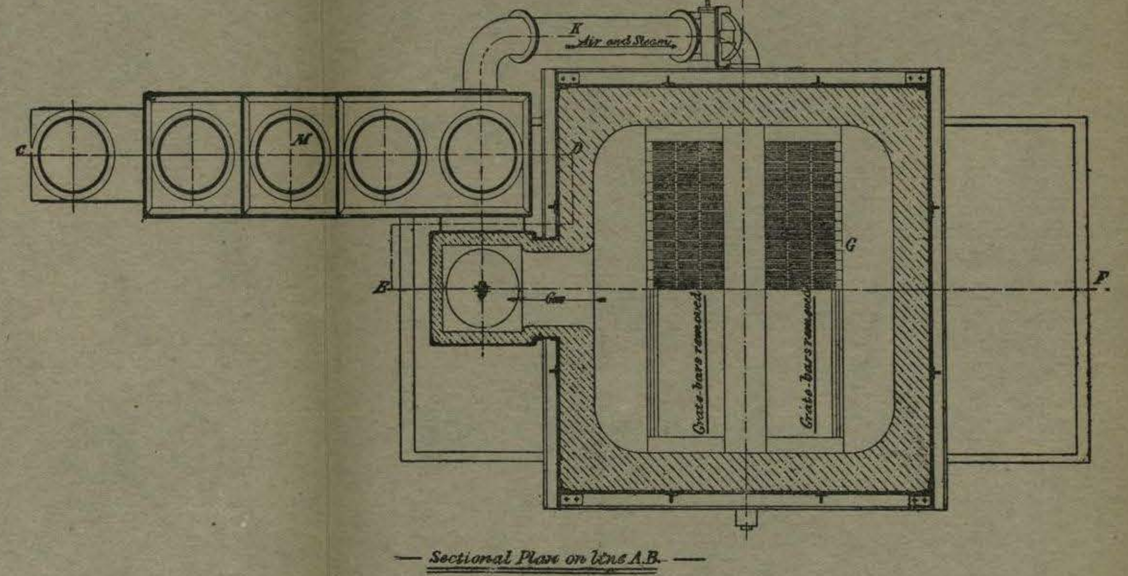

Fig. 103.

Plan, front elevation, and end view (figs. 101, 102, and 103) illustrate the general design of the "Duff" Gas Producer as arranged to work on ammonia recovery plant.

The coal is elevated on to the hopper platform and shot into the hopper, J, from which it is discharged into the gas-tight charging hopper, H, from which it is dropped into the producer chamber, G.

A mixture of superheated air and steam is blown through the superheater, M, and the pipe, K, to underneath the gratings, N, through which it is distributed over the base of the fuel bed.

The gas escaping from the top of the fuel bed issues through the valve, L, then through the dust collecting chambers and pipes of the superheater, M, alternately, issuing at O to the collecting main leading to the ammonia recovery plant.

A shaking arrangement is provided for shaking the dust out of the distributing grids at the base of the producer, and suitable operating mechanism is provided at the top of the producer for shooting in the coal and trapping the gas, while at the base of the producer means are provided for collecting and drawing off the dust. The ashes are removed through water-sealed troughs at the base of the producer.

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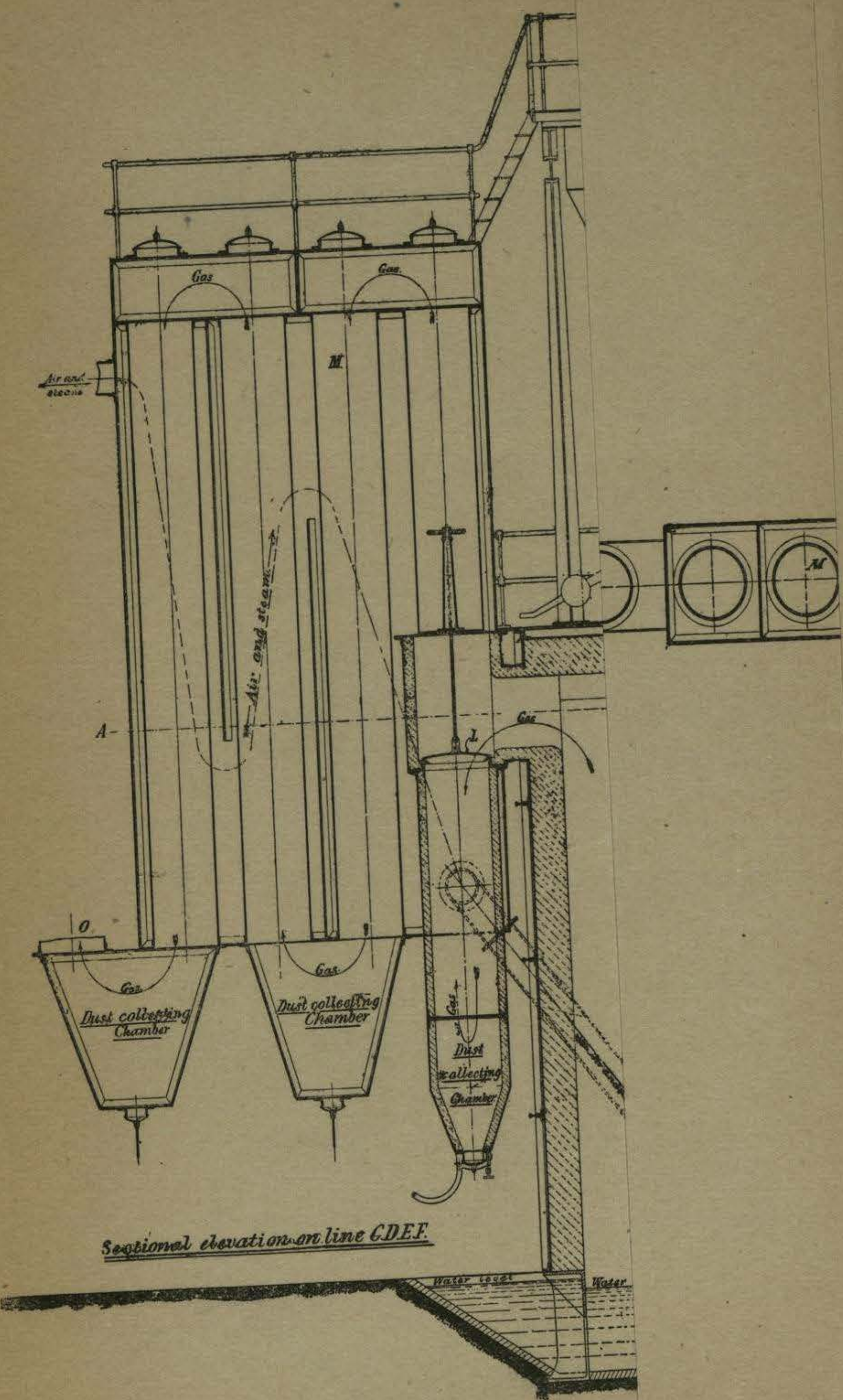

charging hole in the producer, when the fuel is discharged into the producer. As the barrel revolves it takes up another charge of coal from the hopper, and again deposits it in the producer. This arrangement has given very satisfactory results at the works of the Steel Company of Scotland, where it has been in use for some time.

The Dawson Producer (figs. 95 to 100, Plate v.).—This is a water-bottom producer, and is an excellent representative of the type. Here the ashes fall into a trough of water at the bottom of the producer, from which they can be drawn from time to time, the water acting as a seal to prevent the escape of gas. The shell, which is a cylindrical iron casing, is lined with fire-brick, and rests on short columns, E, E, E, in the water trough, the air and steam being injected through a centre pipe, F, which is covered with a conical cap, A, with small air spaces for the air and steam to pass into the body of the producer. The gas is drawn off at the top through the opening marked "gas exit," on one side of the producer, and passed through the short horizontal flue to the downtake. In starting the producer it is usual to fill it above the water level with ashes, and then light the fire and charge the fuel in the usual way.

The advantages of the water-bottom producer, which is the type of producer now in very general use, are that practically all heat from the ashes is utilised by converting the water into steam, and the ashes can be readily withdrawn and are cool enough to be easily removed. On the other hand, water bottoms are liable to increase the percentage of Sulphur in the gas, and for this reason they have in some works been discontinued, solid bottoms being substituted.

The Duff Producer (figs. 101 to 103, Plate vi.).—This is another form of producer which is being largely used in this country, especially in connection with Ammonia recovery plants. One special feature about it is that the steam and air are superheated by the gas which comes from the producer, the gas being thus partially cooled before being taken to the Ammonia recovery plant. By thus utilising the sensible heat of the producer gases to heat up the air and steam before they are forced into the producer, an additional number of heat units is introduced, which enables a greater quantity of steam to be injected into the producer without cooling it down below a fair working temperature. Particulars of the general arrangement will be readily understood from the figures (Plate vi.), to which a description is attached. The producer can, of course, be used either with or without Ammonia recovery plant.

The Mond Producer.—When the tarry matters resulting from the distillation of coal are passed through a bed of incandescent fuel, they are converted entirely into gases; many attempts have been made to do this, and at the same time to recover the Nitrogen present in the fuel in the form of Ammonia, but only with partial success. In the latest form of Mond producer they have not only succeeded in destroying the greater part of the tar resulting from distillation, but also in recovering something like 90 lbs. of Sulphate of Ammonia per ton of coal gasified, which is equivalent to a recovery of about 70 per cent. of the Nitrogen originally in the fuel.

This is largely effected by injecting into the producer very large quantities of steam—about 2½ tons for every ton of coal used—thus maintaining a much lower temperature in the producer than is usual, so that the resultant Ammonia is not decomposed, the fuel cakes only slightly, and only a little clinker is formed.

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 gas containing the Ammonia is passed through an absorbing apparatus. The fuel is mechanically fed into the producer, and is charged in large quantities of 8 cwts. to 10 cwts. at a time, and the ashes are withdrawn without interfering with the regular continuous working. The gas generated is uniform in quality, and, as no tar is produced, the plant can be kept clean, and the gas cooled to any desired extent, without blocking the pipes and valves.

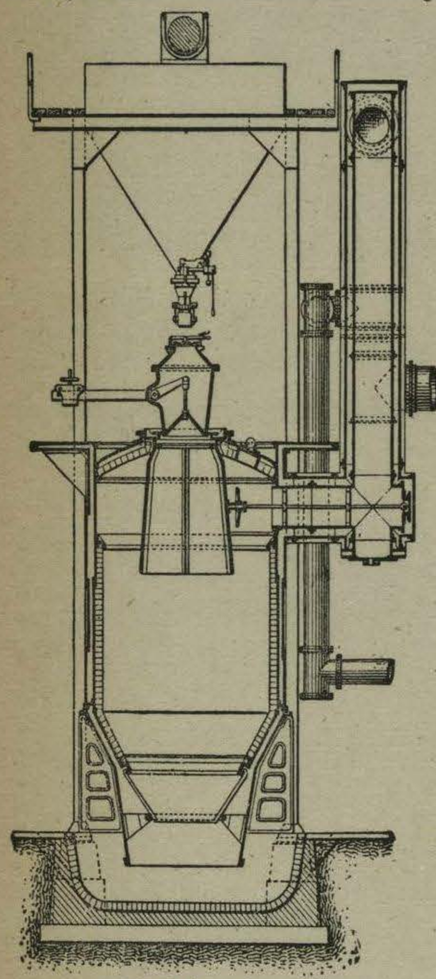

Fig. 104.—Mond Gas Producer.

The gas produced is very high in Carbonic Acid, but this is to a great extent compensated for by the large percentage of Hydrogen, and the calorific value appears to be quite equal to ordinary producer gas.

The following are average analyses :—

	Per cent.	Per cent.
Hydrogen (H), . .	24·8*	27·5†
Marsh Gas (CH_4), .	2·3	2·0
Carbon Monoxide (CO),	13·2	11·0
Nitrogen (N), . .	46·8	43·0
Carbon Dioxide (CO_2), .	12·9	16·5

The question how far such a gas is capable of yielding the high temperature necessary for steel making may, in the opinion of some steel makers be open to doubt; but, from the experiments of Mr. Darby,‡ there seems reason to believe that, provided the gas is heated to a high temperature by the usual system of regeneration, it will give good results, notwithstanding the large percentage of incombustible gases present.

Against the recovery of the Ammonia in this producer must be set the cost of raising the large quantity of steam required; but when full allowance is made for this, there is still a very substantial balance left. The reason why the producer has not been more largely adopted in steelworks' practice is probably mainly due to the considerable cost of the plant as compared with an ordinary producer plant of the same capacity. A few years ago a large company was formed to manufacture the gas and distribute it through mains to various works within a definite area, and there is no question that a gas suitable in all respects for many metallurgical and manufacturing operations can be produced and distributed at a comparatively low price.

* *Min. Proceed. Civil Engineers*, vol. cxxix., p. 210.
† *Iron and Steel Inst. Journ.*, 1896, vol. i., p. 144. ‡ *Idem.*

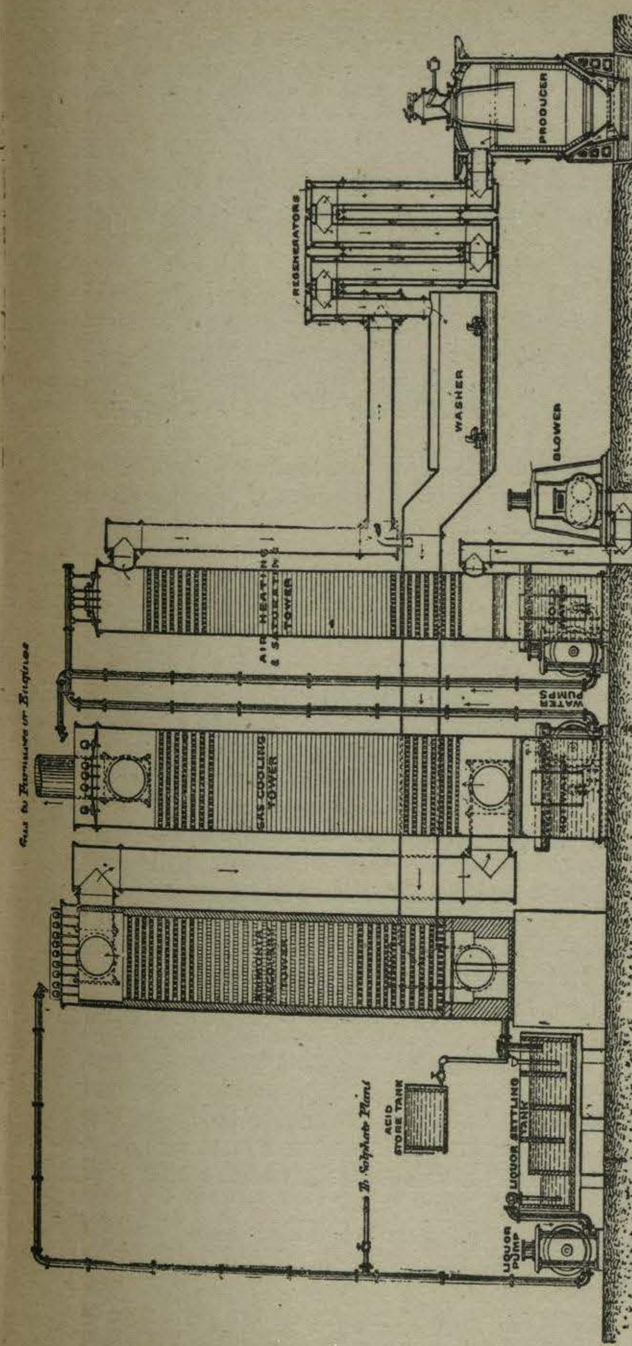

Fig. 105.—Mond Producer and Ammonia Recovery Plant.

The hot gas leaving the producer passes into the regenerators, consisting of a series of wrought-iron vertical double tubes, so arranged that, while the hot gas is being cooled by passing in one direction through the inner tubes, the air and steam are being heated by passing in the opposite direction through the annular space between the tubes. The gas then passes into the long chamber called a washer, which is kept completely filled with fine spray by revolving dashers which just skim the surface of the water. By this intimate mixture of gas and water spray, the temperature of the gas is reduced to about 90° C. The gas then passes to the Ammonia recovery tower on the left, as shown by the arrows, and meets a descending stream of Sulphuric Acid, which deprives it of its Ammonia, and finally it passes into the cooling tower, which is filled with wood packing, to give a large surface where it meets a downward current of cold water, when a great portion of the steam it contains is condensed. It is then taken direct to the furnace for use. The hot water from the gas cooling tower is pumped into the air heating tower on the right-hand side of the diagram, where it gives up its heat and saturates the cold air with steam passing through it on its way to the producer. Throughout the process the gas is under pressure.