Mr. Rowan. maximum quantity of ammonia were recovered from the coal, the temperature of combustion in the producer was not in that event suitable to the production of good heating-gas, and the apparatus introduced by Mr. Beilby, at Oak-Bank Works, was a case in point. He extracted the maximum quantity of ammonia from the coal, and consequently did not produce a quality of heating-gas which was particularly good, as the analyses he had quoted showed; but at the same time, where the fuel containing nitrogen was burnt in an atmosphere of steam, a very fair quantity of ammonia might be recovered, consistently with the production of good heating-gas.

Correspondence.

Mr. Beilby. Mr. G. Beilby observed that not the least interesting part of the Paper was the table of analyses of producer-gases; it would, however, add much to its value for purposes of comparison if the numbers representing the calorific value per 100 litres were extended for all of the gases analysed. The want of this extension had led the Author into an error which he would no doubt be the first to recognize, when it was pointed out. On page 5 of the Paper it was stated that the conditions under which Young and Beilby's apparatus was worked were unfavourable for the production of good heating-gas, owing to the considerable quantity of carbonic acid which was formed. The latter part of the statement was true, but it was equally true that a proportionally large quantity of hydrogen was also produced, so that the calorific value of the gas was above, not below, the average of producer-gases. Selecting analyses 15, 26 and 47 as good representative examples of Siemens, Wilson, and Young and Beilby gas (pp. 50, 51), and extending the calculations of calorific value, the following results were obtained:—

	Siemens (No. 15).	Wilson (No. 26).	Young and Beilby (No. 47).
Quality of coal . .	Not stated.	Yorkshire slack.	Lanarkshire slack.
Calories per 100 litres	116,753	124,302	147,433

Evidently No. 47 was susceptible of great enrichment by the removal of carbonic acid (say for chemical purposes), or by its reduction to carbonic oxide by passing the scrubbed gas through red-hot coke.

Mr. Clerk. Mr. Dugald Clerk remarked that the Paper clearly described the practical points involved in the construction of an efficient producer, as well as some parts of the theory of the use of gaseous instead of solid fuel. He thoroughly agreed with the Author in thinking it likely that gas-firing would in time become much more extended than at present, especially for metallurgical work where high temperature was the principal consideration. When high temperature was not the main point, as in steam-raising, he did not believe that the preliminary gasification of the fuel offered much advantage; this, he thought, was apparent from a consideration of the necessary loss in all existing methods of gasifying fuel. With pure carbon in a producer, for example, and air alone without steam, a perfect producer would give a mixture of carbonic oxide and nitrogen only, the composition being 1 volume of carbonic oxide and 2 volumes of nitrogen. The gases leaving would be at a high temperature, and if cooled before reaching the place where heat was to be produced, only 70 per cent. of the amount of heat which the original carbon would give if burned direct would be evolved. That was taking the quantity of heat evolved by a given weight of carbon when burned to carbonic acid as 100, then when burned to carbonic oxide 30 would be evolved, leaving 70 to be evolved by burning the carbonic oxide to carbonic acid. In gasifying carbon there was therefore a loss of heat which could be avoided in either of two ways:—(1) By retaining the heat in the gas formed; (2) by abstracting the heat from the gas formed in such a manner that it might be rendered available in a chemical reaction to give more inflammable gas. The first system was used in some kinds of the gas-firing of ordinary coal-gas retorts, where the gases from the producer impinged almost directly upon the retort without a long passage and cooling. The second method was applied when some kind of regenerator was used to cool the issuing gas and heat the entering air, which in this case must have steam along with it. When steam acted on hot carbon the reaction, as far as it ultimately resulted in producing inflammable gas, was Mr. Clerk.

$$H_2O + C = H_2 + C\,O.$$

This reaction could not proceed without a large absorption of heat, for 18 parts by weight of steam and 12 parts by weight of carbon required an expenditure of 39,540 heat-units to produce by decomposition 2 parts by weight of hydrogen, and 28 parts of carbonic oxide. Mixing steam and, in the proper proportions, air supposed to have given to it by regeneration all the heat of the issuing gases, and supposing no loss by conduction, then pure carbon would yield a gas of the following composition:—

	Volumes.
CO =	38·7
H =	16·4
N =	44·9
	100·0

Mr. Clerk. This gas would on burning give the same amount of heat as the direct burning of the original carbon; it was the best gas capable of production from air, steam and carbon, and might be used as a standard of efficiency of producers. In practice, naturally some loss was necessarily made. None of the analyses on p. 50 showed an efficiency so high as 80 per cent., although several closely approach that figure. A more careful application of the regenerative system was necessary if improved results were to be obtained; but 80 per cent. was a high efficiency, and if practical difficulties were more thoroughly overcome, greatly extended usefulness would follow without the necessity of improvement on this point. For gas-engine purposes the principal difficulty at present was tar; in the Dowson producer this trouble was overcome by burning anthracite, but in order to be generally applicable, ordinary fuel of the cheapest kind would require to be gasified without producing tar. The Wilson producer, excellent as it was for furnace-purposes, was as yet inapplicable to the gas-engine; an engine of his own, tried with it several years ago, could not be worked continuously on this account. The late Sir William Siemens, long as he worked with the gas-engine, and originating as he did the gas-producer, was unable to get the two to work together. The application of the gas-producer to the gas-engine would undoubtedly greatly extend the usefulness of producers and engines alike. The main advantage of gaseous-fuel lay in its capability of application at the point where heat was required, with just the air necessary for combustion and no more, and the ease of using regenerative methods in handling it.

Mr. Coleman. Mr. J. J. Coleman observed in reference to the formula given by the Author at the commencement of the Paper, p. 4, that the conversion of the solid fuel into the gaseous was caused in the Siemens, the Wilson, and other similar producers, by the admission of air, the oxygen going to form CO, and carrying along with it the usual quantity of inert nitrogen. Instead of pure carbonic oxide, a gaseous fuel was produced largely diluted with nitrogen; but when it was burned in air, instead of the resulting temperature being

$$\frac{2{,}403}{1 \cdot 57 \times 0 \cdot 2164 \times 1 \cdot 91 \times 0 \cdot 244} = 2{,}982^\circ \text{ Centigrade,}$$

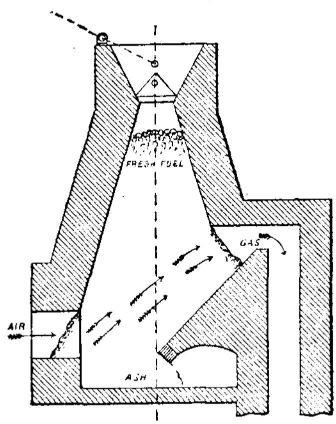
it was much lower, namely,

$$\frac{7 \times 2{,}403}{11 \times 0 \cdot 2164 \times 26 \cdot 8 \times 0 \cdot 244} = 1{,}805^\circ \text{ Centigrade.}$$

The temperature of combustion of carbon, 2,717° Centigrade, was therefore 912° Centigrade higher than that of the CO obtained in the ordinary gas-producer—this difference of temperature appearing as sensible heat in the gaseous products, and in the case of gas from coal a portion of it disappearing as the latent heat of the distillation of the hydrocarbons. This calculation was, of course, somewhat modified by the fact that the small quantity of steam used in ordinary producers (1 part of steam to 20 parts of air in the Wilson producer,) formed water-gas, to which the formula quoted by the Author applied. As water-gas existed only in small quantities in producer-gas, and as the Author subsequently stated "that a continuous water-gas producer has still to be invented," it was evident that the formula adduced had little bearing on the various processes described. In the Wilson producer, the Author stated that "this upper portion should be a veritable retort." No doubt this was as it should be; but it would be evident, to any one experienced in the slowness of the distillation of coal as carried on in the ordinary gas-retorts, that this upper part of the Wilson furnace was far from being so, taking into consideration the thickness of the walls of the conical part, and the shortness of the chamber containing the fresh fuel, as well as the comparatively low temperature of the gaseous-products. The Minary producer, with its retort of iron, would be much more efficient in this respect, and both retorts, he thought, would fall short of the Gröbe producer, which had the two operations entirely distinct. He had no doubt that the regularity of the gaseous-products claimed for the Wilson producer was due principally to keeping the fuel as high in the retort part as was practicable, always ensuring that the incandescent coke covered the outlets for the gas, and also taking care to have a fresh charge put in before the hydrocarbons had been entirely distilled from the last one. In the Wilson automatic producer (Figs. 43, 44, 45) the retort part was entirely dispensed with, an arrangement which must of necessity give a supply of gas very irregular in quality; such a producer could not be worked to advantage singly. An automatic supply of fuel under such conditions would certainly be a much greater desideratum than a regular discharge of the ash, which with ordinary coal would not exceed 10 per cent. of the fuel used. Fig. 73 (p. 82) represented a producer which had been introduced successfully by Mr. J. W. Macfarlane, of Glasgow, and which had some excellent features, more especially the ease with which it could be cleaned out, and in the regularity of the gaseous-products. The first of this kind was erected in the Lochburn Ironworks, about seven years ago, and had been regularly at work Mr. Coleman.

Mr. Coleman. since that time, drying cast-iron pipe-moulds. Quite recently one of these producers had been erected in a large engineering works in Glasgow, the gas from which had been used successfully for all the drying and melting required in a large brass-foundry; that was to say, it had been used in a large reverberating furnace, provided with a Gorman continuous regenerator for heating the air for combustion; and it had also been used for melting in crucibles placed in specially constructed furnaces designed by Mr. Macfarlane, which were so arranged that the crucible formed an integral part of the furnace, and was capable of being tilted without being removed from the furnace, and consequently never needed to be touched with the tongs, as usual in ordinary brass-founding. Any one examining the various operations could not but be struck with the

Fig. 73.

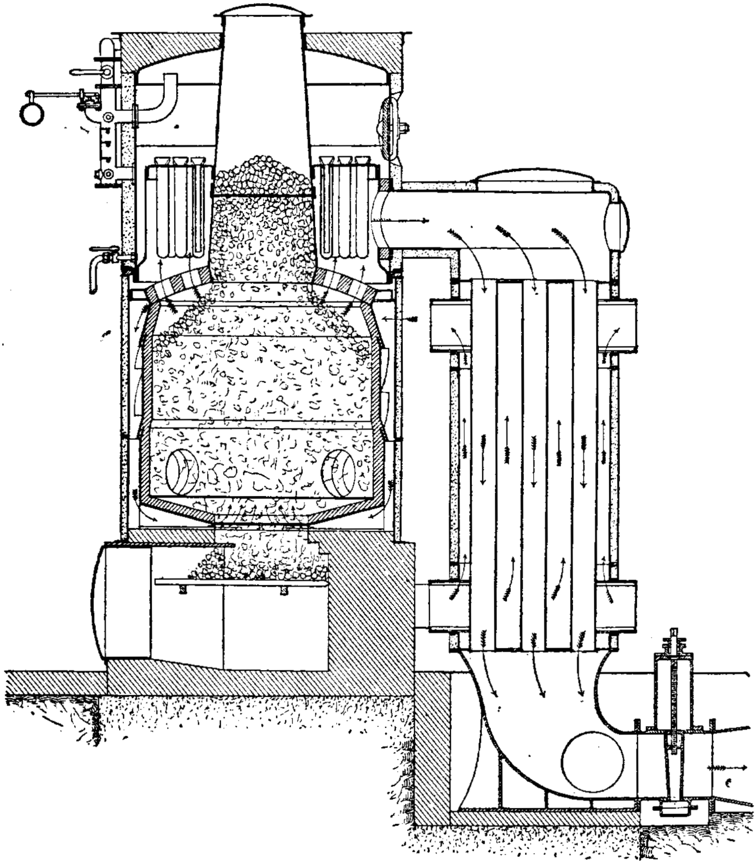


Macfarlane Producer.

ease and cleanliness with which they were performed, and with the apparent regular supply of gas from one producer, and the facility with which the flame could be regulated by the air-supply. In this producer the air, which was supplied by a Korting blower, entered the natural slope of the ash, passed diagonally upwards through the incandescent coke, and left by the natural slope of the coke. The ash mostly accumulated where the air entered, and was easily and rapidly withdrawn through the doors. The bell in the hopper was made to open upwards instead of downwards as usual, which was intended to allow of its being changed without stopping the producer entirely. The column of fresh fuel rested on the bed of incandescent coke, and the hydrocarbons were gradually distilled, and had to pass through a portion of the incandescent mass before finally passing into the outlet flue. Mr. Coleman.

Mr. A. Fichet submitted a description of Muller and Fichet's Universal Gas-producer. The apparatus (Fig. 74), which was designed in June 1874, consisted of a cylindrical or rectangular Mr. Fichet.

Fig. 74.



body of boiler-plate, or cast-iron, furnished with a lining of refractory material. In this vessel the fuel was gasified. Air was forced in at the lower part by means of a steam-jet, and the slightly funnel-shaped base acted to direct the mixture of steam and air to the middle of the fuel. The top of the retort was formed by a firebrick arch perforated by holes, allowing the

Mr. Fichet. gas to pass to an upper chamber. Through the axis of this chamber passed a hopper of boiler-plate, resembling a truncated cone, attached to the roof of the retort, and serving for the introduction of the fuel. The latter descended little by little till it reached the retort, where it was distilled by the heat of the gases passing through the perforated arched roof. The heat from this source also served to generate the steam necessary for admitting the air. To this end the upper chamber formed a ╔╗-shaped steam-boiler furnished with Field tubes, distributed around the hopper which passed through it axially. This disposition utilized the greater part of the heat of the gases of combustion without any admixture of air. In order to cool them completely before distribution, they were, on their exit, made to traverse, in a downward direction, a nest of tubes around which circulated the mixture of air and steam furnished to the retort by the injector. By this means the air was superheated without expense. In order to avoid loss of heat by radiation, the generator was furnished with a double envelope, the outer wall of which was further covered with a layer of non-conducting material. In the annular space thus provided the air to feed the furnace circulated, previously heated in its passage round the tubes of the gas-cooler. By this means the mixture of air and steam attained a high temperature before coming in contact with the fuel, and thus allowed of using a higher proportion of steam than would have been possible without such superheating. The steam was decomposed in its passage through the generator, thus providing combustible gas. It might therefore be said that the sensible heat of the gas had been utilized at the time of its production in order to augment its calorific power. The gas being cooled, could be distributed to the various furnaces of a factory, to be there burnt in the ordinary way with cold or hot blast, and on occasion could itself be heated by the passage through regenerators, according to the heat desired to be attained in the furnaces. This generator had been arranged so as to utilize inferior coal, and such as was not ordinarily adapted to the gas-producer. Instead of attempting, as some had done, to melt the ash, Messrs. Muller and Fichet had sought to obtain a moderate rate of working. A convenient number of openings at the bottom of the generator, allowed of its being cleaned out. Generally the burning fuel reposed on a bed of ash and scoria easily permeable by the air. When this bed became too thick some of it was cleared out. In ordinary work it sufficed to do this once a day. The joints were made with asbestos cloth, which prevented the escape of the gases. Below the tubular cooler was a casting of one, two, or three pipes, furnished with valves to direct the gas into the required direction. With such a disposition of apparatus it was possible to install a gas-producer in some convenient corner of the factory, and to conduct the gas from it to any required point as was done with illuminating-gas. To obviate an inconvenience arising from irregular consumption, a gasholder might be employed, thus ensuring a supply at constant pressure, and rendering the working of the producer and of the furnaces mutually independent. As regarded rate of working, this producer would easily gasify 100 to 120 kilograms of fuel per square metre of section (20·5 to 24·6 lbs. per square foot) per hour, and by slightly augmenting the force of the blast the product could be increased. When coal of too rich a quality was employed, distillation was produced in the hopper surmounting the retort, and this caused the accumulation of a mass of coke which would not feed properly into the vessel below. If such fuel were used it would be necessary to leave at the base of the arched roof several holes, through which iron bars could be introduced to break up the coke. In conclusion Mr. Fichet justified the name "Universal Gas-producer" by the consideration that the apparatus, being altogether separate and distinct from the furnaces in which the gas was to be burnt, was capable, either singly or by grouping, of making the gas for all the furnaces of a factory, and was applicable to nearly all industries. Among the fuels of little value which could be utilized with advantage in this producer were coke-breeze, often a waste product, and the cinders falling from the grates of ordinary furnaces. Such materials could be charged in the hopper either alone or mixed with coal, and would furnish excellent gas. Mr. Fichet had the pleasure to present to the library several pamphlets bearing on the employment of producer-gas.[1] Mr. Fichet.

Mr. W. Foulis stated that about four years ago, shortly after Sir William Siemens patented the circular form of gas-producer referred to by the Author, he proposed to Mr. Foulis to apply a producer, somewhat similar in construction, to heating gas-retorts. Mr. Foulis.

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[1] "Notice sur les travaux scientifiques de M. Ébelmen." Tract 4to. Paris n.d.

"Notice sur l'appareil de M. Orsat pour l'Analyse des Gaz." Par M. Fichet. Tract 8vo. Paris, 1873. (Extrait des Mémoires de la Société des Ingénieurs-civils.)

"Etudes sur la combustion et sur la construction rationnelle des Foyers industriels." Par A. Fichet. Tract 8vo. Paris, 1874. (Extrait des Mémoires de la Société des Ingénieurs-civils.)

"Exposition Universelle de 1878. Notice sur les appareils présentés par MM. Muller et Fichet, Ingénieurs, &c." Tract 8vo. Paris, 1878.

Mr. Foulis. As in this case coke was the fuel to be used, all arrangements for collecting the gas and drawing it through a portion of the fuel were unnecessary. Four producers somewhat resembling in shape that shown by Fig. 54 were erected at Glasgow Gas-works. This form of producer was soon found to be unsuitable for the fuel then in use, which consisted entirely of the coke from Cannel coal having from 15 to 25 per cent. of ash. Many modifications in shape were tried, and it was ultimately found that the most suitable form was a plain cylinder of equal diameter throughout, without grate-bars, and having four openings for air at the bottom, sufficiently large to allow a shovel being inserted to remove the ashes. These openings had no doors, but were left always free. There was a jet of steam at each opening, the object of which was to prevent the ash from clinkering. Various arrangements were tried for getting the necessary steam from the evaporation of water by the heat of the producer, but in all these arrangements the quantity of steam produced was more or less variable and uncertain: and as the amount required was very small, provided the supply was constant, it was decided to take a supply of steam from the steam-boilers of the works. The best results were obtained when the steam was made to play softly over the whole opening, so as to mix thoroughly with the air passing in to support combustion. These producers had proved highly successful, and there were now in Glasgow Gas-works more than two hundred of them, heating about seventeen hundred retorts. The producers were charged every six hours with red-hot coke drawn directly from the retorts. The whole mass of fuel might therefore be considered to be in a state of combustion from the time the producer was filled; and there was therefore a fairly equal production of gas during the charge. Many experiments had been made on the composition of the gas at different periods of the charge. The following analyses might be taken as an average of the quality of the gas at different periods:—

	One hour after filling Producer.	Three hours and thirty minutes after filling.	Five hours and forty minutes after filling.
Combustible gases—			
Carbonic oxide and hydrogen	32·7	34·7	37·6
Non-combustible gases—			
Carbonic acid	7·2	5·3	3·4
Nitrogen	60·1	60·0	59·0
	100·0	100·0	100·0

It would be observed that the gas improved in quality as the charge burned down, that was when the depth of fuel was less and the temperature was higher. All the experience with these producers went to prove that in order to get good gas it was necessary to have a high temperature in the producers. The successful use of gas for heating depended much on the method of using it in the furnace. The arrangement of ports for the admission of air and gas had to be varied according to the purpose for which the heat was required. When a very high temperature was desired over a limited surface, as for example in the case of welding iron, the air and gas should be made to mix thoroughly immediately on entering the furnace. When, on the other hand, a more moderate temperature, extending over a larger surface, was wanted, as in heating gas-retorts, this immediate mixing should be avoided, and the air and gas should be made to flow through the furnace side by side, gradually mixing as they advanced. Much of the success of the furnaces at Glasgow was due to the careful arranging of the gas- and air-ports for this purpose, so as to get an equal temperature throughout the whole of the retorts without intense local heat at any point. As an example of the benefit of gaseous-fuel, he might mention that since the introduction of these furnaces only one-half the fuel was used, while the retorts were capable of carbonizing 30 per cent. more coal. Mr. Foulis.

Mr. B. D. Healey remarked, on the building of curtain-walls for the purpose of compelling the hydrocarbons to pass through the incandescent fuel, that in 1864 he applied this plan to sixteen producers at the Barrow Steelworks, from drawings supplied by the late Sir William Siemens. They did not answer well, owing to the charging hoppers remaining in their former and accustomed position, namely, at the top of the incline in front of the grates, the reason being that the fuel was too thin over that part of the grate below the arches, and the gases generally passed, not through the incandescent part, but through the layer immediately above, which was not hot enough to effect the fixing of the hydrocarbons. He then removed the charging hoppers to a central position over the fire-grates, which enabled him to keep a layer of fuel nearly uniform in thickness over the whole of the grate surface, and to fill up some distance above the arch, without having too much fuel on the incline. Under these conditions, the quantity of soot and tar in the tubes was considerably reduced; but as the producers came in turn to be repaired, the curtain-walls were not properly attended to, occasionally a ring of the arch would fall, and in course of time they were abandoned. Since then automatic feeders (Dowker and Smith's) had been substituted for the central charging hoppers, and these feeders he considered were of great Mr. Healey.

Mr. Healey. assistance in securing a regular quality, as well as a more constant supply of gas, and the soot and tar were also thereby reduced. In building producers at the same level as the furnaces they had to supply, it was of course optional whether steam-blowers or siphon-tubes were used, but he had always insisted upon keeping the producers below the furnaces where practicable. It was a great advantage to have a decided pressure at all times. During clinkering, when the pressure depended upon blowers, the back-pressure at the fires which were being clinkered was very inconvenient to the workmen. Moreover he had repeatedly heard of explosions being caused in small installations where only two or three producers were used, which would not have occurred had the level of the grates been below the level of the furnaces. At the present time he was using his own producers (with steam-blowers), a modification of the form for which he obtained a patent in 1872. They were liked by the workmen, being handy to clinker, and there was very little loss of coke in clinkering. He had also fitted to the eight water-gas producers at the Trimsarau works annular blast-boxes, with cleaning holes opposite each jet, and with elbow-pipes fitted with doors, under which was a tramway for taking away the clinkers.

Mr. Isherwood. Mr. B. F. Isherwood remarked that there were many circumstances in which the production and use of gaseous-fuel might be advantageous, irrespective of economy. For example, the houses of a city might be supplied with such fuel as a matter of convenience without regard to cost, just as illuminating-gas was generally used, although the same quantity of light could be produced at far less expense by burning the various distillates of petroleum in suitable lamps. And many other cases might be cited, in which advantages other than economy decided the use of particular articles of consumption. The various gas-producers which had been invented, and the results obtained from them, were well worth study and experimental investigation, because their use might be desirable for other reasons than that of a cheaper production of heat, which appeared to be the principal claim at present advanced for them. Nevertheless, the belief that a given quantity of heat could be produced by such means, at less cost than by burning coal in a solid state on a grate in the usual manner, must be dismissed as erroneous, and the benefits to be derived from gas-producers must be considered from a different aspect than an imagined superiority of the combustion of gaseous-fuel over that of solid fuel. The assumption was made as a matter of course, that the consumption of coal on a grate, as in the furnace

Mr. Isherwood.

of a steam-boiler, for example, was imperfect, and that consequently a considerable portion of the possible heat obtainable from the coal was lost. In other words, there was taken for granted that the combustible constituents of the coal were not burned to saturation with oxygen, that a large portion of the fixed carbon was converted into carbon monoxide instead of into carbon deutoxide, and that a large portion of the volatile matter wholly escaped combustion. Now in these respects the exact facts relative to the ordinary combustion of coal admitted of being known with absolute certainty by chemical analysis of the gases of combustion drawn from the chimneys of steam-boilers. The mean of many hundreds of such analyses from different chimneys, and for different bituminous coals consumed, showed that a given bulk of these gases, exclusive of aqueous vapour, contained about 0·038 per cent. of carbon monoxide and about 0·025 per cent. of free hydrogen: no hydrocarbons were found, but from 9 to 9·5 per cent. of free oxygen was present, proving that double the quantity of air passed through the fuel that was chemically used for the combustion. The above percentages were for very bituminous coals producing much black smoke, and represented a loss of about one-twelfth of the coal thrown into the furnace; which twelfth, or about 8·3 per cent., passed into the atmosphere unconsumed. In the case of anthracite, about one-fortieth of the quantity thrown into the furnace, or about 2·5 per cent. of the coal, escaped into the atmosphere unconsumed, and the free oxygen found in the dry gases of its combustion was about 10 per cent. of their bulk, showing that twice the air used in the combustion passed through the anthracite. Between these two extremes of solid fuel, the very bituminous coal and the anthracite, the loss varied from the 2·5 to the 8·3 per cent., according as the proportion of fixed carbon was greater or less. To these narrow limits then was restricted any possible improvement in the economic combustion of coal; and as absolute perfection could not be commanded by any method, only a portion of this small margin could be saved. In the foregoing statement of the results of the analyses of the gases of combustion was found the fact that twice as much air passed through the coal as was chemically needed for its perfect combustion; and this proportion obtained for all kinds of coal, from the most bituminous to the purest anthracite. The additional quantity of air, which passed through the furnace unaltered, of course involved a loss of heat represented by the product of its weight, specific heat, and number of degrees between its temperature when entering the furnace and when leaving the

Mr. Isherwood. boiler. This was a very large loss under the most favourable conditions; but it could not be lessened by any previous conversion of the coal into combustible gases and then burning them in the air, which was the method of the gas-producers, although the assumption—and it was only an assumption—was made as another matter of course, that the excess of air was due to the fact of the coal being in lumps, and that consequently much air flowed through the interstices without giving up its oxygen; but that if the coal were previously reduced to combustible gases and then mixed with the air, no more of the latter would be required than was chemically necessary for the combustion. The fact was that hydrocarbon combustion took place between only certain limits of temperature, the lowest being that of ignition, and the highest being that of the dissociation of the compound gases of combustion. Between these lay the temperature of maximum effect; that was to say, the temperature at which the mutual attraction of the hydrocarbon elements and of the atmospheric oxygen was a maximum. As the temperature produced by combustion increased, this attraction decreased, and only a portion of the oxygen would combine, the remainder continuing in the free state. When the temperature of the furnace, or more precisely, that of the gases of combustion at the moment of their formation, attained about 2,000° Fahrenheit, which was the temperature found in practice, exactly one-half of the atmospheric oxygen entered into combination, the remaining half continuing free; consequently, to consume the whole of the coal, twice the quantity of air necessary to furnish the oxygen chemically needed had to pass through the furnace. These facts, discovered by Bunsen, were proved by the every-day results of combustion in the furnaces of steam-boilers, and by the analyses of their gases of combustion. Such being the case, exactly the same double quantity of air chemically needed would be required for the complete combustion of the hydrocarbons, whether in the solid or in the gaseous state. And, further, the temperature of the gases of combustion, at the moment of their formation, would be exactly the same whether the hydrocarbons were burned to oxygen saturation in the solid or in the gaseous state. With a free supply of air, as in the case of the furnace of a steam-boiler, pure carbon would burn completely to oxygen saturation, and there would be no loss due to incomplete combustion. The reason why the hydrocarbon compounds were not completely burned was because their temperature of volatilization was lower than their temperature of ignition, and the rapidity of their passage from the furnace to the chimney-top was so great, that more

Mr. Isherwood.

or less of them escaped into the atmosphere before they could attain the latter temperature. The loss of fuel, due to incomplete combustion, was wholly of the volatile hydrocarbons; the fixed carbon always burned completely to carbon deutoxide. Of course, if a very thick mass of coal were placed on a grate whose area of air openings was very small compared with the mass and depth of the coal, the fixed carbon could be largely burned to carbon monoxide, and the volatile portion could be nearly wholly distilled unburned, as in the case of gas-producers; but when the coal was properly burned with such a supply of air as was commanded on ordinary grates, and with the depth of coal employed in the furnaces of steam-boilers, with the view of obtaining the maximum heating effect, there was not the slightest difficulty in obtaining the results herein previously stated. Various attempts had been made to improve the assumed very incomplete combustion of coal on ordinary grates; one of the oldest methods was the "dead-plate" or coking-plate invented by Watt, and placed at the front of the furnace. The fresh coal was laid upon this plate and coked by the heat of the fire beyond it, the volatilizable portions passing over the incandescent fuel in their way to the chimney, and being thus subjected to a sufficiently high temperature and with sufficient air present, the assumption was that they would be completely burned. This system had been largely imitated by the step-grate in continental Europe. The whole idea was based on fallacious assumptions, and careful experiments had proved that nothing whatever was gained by its use with even the most bituminous coals. Neither had anything been gained by finely pulverizing the coal, mixing the dust with air, and blowing the mixture into a furnace, on the grate of which was a mass of incandescent fuel, with a view to the more intimate mixture of the coal and air. Equally complete had been the failure of the Beaufumé gas-producer. In this system the fixed carbon of the coal was burned in one vessel or gas-producer to carbon monoxide, distilling over with it the volatile hydrocarbons which, together with the carbon monoxide, were burned as completely as possible in the furnace of another vessel called the boiler, the heat being used to vaporize water. The gas-producer was surrounded by water which was pumped into the boiler, so that no heat, except by external radiation, was lost in the producer. The combustion in the boiler was wholly of gaseous-fuel mixed with air; nevertheless the most accurate experiments made with this system in the French marine arsenal at Cherbourg showed that no economic or other gain was obtained over what was given by an ordinary

Isherwood. steam-boiler and furnace, having the heating surface of the Beaufumé producer and boiler combined, and in which the same weight of similar coal was consumed per hour. It was owing to the failure of the principle, and not to the fact that the heating-surface in use was inconveniently divided between a producer and a boiler, which caused the definitive abandonment of the Beaufumé system; and the same result would follow with all other gas-producers used for the manufacture of gaseous-fuel. In fact, all the various kinds of gas-producers for the manufacture of gaseous-fuel were essentially the same, differing only in unimportant practical details, and one kind was about as good as another; they would all give the same economic result when tried under proper comparable conditions. The facts seemed to have been entirely overlooked that the air was in the gaseous state, that it was in complete contact with the molecules of the solid coal with which its oxygen was to combine, and that the two could not possibly be brought into closer contact or more intimate connection by previously gasifying the coal. Also, that as in the ordinary furnace of a steam-boiler the volatilizable hydrocarbon portion of the coal was always burned in the gaseous state after mixture with air, no producer was needed to bring about this effect, because the temperature of volatilization of these hydrocarbons was less than their temperature of ignition. Gas-producers had their true use in the manufacture of water-gas for illuminating purposes, to which alone their future would be limited. The present state of the subject strikingly manifested the danger and folly of abstract investigations of physical phenomena, of determining, *à priori*, how Nature might, could, would, or should act, instead of putting the direct question of how did she act, by means of sagaciously devised experiments. The phenomena of combustion could be investigated only by experiments on a large scale; and not by imagining conditions and results, the former probably having no existence, and the latter not following even if the conditions did exist.

Professor Dr. Lunge. Professor Dr. G. Lunge did not suppose that the Author intended his Paper to be an exhaustive treatise on gas-producers, and it would not be right to blame him for having left out a considerable number of the different descriptions of gas-producers constructed in all industrial countries. Still it might have been desirable not to omit some of the most important and successful of the new gas-producers, as Haupt's, and especially Liegel's (the former was not mentioned at all, the latter merely by name). Although a reference to regenerators or recuperators did not seem to have entered into the Author's plan, yet he could not understand how he could have *omitted mentioning that* large and *important* class of producers, which embodied some of the principles of recuperators, especially the heating of the air without any special apparatus, such, for instance, as those of Bicheroux and of Boëtius. Without that the history of gas-producers was hardly intelligible. The Author also had not mentioned the fact that, at least on the Continent, there now seemed to be a general tendency towards attaching the producer to the furnace itself; that was converting by suitable modifications the ordinary fireplace into a gas-producer. This effected a great saving in the cost of plant and in space, and it especially prevented the loss of heat by radiation on the passage of the gas from the generator to the furnace. Lastly, the Author seemed *not to* have appreciated *the great importance of continuously* removing the incombustible residue in the form of a liquid slag, for which Liegel's producer would have afforded one of the best examples. In short, Dr. Lunge thought that the Author did not bring the subject of gas-producers forward in all its more important bearings. Professor Dr. Lunge.

Dr. Lunge refrained from criticising details, except two points, both occurring on p. 7, where the Author repeated fallacies which he was sorry to meet with constantly, although there could not be any doubt upon the point, and although they were of a very elementary nature. The Author, by a method of calculation of which he could not follow the details, arrived at the conclusion that the use of steam in the Wilson producer showed "an apparent saving" of 6·9 per cent. in theoretical heating-power. Now it was one of the fundamental laws of nature that it was impossible to produce energy from nothing, and hence the hydrogen formed by the decomposition of steam must have been formed at the cost of the calorific power of some of the carbon. In whatever roundabout way the calculation might be made, it would be impossible to show an increase of heating-power, any more than to gain motive force by any arrangement of wheels and levers interposed between the primary motive power and the place where it had to perform work. Steam, therefore, could not produce any saving of heat, apparent or otherwise, so far as theoretical calculations were concerned, and the Author dealt only with such in the place mentioned. Whether the introduction of steam in given cases was a practical benefit or not was quite another question.

The other fallacy was the assertion that a higher temperature of combustion could be obtained by producing gas free from nitrogen. From the context it was evident the Author here

Professor Dr. Lunge. meant "water-gas." Now he (like many others) did not notice that the temperature of the flame was always a function of the volume of the gaseous products formed during combustion, and that this volume in the case of water-gas was not smaller, but larger than in the case of ordinary producer-gas; the quantity of nitrogen, moreover, was exactly the same in either case. For whether 12 parts (by weight) of carbon were burned directly with 32 of oxygen into 44 of carbon dioxide, or first with 16 of oxygen into 28 of carbon monoxide, and this afterwards with other 16 of oxygen to 44 CO_2, the 44 CO_2 would be accompanied by the quantity of nitrogen corresponding to the 32 parts of oxygen used, namely, 107 N. Now in order to burn theoretically perfect water-gas, free from nitrogen, according to the formula $C + H_2O = CO + H_2$, the identical 32 parts of oxygen were required, accompanied by the identical 107 of nitrogen, and to this must be added the aqueous vapour formed during combustion, whilst the heat theoretically produced in the case of water-gas was less than in the direct combustion of coal, because the liquid water with which the process commenced must be reproduced in the shape of steam. The combustion temperature of ordinary generator-gas, if it was not allowed to cool down during its passage from the producer, was theoretically equal to that produced by the direct combustion of carbon, for which Dr. Lunge would accept the value given by the Author, namely, 2,716° Centigrade. That of theoretically perfect water-gas, according to the formula, $CO + H_2 + O_2 = CO_2 + H_2O$, would be—

$$\frac{68{,}370 + 57{,}560}{44 \times 0{\cdot}217 + 18 \times 0{\cdot}481 + 2 \times 53{\cdot}6 \times 0{\cdot}244} = 2{,}839^\circ.$$

Such a difference was of no moment, all the more as even 2,716° was above the temperature actually obtainable, owing to the partial dissociation of CO_2 and H_2O. Moreover that difference more than vanished when water-gas, as it was practically made, was compared with ordinary good producer-gas.

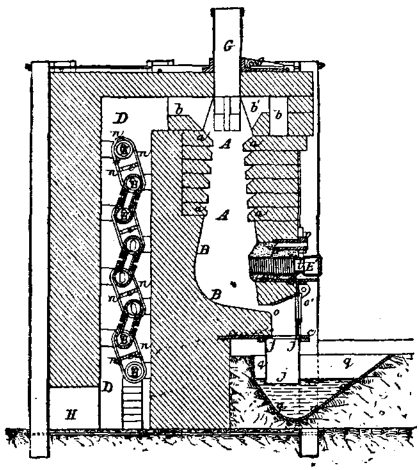
He was convinced that the temperature of a flame of good water-gas was much higher than that of coal-gas burned in a Bunsen burner, inasmuch as the water-gas flame for the same amount of gas burned was very much smaller, and therefore the loss of heat by radiation must be correspondingly less.

In one respect he entirely agreed with the Author, namely, that the well-known old type of Siemens producer was very much behind other apparatus of that kind, and that it owed the widely-spread application it enjoyed at one time only to the celebrity of its inventor, and to his great achievements in other applications of gaseous-fuel. Professor Dr. Lunge.

Mr. W. L. E. McLean stated that apart from the drawback of having to feed the "Lancefield furnace" slowly by hand, Scotch coal had been found very unsuitable for it. Mr. McLean.

Mr. E. Minary submitted a description of his producer with forced blast and fluid cinder, which formed a modification of his double-combustion hearth mentioned at p. 18 of the Paper. The apparatus (Fig. 75) was based on the principle first of converting the fuel into gas, without losing the heat disengaged at the time of the production of the carbonic oxide on the first hearth; secondly, of Mr. Minary.

Fig. 75.



Minary Producer.

volatilizing the hydrocarbons by the heat of the gaseous current from the first hearth; and thirdly, burning the gases in a combustion-chamber of firebrick exempt from all contact with solid fuel, the walls of the chamber attaining a very high temperature. This chamber had to be sufficiently roomy to allow of the gas occupying at least two seconds of time in passing through it, so that the reduction of its speed of transit caused the formation of eddies, which induced admixture with the air let in from the top of the chamber. In this way complete combustion was effected with only the volume of air strictly necessary, at the same time that the maximum temperature was obtained, and that all the heat due to the chemical composition of the fuel was set free. The apparatus was so designed that these operations were conducted

Mr. Minary. automatically, the fuel being fed to the generator by gravity, as required, to fill up the gaps produced by combustion, and by the separation of the mineral and other refractory constituents of the fuel which passed off after liquefaction by a small circular orifice *o*, at the bottom. This liquefaction was obtained by the addition of limestone to the fuel, converting the refractory constituents of the latter into fuzible silicates under the influence of the high temperature of the furnace. No attention was necessary beyond that of a man to charge the fuel to the hoppers at fixed intervals, and to remove the slag, already broken up by falling into a water-space below the hearth. The generator was of firebrick, having an interior compartment, A A, of rectangular section, larger at the bottom than at the top, in order to facilitate, by spreading, the descent of the fuel. The walls of this chamber, instead of being flat, were formed of chamfered sections, *a a*, in order to induce during descent the movement of the fuel from side to side alternately. The part immediately below this compartment, B B, formed the hearth of the producer. Its peculiar shape was designed to lessen the effect on its walls of the intense heat; at the bottom it was formed like a crucible, and it was furnished at one side with a small circular opening, *o*, through which the liquid slag passed on its way to the water-space, *q q*. The hearth, B B, was furnished with one or more tuyeres formed of tubing, through which flowed a current of cold water. The pipe, E′, conveyed the blast, previously heated by passing through the pipes E E. The blast was produced by any suitable apparatus capable of delivering the air at a proper pressure. The chamber, D D, was rectangular throughout its entire height. It was traversed in the direction of its larger diameter by eight cast-iron pipes, E E, arranged in a zigzag direction, so that the descending current of gas from the producer was obstructed by each pipe, and so obliged to form eddies, resulting in the more efficient heating of the air-blast carried by these pipes. At the bottom of the chamber, D, was an opening, H, through which the gas passed away to the furnaces in which it was to be burnt. The producer was fed by the hopper, G, made of sheet-iron, of which the cross-section formed a flattened ellipse.

The foregoing remarks and illustration related to the producers actually constructed by Mr. Minary, and which had been satisfactorily tested, although the severe depression existing in the French metallurgical industry had temporarily stopped the working of the factories where they were employed. Experience had suggested the following important modifications of the original design, which would be carried out in future apparatus. In

Mr. Minary.

the system of tubes in the heating-chamber, D D, would be substituted a single pipe placed in the chimney for the escaping gases in the re-heating furnace. The chamber thus disencumbered of the pipes *n n* would be used as a combustion-chamber. In the roof would be formed an air-inlet, 1½ inch wide, covered by a small sliding ┏┓-shaped casting, serving to regulate the supply, which would ordinarily be that obtained from the inlet opened to the extent of ¾ of an inch. The reason for this alteration in the design was very curious and interesting. It had been found that air heated to a very high degree did not suit the producer. The original disposition of the tubes heated the air to above 400° Centigrade (752° Fahrenheit)—a temperature so high that the slag partially volatilized, and the result was volatilized matters opposed the combustion of the gases in the combustion-chamber. It was noticed that when the gazogene was worked with an air-blast exceeding 150° Centigrade (302° Fahrenheit) the pipes became white hot, and the gases arriving from the combustion-chamber, instead of being clear and perfectly transparent, were dull and opaque. Combustion no longer operated upon the whole of the gas, but only on the upper strata, and the temperature of the remainder became stationary at a point below the welding-heat of iron. The resemblance remarked between these conditions and those of the cases of blast furnaces working gray highly carburetted iron led Mr. Minary to analyse the dust deposited under such circumstances from the producer-gas; it was extremely fine and white. It contained silica, alumina, lime, magnesia, and traces of iron, that was to say, all the elements constituting slag. When the heating apparatus was superseded by a single pipe delivering the air at 100° Centigrade (212° Fahrenheit) complete combustion of the whole gases was obtained, and a heat produced in the combustion-chamber sufficient for the welding of iron bars. Minary had not yet published this discovery, which explained how it was that the gas given off by blast furnaces working grey pig were so feebly combustible.

Dr. Schilling.

Dr. N. H. Schilling remarked that the Paper was mainly a summary of gas-generators, without dealing with their working or giving the result of experience acquired from a practical acquaintance with them. His personal experience consisted specially in gas-generators and regenerator works for making gas for lighting purposes, which had barely been mentioned in the Paper. It seemed that the Author had taken no notice of the work done in Germany. The scientific researches of Dr. Bunte opened up new

Dr. Schilling. ground.[1] Dr. Schilling's communications on the construction and working of furnaces in Germany, and their views on heating by gas, would be found in detail in the "Journal für Gasbeleuchtung." He had an impression that the heating of retorts in gas-works was regarded in England from a slightly different point of view to that in Germany.

Mr. Stevenson. Mr. G. E. STEVENSON remarked that the Paper was a good description of the various producers or generators which had been designed for the purpose of gasifying coal or coke, but it was not of great interest to the gasworks manager, as it dealt principally with apparatus designed for other purposes than heating gas-retorts. The reference at the close of the Paper to the producers introduced into gas-works did not give an adequate idea of what had been done in this direction. It was not correct to say that "the principal (producers) are those of Klönne, of Dortmund, of Valon, of Baecker, the Dessau or Didier producer used in Dresden, and the modification, or so-called modification, of the Siemens circular producer used in the Corporation Gasworks at Glasgow." It could not be claimed for the Valon furnace that it was one of the "principal," for this furnace contained nothing of individual interest, but was a copy of that introduced by Mr. George Livesey at the South Metropolitan Gasworks (which itself was, in principle, taken from that of Liegel), but with an extended development of regenerating flues. As a matter of fact these furnaces, as well as those of Liegel and Klönne, could not be called "producers," as they were nothing more than deep furnaces, in which the combustion was completed at the top of the furnace by a fresh supply of air being introduced at that point, the primary supply at the bottom of the furnace being insufficient for entire combustion of the fuel. As regarded the application of gas-generators to the retort-settings in a gasworks, the principal difficulty was the disposal of the residue. For this reason, two main differences arose in the method of gasifying, the one in which it was attempted to remove the residue, by melting it and running it out at the bottom of the furnace, the other in which the constructors sought to prevent the formation of clinker, and to reduce the residue to soft ash, which could be removed without difficulty. The first generators applied to gas-retorts in Germany were of the former kind, namely, those of Didier, Hasse, and Liegel. In the two first success was not obtained, because the destruction of

[1] Some account of these researches will be found in the Min. Proc. Inst. C.E. vol. lxv. p. 393, and vol. lxxiii. p. 430.—SEC. INST. C.E.

Mr. Stevenson.

the lining of the generators was too great. The furnaces had large horizontal openings at the bottom on the level of the hearth, and the fireclay lumps surrounding these openings were quickly destroyed. Liegel claimed to treat successfully the clinker on this principle, by so constructing his furnace that the partially melted clinker remained as a thin stratum, covering and protecting the brickwork, and the superfluous clinker escaped from a narrow slot at the bottom of the furnace, falling directly down into an ash-pit, and not, like the Didier, remaining on a hearth in proximity to the furnace sides until drawn out by rakes. It must be stated that the Liegel furnace, though successful with the coke from certain classes of coal, was not adapted to those, the coke from which produced a clinker difficult to fuse. The other system of dealing with the residue was originated by Dr. Schilling assisted by Dr. Bunte at the Munich Gasworks. These gentlemen placed a flat pan or tank containing water beneath the grate of the generator, and evaporated the water by conducting the waste gases under the pan, after they had left the regenerator. By this means they succeeded in preventing the formation of clinker, the residue consisting of friable breeze or ash, which could easily be removed. Other constructors, such as Klönne, adopted the use of water and steam for the same purpose. The Munich furnace and the "Didier" furnace were true generators or producers, being separated from the furnace where the object to be heated existed; the others, excepting the Siemens producers, were constructed within the retort-setting itself, and formed part of it as an ordinary furnace. The main object in the application of gaseous-firing to retorts was the adaptation of a suitable system of regeneration, which should combine efficiency with economy in the construction, and not occupy an unnecessary amount of space. For this latter reason the regenerating flues had been, in all the systems, placed below the retort-setting on either side of the furnace. The systems of Schilling and Klönne possessed the most complete regeneration, and gave the most economical results in regard to consumption of fuel. That of Liegel was less expensive, and gave a high heating power, but the proportion of fuel used was somewhat greater.

Mr. W. S. Sutherland.

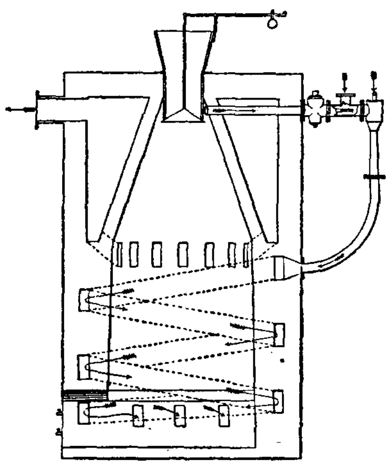
Mr. W. S. Sutherland was constrained to criticise some parts of the Paper. In a communication to the Society of Chemical Industry[1] he endeavoured to classify gas-producers according to their natural development. He feared that water-gas producers, in which the fuel was put into retorts and raised to the required

[1] Vol. ii. 1883, p. 62.

Mr. W. S. Sutherland. temperature by heat applied externally through the retort-walls, and then immediately to the fuel, would not come into favour. The temperature was too high for the stability of the complex conditions which would have to be present, and the only use of the external fire would be to act as the steam-jacket did to a high-pressure steam-cylinder with cut-off valve. From actual experience on a large scale with water-gas producers Mr. Sutherland still held the opinion expressed in his Paper just referred to, only supplemented by their expansion caused by some improvements in the methods and apparatus to be used. These had been thought out and patented, and would in all probability come into immediate use. From referring to the Author's description and criticism of his producer of 1874, Mr. Sutherland would say that this patent embodied the results of actual work carried out in 1872 and 1873, and that he and his friends had at that time very distinct ideas and views as to the collection of by-products from the gas. Probably if he had stated all the possibilities suggested by those ideas he would have been laughed at, but he had been working at the recovery of these products ever since, and at the elimination of nitrogen from the gas, and if it was complained that he had not given more detailed descriptions and drawings in the patent of 1874, he would submit that they were sufficient for their purpose.

Mr. Tervet. Mr. R. TERVET observed that the chronological synopsis of the various types of gas-producer, which had from time to time been introduced, proved that the only one capable of general application, and useful for dealing with fuel at present valueless for ordinary purposes of firing, was the Wilson gas-producer. Although it fell far short of the ideal, yet it realized all that was claimed for it, and must, until supplanted by a better, gradually make its way wherever gaseous-fuel was applied. Indeed, from the principle of working, and the method by which the results were sought to be obtained, it might be said to be practically perfect, so far as a knowledge of the reactions within the producer permitted a determination; but so long as it was necessary to introduce such a large volume of atmospheric air as a reagent for the production of carbonic oxide, it was useless to expect any great improvement from a mere modification of the structural features of the producer itself, while the principle of working remained unchanged. It was to be regretted that the Author had not investigated the chemistry of the subject, and dealt with those reactions which regulated the production of gas from coal-slack; as also the formation of ammonia from the potential nitrogen present in the coal. All writers on this subject, with the exception of Young and Beilby, had carefully avoided treating this matter as a practical and scientific problem. As pointed out by the Author, Young and Beilby, by a mere modification in the composition of the reacting atmosphere, had been able to obtain practially all the nitrogen in the coal in the form of ammonia; but this modification of the gas rendered it unsuitable for nearly all purposes to which gaseous-fuel was applied. As an attempt to realize the advantages of the Wilson gas-producer, and also that of Young and Beilby, without any change in the composition of the resulting gas, he had constructed an experimental gas-producer. It would be observed Mr. Tervet.

Fig. 76.



Tervet Experimental Producer.

from the arrangement of the apparatus (Fig. 76) that the destruction of the coal was divided into two stages. Suppose the producer to be at work, and that the upper cone was full. Now, as the total contents sank within the body of the producer, there must remain a space between the mass of caked coal and the wall of the retort. The new charge passed into this space in a comparatively thin layer all round, where it underwent incipient distillation, yielding gas and tar. These, in the form of vapour, were drawn out from the retort by the steam-jet, and together with a regulated supply of air were passed several times round the body of the producer, and finally into the culvert underneath, and thence through the incandescent coal, where the steam and tar were

Mr. Tervet. decomposed; and the gases were conducted away in the ordinary manner. It would further be seen that an equilibrium of exhaust and pressure must be set up by the action of the steam-jet within the producer. Thus the upper cone or retort was always under exhaust, while the lower portion or body of the producer was under pressure. The apparatus worked admirably, destroying all the tars; it yielded a very pure gas, and he was satisfied that the yield of ammonia was far above that obtained by the Wilson gas-producer.

Mr. Thwaite. Mr. B. H. THWAITE said that if solid carbonaceous fuel could be perfectly oxidized with exactly the requisite quantity of air, there would be no reason for its partial oxidation in a gas-producer. Unfortunately, in ordinary practice two or three times the quantity of air theoretically necessary was required to completely oxidize solid fuel in ordinary furnaces, and even with this excessive quantity of air it was almost impossible, especially when the fuel was of a richly bituminous description, to prevent the escape of unoxidized fuel. With this threefold quantity of air there was an enormous preponderance of the diluent gas nitrogen, which not only absorbed a great quantity of heat, both in the partial oxidation by air traversing the fuel, and in its complete oxidation by the air passing over the fuel, but the envelope of inert nitrogen very seriously hindered the action of oxidation. The moisture in the air was also an element which absorbed part of the heat generated. The vapour in passing over a solid fire was not sufficiently heated to produce dissociation; but even if it were dissociated the heat absorbed in this action would not be regained, as the gases passed away in a separate condition as H and O. Thus carbonaceous-fuel in its solid form was not prepared for complete and economical oxidation. The question was therefore of its partial oxidation with a minimum quantity of atmospheric air. If steam was allowed to pass into and through incandescent carbonaceous-fuel, it was dissociated. By this there existed not only the element of oxidation at the expense of a certain number of calories, which in the complete oxidation of the carbon and the reoxidation of the hydrogen was returned, but there was in addition the saving of heat due to the absence of nitrogen. With the partial oxidation of the solid fuel in the gas-producer, the quantity of air for the production of the carbon monoxide (CO) and the balance of oxygen could be almost exactly supplied to the now gaseous fuel, for its complete oxidation to carbon-dioxide (CO_2).

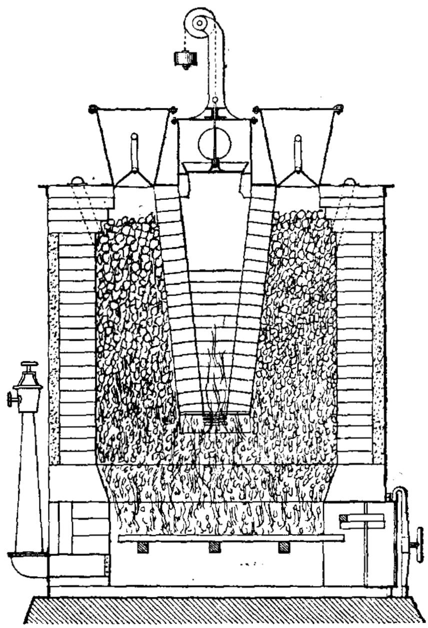
In order to use steam economically, a certain degree of oxidation was necessary to replace the heat absorbed in its dissociation. In one type of gas-producers this was effected by supplying air alone to the producers until there was sufficient heat to allow the supply of steam to be introduced; then both steam and air were allowed to enter together. In another type of gas-producer there were alternate periods of air alone followed by steam by itself. Half the resultant heat generated in the first period was stored in chambers filled with refractory material, through which in the second period the steam passed, and became heated to the degree necessary for its proper dissociation in passing through the incandescent carbon in the producers. This latter type was the most theoretically correct, and yielded the purest and richest gas, containing by volume— Mr. Thwaite.

	Per cent.
H	50
CO	45
CO_2	2·5
N	2·5
	100

In the preliminary blowing-up of the carbon with air, nearly all the sulphur in the fuel was volatilized and removed. This was the type of producer which Mr. Healey and he were applying to the reduction of iron ore in the blast-furnace. The valvular arrangements of these producers were the result of considerable experiment and much thought. In the production of heating-gas, he had found that each of the distinct varieties of coal required a distinct process and apparatus to effect properly its partial oxidation. With some of the anthracite coals the air had to be introduced at different levels in the depth of the fuel, otherwise only a small layer, in proximity to the point of influx of the air-supply, would remain incandescent. And if the air-blast was too powerful, and the heat of the fuel too low, part of the anthracite was removed in a finely divided condition and deposited in the flues. In using bituminous or semi-bituminous coal it was found that unless the volatile hydrocarbons were made to traverse the incandescent portion, and thus become partially oxidized, re-arranged, and fixed, they were deposited in the flues in the form of tar; consequently, in the best arranged producers the outlet flue for gas from the producer was at the level of the incandescent portion of the fuel. Producers should be so constructed that it would be impossible for the air-blast to pass up the inside walls and mix with the combustible gases. This could best be pre-

Mr. Thwaite. vented by arranging the gas outlet in the centre of the producer, as in the Thwaite twin gas-producer (Fig. 77). There should be no serious internal projections on the inside walls on which the clinker could hang, otherwise there would be the inevitable scaffolding of the clinker. The conduits for leading the gas from the producer should be formed of refractory and anti-diathermic material—fireclay bricks were the best. The method of using iron tubes not lined with bricks cooled and condensed

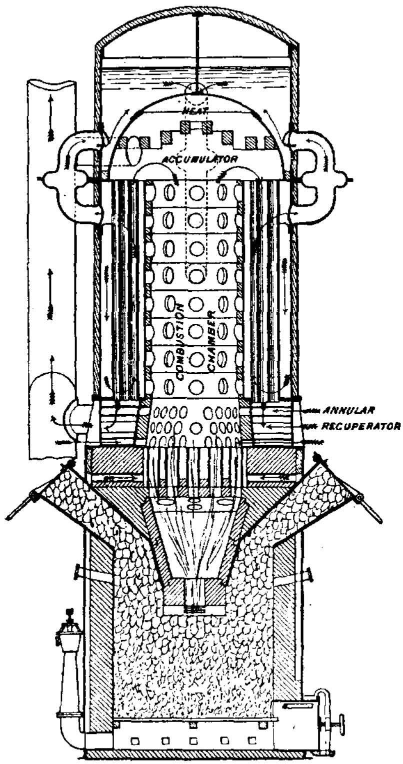
Fig. 77.



Thwaite Twin Gas-Producer.

the gases, not only absorbing their high sensible heat, but producing the tarry deposition of the rich hydro-carbons, the smallest trace of which once formed became a nucleus for a larger accumulation of tarry matter. If the conduits were constructed of bricks or tubes lined with refractory materials, there was rarely any serious deposition of tar; and if it was formed it could easily be burned out by allowing air to enter through a hand-hole in the flue. For gas-valves, Mr. Thwaite had found those of the mushroom-type the most serviceable. For charging hoppers if the producers were of the Siemens type, the simple plug-hopper, Mr. Thwaite. as in the producers of the Bower-Barff furnace, were serviceable; but there was less escape of gas with the ordinary Siemens balanced hopper. The bell-hopper arrangement, with sliding lid, was a good type for forced-blast producers. For pure water-gas producers, at Trimsaran, an arrangement similar to the cross-

Fig. 78.



Thwaite Gas-Producer and Steam Generator.

bar retort doors had been adopted, so that when the pressure of steam, which was 5 lbs. to the square inch, was turned on, there would be no escape of gas. Single analyses of producer-gases were practically useless, as even in the best arranged producers the character of the gas varied with the depth of the fuel, its physical arrangement, the proportion of the fuel to the clinker, Mr. Thwaite. and the pressure of air and steam-blast; consequently, at least ten different analyses should be taken, to obtain a proper representative value of the gas produced. He had found the following clinkering arrangement to be the best, namely, simply driving false or clinkering bars through the fuel just over the ordinary bars, and then withdrawing the latter, allowing the clinkers to fall into the ashpit. The fire-bar arrangement admitted of the air and steam-pressure being more equably applied to the fuel than any of the other arrangements, and consequently promoted the generation of gas of a more uniform quality.

In the Thwaite Twin gas-producer, Fig. 77, he had arrived at the following results:—

1st. The production of a more uniform and regular supply of gas from one producer.

2nd. The prevention of the possibility of the air-blast from passing unaffected through the fuel and mixing with the gases, and the reduction of the probability of explosions.

3rd. Compelling all volatile hydrocarbons to traverse the incandescent portion of the fuel before they could mix with the carbon-monoxide gases.

4th. The feeding of the fuel into the producer without seriously affecting the supply of gas.

It would be seen that this gas was withdrawn very much from the centre of the producer by a hollow dividing-bridge, which dipped below the upper surface of the incandescent portion of the fuel. The hollow bridge practically divided the producer into two divisions, each having its separate charging-hopper. The producer had been adapted for firing the Thwaite Steam-Generator (Fig. 78). Part of the air-blast supply passed from under the producer fire-grate through cavities in the walls, and surrounded a group of tubular gas-burners immediately over the producer. The heat of the products of combustion, after traversing the combustion-flue, heat-accumulator chamber and tubes of the steam-generator, passed through an annular air-recuperator to the chimney. The secondary air-supply for the combustion of the gas was conducted through this recuperator. Healey's gas-producer was the development of the form used by him in the construction of the Elba Steelworks, Gower Road, in 1872, for firing open-hearth steel-melting furnaces. The firebars were in two lengths, resting on a hollow cast-iron bearer placed centrally across the ashpit of the producer, and through which the steam and air-blast pressure entered. By means of a screw-arrangement, workable from the outside, the front bearer-bars carrying the fire-bars could be lowered during clinkering to facilitate this process. Mr. Thwaite.

Mr. T. URQUHART directed attention to the prevalent use of wood for gas-making for metallurgical purposes in the interior of Russia. He had seen, at the Bryansk Steelworks in the Government of Orel, six regenerative gas-furnaces for making Siemens-Martin steel, besides many other gas-furnaces for heating ingots and welding iron, all worked by wood-gas alone. He had seen the same on a lesser scale at the Sormova Ironworks in the Government of Nishninovgorod. So far as he could notice, the wood-gas producers were of the ordinary Siemens construction. The Grazi-Tsaritsin Railway, which was more than 460 miles long, and equipped with one hundred and forty-three locomotives, was the only railway in existence on which petroleum-refuse was used, to the complete exclusion of all other kinds of solid fuel, for locomotive purposes.[1] Plans had been prepared for the introduction of gas in the various furnaces in the central workshops of this line. Meanwhile trials were in progress for working the ordinary reverberatory welding-scrap furnaces with liquid fuel, without gasifying the fuel in a separate producer; the results so far, even with very simple appliances, had been much superior to these attained with coal as fuel. No doubt liquid fuel could be easily gasified in a simple special producer. Mr. Urquhart.

Mr. C. WITTENSTRÖM remarked that the Wilson generators, with their latest improvements, were probably the best for producing the so-called Siemens gas. Since 1881, Mr. Wittenström had been using oil as the fuel, in heating furnaces for his new process of manufacturing wrought-iron castings (Mitis). Mr. Wittenström.

Mr. LEWIS T. WRIGHT regretted that the Author had not investigated the thermo-chemical aspect of the gaseous-fuel question, and thus had avoided arriving at certain erroneous conclusions. In stating that a higher calorific intensity might be obtained with the gaseous-fuel, the Author instanced the fact that when carbon was burned in air a temperature of 2,717·6° Centigrade was arrived at, whereas when carbonic oxide was burned in air a temperature of 2,982° Centigrade was reached. This had nothing to do with the present nor with the immediate future of gaseous-fuel, as no means were known whereby in practice undiluted carbonic oxide could be produced. Generator-gas, having a theoretical composition of 34·3 per cent. of carbonic oxide and 65·7 per cent. of nitrogen, would give a flame temperature of Mr. Wright.

[1] Institution of Mechanical Engineers. Proceedings, 1884, p. 272.

Mr. Wright. 1,915° Centigrade only. The advantage to the extent of 6·9 per cent. in cases where steam was used along with the primary air-supply to internal-combustion producers was purely illusory, as the heat required to vaporize the water into steam had not been taken into the calculation, which heat was not afterwards recovered.

		Calories.
For instance, the 97 kilograms of carbon in conversion to carbonic oxide would afford		231,103
The carbonic oxide thus produced by burning to carbonic acid a further		552,657
		783,760

In the other case—

85 kilograms of carbon into carbonic oxide by air . .		202,513
12 " " by reaction $C + H_2O$ (fluid) = $CO + H_2$ = 28,590 − 68,360 = ...		39,770
		162,743
97 kilograms of carbon in the form of carbonic oxide burned into carbonic acid	552,657	
2 kilograms of hydrogen burned to water vapour	57,560	610,217
		772,960

—or a loss, as compared with the first method, of 10,800 calories, or 1·38 per cent. These 10,800 calories were required to convert the 18 kilograms of water into steam to feed the generator. It must always be remembered that in these steam-fed generators the steam required fuel for its production, and that the heat expended in evaporation was not afterwards recovered. The reaction in question was

$$C + O = CO \ldots\ldots + 28{,}590 \text{ calories},$$

or nearly 30 per cent. of the total thermal efficiency of carbon oxidized to carbonic acid. The Author, in mentioning that illuminating-gas had a higher calorific value than ordinary water-gas, but not higher than the gas made in the apparatus of Lowe and Strong, should have stated that the Lowe gas was illuminating-gas (it was so mentioned in the Appendix in the notes on the analyses Nos. 50 and 51). Mr. Wright had on various occasions endeavoured to gasify coal by the method 5, but always with unfortunate results, amongst them the trouble of obstructed pipes. The Allen-Harris process was founded on the principle of gasifying anthracite in retorts, similar to those used in ordinary gasworks, by means of

Mr. Wright.

steam; but it was probably inferior to those processes where water-gas was manufactured in the so-called "gazogenes," by "blowing" the fuel alternately with air and steam. The fractional method of burning carbonaceous-fuel, based on the property carbon possesses of forming two oxides, by passing one fraction (one-half in the case of a partly carbonaceous-fuel) of the supply of air requisite for the combustion of a given quantity of the fuel in a given time, through an excess of the fuel placed in a deep firebrick chamber called a generator, and reserving the remainder of the requisite air-supply for the final oxidation of the carbonic oxide produced by the first stage, had of course other advantages than the possibility of thereby effecting the combustion of the fuel with (closely) the theoretical air-supply. Heat from waste products of combustion could be transferred to the secondary air-supply, thus increasing the temperature of the final stage of combustion. There were doubtless considerable advantages attending the introduction of a limited quantity of steam to generators for the absorption of heat. The reaction between the incandescent coke and the steam kept the generator cooler, and prevented the fusion of the ashes into more troublesome slag or clinkers, which forming at the base of the generator choked up the air-passages. This absorbed heat was afterwards recovered in the combustion of the resulting carbonic oxide and hydrogen. The fractional method of fuel-combustion also admitted of the recovery of tar and ammonia, by the cooling and treatment of the gases formed in the first stage; but it must always be a grave question whether the inevitable losses of heat attending this process would not largely neutralize the value of the recovered products. The recovery of these from blast-furnaces was a rather different matter; but, in any case just now, their utmost value could hardly be more than *1s. 6d.* per ton of coals, without deducting anything for expenses of their collection, wear and tear of plant, and interest on the capital outlay. Mr. Wright was of opinion that, at the present values of tar and ammonia-products, their recovery from blast-furnaces must be a certain commercial loss. It would be interesting to know what financial profit had attended the experiences at Gartsherrie and Langloan. A little while ago gas-manufacturers were receiving high prices for tar and ammonia, and inflated by a success not due to their exertions, but to outside influences in many quarters, they indulged in vain boasts which produced much excitement in the public mind. Exaggerated statements were rapidly promulgated, even in technical periodicals, respecting enormous profits

Mr. Wright. made by coal-gas concerns out of residuals, and how the gas could be given away. Of course, these inflated ideas caused the influx of capital into various schemes for the production of "residuals" from coal, and even coal-gas itself. The output of these schemes coming just on top of a bad trade, when all values were diminishing, and demand was decreasing, and whilst owing to other causes the consumption of gas was yet extending, and consequently the tar and ammonia from gasworks were increasing in amount, caused a drop in the values of gas-products, from which the market would be long in recovering.

Mr. Rowan. Mr. F. J. Rowan observed that, while admitting that the addition of the numbers representing the calorific value per 100 litres to all the analyses would increase the value of the Table in the Appendix for the purpose mentioned by Mr. Beilby, he felt that, as the analysts had not in each case furnished these figures, it would not be proper for him to add them, as he published with the analyses the names of their authors. They could, however, easily be found from the following data :—

1 litre H	. . . .	= 3,106 gramme Centigrade units.
1 „ marsh gas	. . . . .	= 9,587 „ „ „
1 „ CO	. . . .	= 3,130 „ „ „

He did not, however, admit the fairness of Mr. Beilby's comparison of Analysis No. 47 with Nos. 15 and 26, for the reason that, as shown by Mr. Beilby's Paper in the "Journal of the Society of Chemical Industry," vol. iii., p. 216 *et seq.*, and as stated in the notes appended to the analyses, *ante* p. 55, gas of the composition of Analysis No. 47 had not been produced. That analysis was merely an estimate of the extent to which No. 46, which was the gas produced at Oakbank, might be expected to be improved, provided the air and steam-supply were accurately proportioned, which was a matter not very easy to realize in practice. Mr. Isherwood's estimate of the advantages to be derived from the combustion of gaseous as against solid fuel, restricted "the possible improvement in the economic combustion of coal" to the narrow limits represented by a saving of from 2·5 to 8·3 per cent.; and as regarded the loss occasioned by reduction of temperature due to the presence of an excess of air in furnaces fed with solid fuel, he remarked that it could "not be lessened by any previous conversion of the coal into combustible gases and then burning them" with air. He was, however, proved to be wrong in these ideas by the many recorded results of economy of fuel obtained in many heating operations by the use of gas. The reasoning founded upon

Bunsen's experiments was not sound, because these experiments did not strictly apply to totally different conditions as regarded the abstraction of the heat produced by combustion, as compared with those which were present in Bunsen's apparatus. Regarding the trials of the Beaufumé apparatus at Cherbourg, Mr. Isherwood had evidently not observed the results communicated by the late Professor Rankine to the Institution of Engineers in Scotland, which showed an economic gain of above 30 per cent. over what was given by an ordinary steam-boiler and furnace, using the same quality of coal as the gasifier. The Paper could not, as Dr. Lunge observed, be supposed to be an exhaustive treatise on gas-producers, if those fireplaces which were attached to individual furnaces, and which in their action resembled separate gas-generators, were included under the general title, these, with the exception of Ekman's, having been excluded from the Paper. This was a large class in itself, including, besides Haupt's and those of Bicheroux and Boëtius, those of Ponsard, Gorman, Smith-Casson, Price, and many others; and the consideration of such appliances could not be treated properly apart from the subject of the furnaces of which they formed an integral portion. It was questionable if the heating of the air used for combustion in the producer could be of any benefit. The use of recuperators for heating the air used in the combustion of the gas in furnaces was another matter, and belonged to the subject of the use of furnaces, so that it was quite possible to consider apparatus for producing gas apart from the subject of recuperators. It might be convenient under some circumstances to have a gas-producing fireplace for each furnace, but it was certainly impossible that this plan could compare favourably with that of the use of separate producers for general application, in respect of cost or of space. The cost and size of furnaces must be increased by the addition of such fireplaces, and the gas-producing plant was not available for working any other furnace than the single one to which it was attached, so that there could be no distribution of gas over works, and in the event of some furnaces not being used, the gas-producing plant and the outlay represented by it were unproductive. On the other hand, the fuel had to be distributed to many points, at each of which stokers must be provided, instead of both being concentrated at one place, and thus labour charges were also increased. It had not in the past been found advantageous to the working or life of gas-producers to raise their temperatures of combustion sufficiently high to melt the ash, apart from the inconvenience of mixing fluxes with the fuel, which that plan entailed. Mr. Rowan.

Mr. Rowan. It was possible that Mr. Liegel or Mr. Minary might have made some improvements in this direction, but that remained to be proved by practical work. Both Dr. Lunge and Mr. Lewis T. Wright had criticised adversely his employment of Schöffel's figures, showing the effect, as regarded the working of the producer itself, of the use of steam and air instead of an air-supply exclusively; but the criticism was unnecessary, because he did not enter fully into the thermo-chemical data connected with the question of gas-production and use. All that the figures were used for was to show that, considering merely the question of the two methods of working producers, and ignoring for the moment the question of the supply of steam, there was no disadvantage in employing steam. In fact, as producer-gas had almost always to be conducted some distance, and lost heat in this operation, there was an advantage in the use of steam arising from the lower temperature of the gas produced when it was used. It might have been added that, in practical working, the use of steam was advantageous on account of its reducing the temperature at certain parts of the producer, and facilitating the handling of ash and clinker. Dr. Lunge, Mr. Wright, and Mr. Coleman also referred to his employment of Mr. Galloway's equations, in terms similar to those used by Mr. Head on that subject. He could not, however, perceive how they considered it fair to insist upon a comparison between pure carbon and producer-gas, while they objected to one —which was certainly more just for the purpose for which it was employed—between pure carbon and pure carbonic oxide. If accuracy were their aim, why did they not compare the combustion temperature of producer-gas with that of coal? He dissented from Mr. Wright's opinion that these equations had no bearing upon the future of gas-production, because he maintained that it was possible to produce heating-gas which approximated more nearly to pure carbonic oxide than the present quality of producer-gas did; and this opinion was not subject to Dr. Lunge's interpretation, that by carbonic oxide he meant water-gas. In that event these equations showed that a temperature superior to that which could be obtained from solid fuel might be secured by the direct combustion of such gas with air, apart from assistance by recuperation. In fact, Dr. Lunge admitted that the combustion-temperature of even ordinary producer-gas, if it was not allowed to cool down during its passage from the producer, was theoretically equal to that produced by the direct combustion of carbon; and therefore it must be above that produced by the combustion of ordinary coal, so that Dr. Lunge supported the contention. In regard to Mr. Lürmann's Paper, he had directed his remarks to the assertions contained in it that the production of carbonic oxide required no heat, and that heat became latent only in the distillation of the hydrocarbons. Mr. Wright, like Mr. Lürmann, had evidently omitted to notice that the formation of carbonic oxide required the transformation of carbon from the solid into the gaseous form, and that, as carbonic oxide was usually obtained from carbonic acid (by its combination with, or dissolution of, carbon), there was also a resulting increase of volume, both of these actions involving the absorption of a considerable quantity of heat. Although it was permissible to speak of the thermal equivalent of the reaction $C + O = CO$, yet that equivalent was merely the difference in amount between the amount due to the complete combustion of carbon to CO_2, and the amount derived from the combustion of CO to CO_2. The direct combustion of solid carbon to CO with disengagement of heat, no CO_2 having been primarily formed, was an unknown chemical process. Mr. Rowan.

With respect to the denomination of the Lowe gas, he had stated in the Appendix, p. 53, that the Lowe gas was illuminating gas, and he presumed that Mr. Wright would admit that even then it remained "water-gas."

He had not seen the producer mentioned by Mr. Coleman, but from inquiries he had learned that its action was not invariably successful. He was in full accord with the remarks of Mr. Clerk, with the one exception that, in the face of the evidence brought forward in the Paper, he could not agree with him in the statement that the late Sir William Siemens originated the gas-producer. No doubt there was a large field for the employment of a good gas-producer in conjunction with the gas-engine. The tar difficulty could be overcome, even if producers of the Wilson type were used, in either of two ways: first, by using coke or anthracite as the fuel in the producer; or, secondly, by washing the gases produced from bituminous coal, neither of these methods offering much difficulty in practice. It might be advisable, in obtaining gas for employment in gas-engines, to use some of the cheaper hydrocarbons as the liquid employed in washing the gas.

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19 January, 1886.

Sir FREDERICK J. BRAMWELL, F.R.S., President, in the Chair.

The Discussion upon the Paper "On Gas-Producers," by Mr. Frederick John Rowan, occupied the whole evening.