

In works where large quantities of gas are required, the cost of production at the works would be too low for any outside plant handicapped with the extra cost of distribution to compete; but in the case of comparatively small consumers, especially if there are a large number within a small radius, a large central plant may be able to meet their requirements and supply gas on more advantageous terms than they could produce it in small quantities themselves.

Fig. 104 is a sketch of the producer. It consists of an inner and outer wrought-iron cylindrical shell, the latter lined with fire-brick for a portion of its height, the top is arched, and is lined with fire-brick, while the bottom portion is an inverted truncated cone. The whole producer is supported by cast-iron brackets, and a water bosh at the bottom forms a seal.

The fuel is delivered direct from the railway wagons into a large hopper over the producers, and it is charged into the hoppers of the different producers by a creeper. When the hopper is filled with slack, the hood valve which closes the bottom is opened, and the fuel falls into the bell-shaped casting suspended from the top of the inside of the producer. This internal bell being surrounded by the hot producer gas, the slack undergoes partial distillation, and as these products of distillation have necessarily to pass downwards through some of the hot fuel before they can escape, the tar is practically all destroyed and converted into gas.

At the bottom of the producer are two cast-iron rings, on which sloping bars are fixed, but as these do not reach the centre, part of the weight of the superincumbent fuel rests upon the ashes, which form a reversed cone, filling the centre space down into the water. The ashes are withdrawn from the water bosh in the usual way. The general arrangement of the producer, with its Ammonia recovery plant, is shown in fig. 105.

Mechanical Producers.—Many attempts have been made from time to time to devise methods for mechanically stoking producers, with the object of saving labour, insuring the more regular production of gas by breaking up the clinker, and stirring the fire more completely than can be done by hand-stoking. The solution of the problem has been, however, surrounded with great difficulties; the impossibility of devising any metal stirrer to work at the temperature inside the producer without becoming rapidly distorted or burnt away seeming insurmountable. The essential conditions for success are:—1. That the mechanical appliance must stir the whole of the producer, break up clinker, and prevent air passages being formed. 2. That it must be able to withstand the abrading action of the fuel and clinker at the high temperature of the producer. 3. That, in the event of its meeting with any obstruction, such as a large mass of clinkers, which it is unable to break up, it must neither stop working, nor bend nor break. The Talbot, Hughes, Kerpely, and Rehmann producers now working successfully in America, on the Continent, and in this country, apparently fulfil most of the above conditions, and are gradually being introduced into various works.

The Talbot Producer.—This producer (fig. 106) is designed with a stirrer consisting of a vertical shaft carrying two radial arms, and having both a vertical and a rotatory movement.

The stirrer is water-cooled by a flexible copper tube, carrying water in a constant stream to both ends of the radial arms, and this stream finds an exit at the top of the shaft into a pan, from which it is conveyed away.

The mechanical poking is effected by the slow rotary and up-and-down motion of the stirrer, the vertical shaft being carried up through the cast-iron

top of the producer, supported by a suitable bearing, and extending upwards to the platform resting on the top of the main structure. Its upper end is connected with a crank shaft on the upper platform, by which it receives

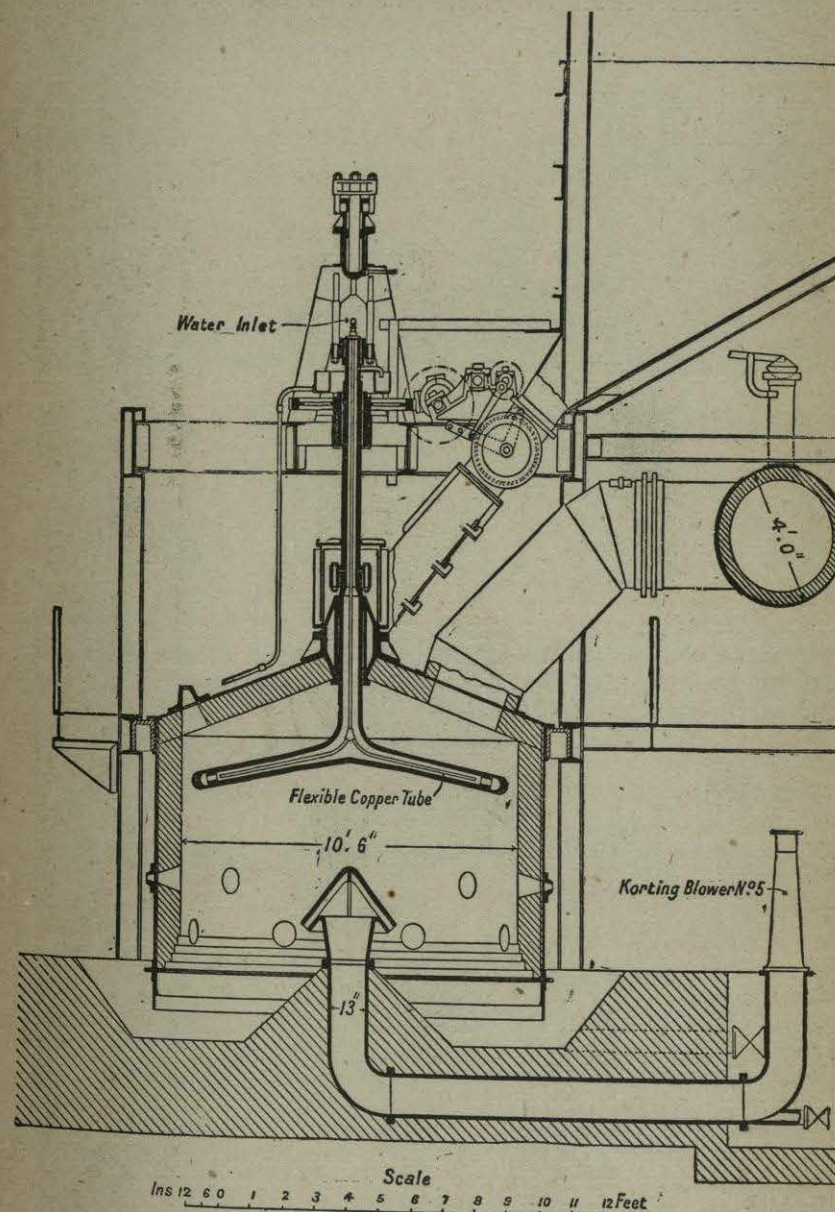


Fig. 106.—The Talbot Producer.

a vertical and reciprocating motion. The crank is driven through suitable gearings at a uniform speed by an electric motor, which also performs the rotary driving of the vertical shaft. The rotary action of the stirrer tends to prevent the formation of clinker, or to break it up as formed, but should

the radial arms come into contact with any solid obstruction, the gear is relieved from liability to break down by a cam which gives way. The electric motor recommended for driving the mechanical poker is of 10 H.P.; wound for a direct current of 220 volts, and fitted with a controller for regulating

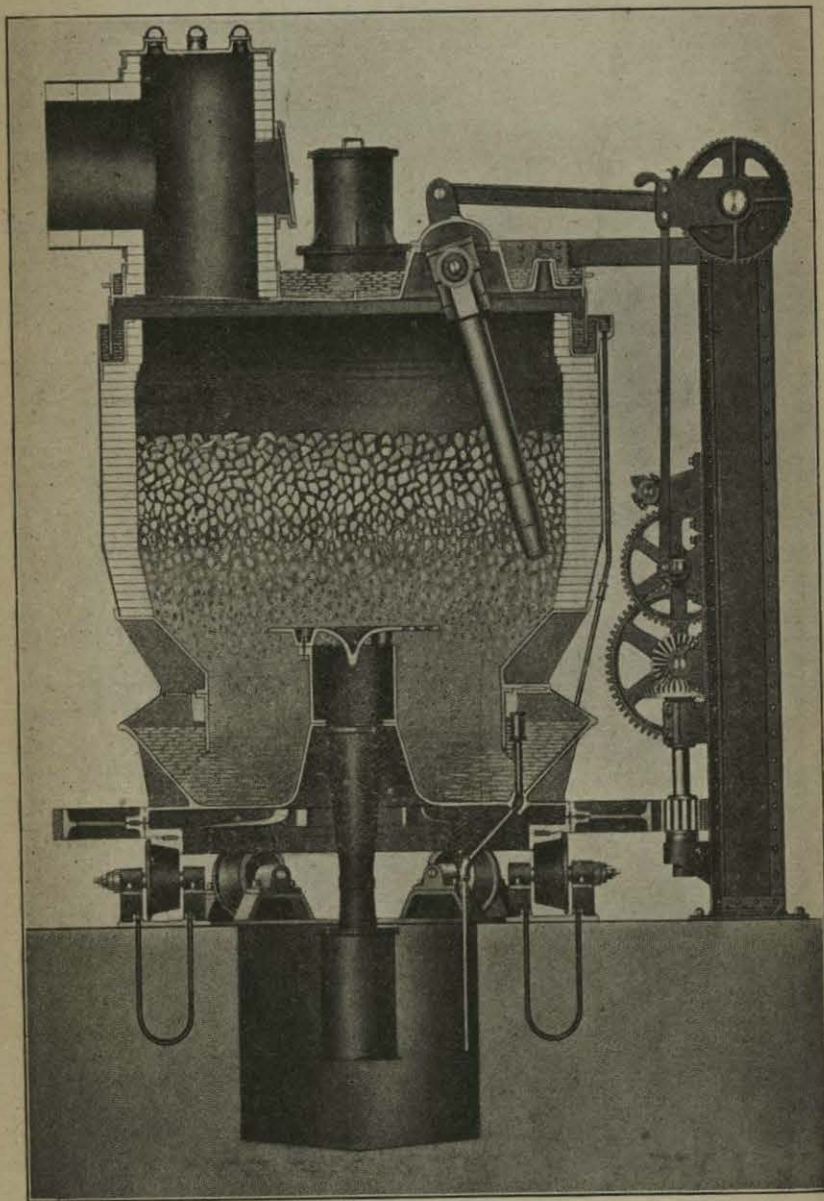


Fig. 107.—The Hughes Producer.

the speed. The motor is of the enclosed type, specially designed for severe and continuous service.

The producer shown in fig. 106 gasifies 1 ton of coal per hour, works

well, and the gas produced contains from 4 to 5 per cent. of CO_2 , 26 to 28 per cent. of CO , 13 to 14 per cent. of Hydrogen, and 3 to 4 per cent. of Hydrocarbons.

The Hughes Producer.—In this producer (fig. 107) the body of the producer is mounted on a turn-table which is slowly revolved. A hollow water-cooled poker suspended from a trunnion independent of the shell of the producer, as shown in the sketch figure, is moved backwards and forwards by means of a ratchet gearing actuated by a crank and crank shaft driven by any suitable means. This mechanism moves the poker backwards and forwards from centre to circumference of the producer, which action, combined with the revolution of the body of the producer, stirs and breaks up the mass of the fuel through the whole producer, and evenly distributes it.

The producer shell is of steel plate, and is secured to a cast-iron base ring, to which is bolted a cast-iron water-seal, forming an ash receptacle. The base ring rests upon supporting columns bolted to a cast-iron revolving turn-table. This turn-table has at its outer circumference a cast-iron rack, into which meshes a spur pinion keyed to a vertical shaft and connected to the main driving shaft by a train of gearing; thus the turn-table is rotated, and with it the body of the producer and the ash pan. The bottom of the turn-table is fitted with a steel tread resting on six conical chilled-iron carrying wheels, and supported by the necessary axles and boxes. As the producer shell revolves, the ashes work down and are deposited in the water-sealed ash pan, from which they may be shovelled direct to car without the intervention of machinery.

The producer top is a steel casting flanged and ribbed to provide for water-cooling, a water-seal being formed by a top flange at the outer circumference of the producer cover. The use of a steel casting for this top adds materially to its durability, for experience has demonstrated that where the parts are exposed to heat, steel castings are superior to cast iron.

Each producer is equipped with two feed hoppers fitted with counter-balanced bells and gas-tight swing covers, placed at unequal distances from the vertical axis of the producer, so that the coal is deposited in concentric rings as the producer shell rotates, thus giving a proper distribution of coal. A gas outlet provided with a cleaning door, peep holes, etc., is attached to the top of the producer cover. This outlet has a short flanged neck, to which a connection from the gas outlet to the gas flue may be made. The power required to operate a producer is about 3 electric H.P., and the standard size producer, which is 10 feet diameter inside the brick lining, is capable of gasifying 1 ton of good coal per hour. This producer is largely used in America, and is said to give excellent results.

The average composition of the producer gas is approximately CO_2 4 per cent., CO 26 per cent., Hydrocarbons 3 to 4 per cent., Hydrogen 13 per cent., Nitrogen 53 per cent.

The Kerpely Producer.—This producer is illustrated in fig. 108, and the special features are the water-cooled bottom section and the continuous but slowly revolving grate, which, as it rotates, crushes the slag or clinker against the walls, and prevents its sticking to the lower part of the walls of the producer. The revolving grate, originally rhombic in shape, is now made circular, but placed eccentrically to the centre line or vertical axis of the producer, and it revolves with the water-cooled ash pan once in three hours. The grate is built up of a number of stepped plates, with

spaces for air to pass between them, so that the air is distributed evenly over the whole producer. The ashes are removed mechanically by a fixed shovel in the ash pit, the height of which is adjustable.

The Rehmann Producer.—This is a modification of the Kerpely producer, the principal difference being in the construction of the grate, which consists of cones supplied with openings (fig. 109). The fuel bed is loosened at the points of the cones above the grate, and slides downwards along these

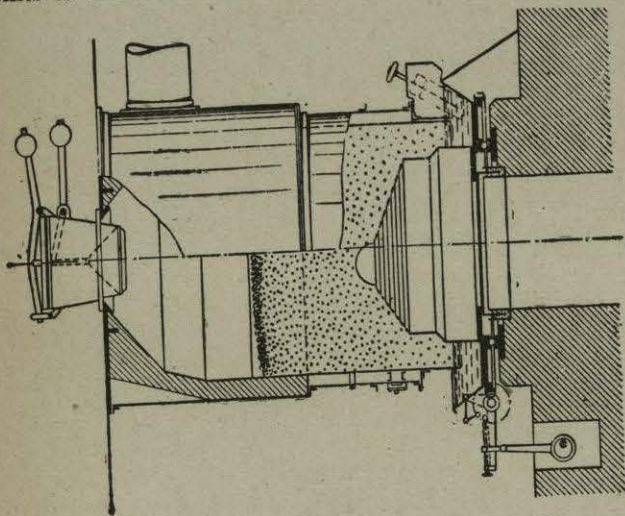


Fig. 108.—The Kerpely Producer.

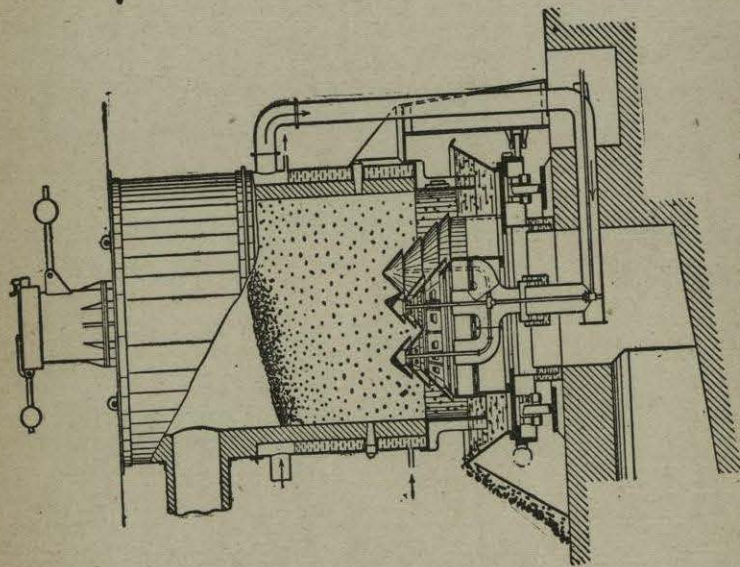


Fig. 109.—The Rehmann Producer.

cones. In the cones are openings for the air supply, but these are covered so that they do not choke as the grate revolves, and air is conveyed to each cone by a separate pipe, and equally distributed over the entire cross-section of the producer. The lower part of the producer casing is built up of removable cast-iron segments, and the base rotates on roller wheels instead of balls. Both this producer and the Kerpely are being largely used on the Continent, and are said to give very satisfactory results.

The composition of the gas from different producers of the ordinary type will vary very little when the same fuel is used, and, provided they are worked with care, the quality of the fuel, careful stoking, and regulation of air and steam supply will have far more influence on the quality of the gas than the particular form of producer.

Fuel for Producers.—All kinds of fuel are used in gas producers, from fine slack to fairly large coal; but probably the most economical form of fuel to use is good clean screened nuts about the size of walnuts, as, although costing more than common slack, it more than compensates for the extra cost by the regular working of the producer, better quality of gas, and less ash, &c., that has to be removed from the bottoms of the producers. The quality of the coal, whether a good gas coal or not, is also important; but although some coals give better results than others, owing to a larger percentage of volatile matter and freedom from ash, almost any coal *low in Sulphur*, if in fair mechanical condition, is suitable for producer work.

One of the great difficulties in producer work is the clinkering of the ash, and, so far as circumstances will permit, it is most desirable to select coals which produce as little clinker as possible.

Coke can be and is used to some extent with forced draught, but coal in some form is almost universally employed in steel works for gas production.

Charging Fuel in Producers.—The regular charging and even distribution of the fuel over the top surface area of the producer to maintain a bed of fuel of equal thickness in all parts is of great importance, and the various automatic mechanical feeds which have been devised all aim at this. A feeding device should as far as possible fulfil the following conditions:—

(1) It should be continuous, steadily supplying any required amount of coal during a given time, and the speed of the feed should be easily regulated, so that the coal supply can be adjusted to the amount of gas required in a given time.

(2) It should distribute the coal uniformly over the surface in the producer, making a body of equal thickness throughout, which offers an equal resistance to the air injected.

(3) It should also be simple in its construction, needing very little repairs, so that it may be run by unskilled labour.

A device known as the *Bildt Automatic Feed* is shown in fig. 110. It is very ingeniously designed on definite mathematical principles, and should, theoretically, give excellent results, and from the reports from America and elsewhere where it has been adopted these appear to be borne out in practice.

It consists, as will be seen from fig. 110, of a coal-holder resting upon and attached to the top of the producer, below which is placed a rotating distributing disc, *A*, provided with specially-constructed blades, *b* and *b'*, serving to distribute the coal evenly over the charging area. The disc is rotated by a vertical shaft resting upon the top of the coal-holder and a worm gearing, *d*, which in its turn is driven by cone-pulleys, *e*, by which the speed can easily and quickly be changed to feed more or less coal, as may be required.

The rotating of the disc will require only about $\frac{1}{10}$ H.P.

To suit different sizes of coal, the opening between the discharging mouth of the holder and the disc is adjusted by lifting the vertical shaft, which slides through the worm gear. This may be done by a screw-wheel at the upper end of the shaft.

The size of the coal is immaterial so far as the charging is concerned; lumps, dust, or both mixed, are equally well distributed.

The top of the rotating disc can be made level or sloping, but not

exceeding the angle of friction between the disc and the coal. The speed of the disc is for small gas producers about $\frac{1}{7}$ revolution per minute, and for big ones up to $\frac{1}{2}$ revolution in the same time. The disc is generally made of cast steel.

The holder, which can be made large enough to receive any desired quantity of coal, is filled through a hopper provided with a sliding damper. The coal is brought from any larger deposit and supplied by a coal-conveyor or by any other convenient method.

The apparatus can be applied to producers of any size, as it distributes the coal equally well over a large or small area.

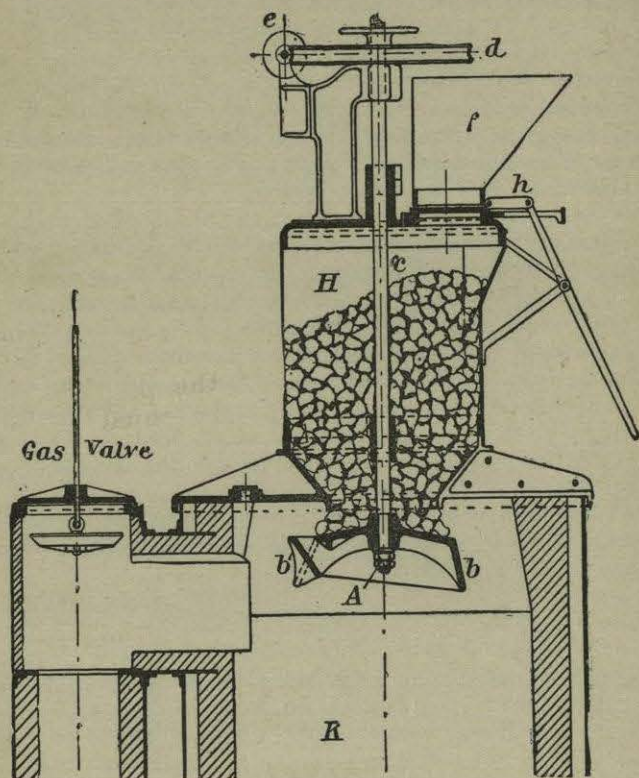


Fig. 110.—The Bildt Automatic Feed for Gas Producer—A, Distributing disc; H, coal-holder; K, producer; c, shaft for rotating A; d, e, gearing for rotating shaft; b, b', blades on disc, A; f, hopper; h, lever for discharging hopper into holder, H.

Efficiency of Producers.—In large works, where batteries of 20 or 30 producers are frequently employed, it is a most important matter that these should give for the particular fuel used as large a yield of gas of good quality as possible, and the relation between the heating values of the coal charged into, and of the gas evolved from, the producer, constitutes a test of the efficiency of the producer. The efficiency of a producer may be defined as the ratio of the heat units capable of being obtained from the gas as it leaves the producer, and the heat units which the coal from which the gas is made is capable of yielding. Thus, if a certain quantity of coal has a heating value of 100, and the gas evolved from such a quantity of coal has a heating value of 50, the efficiency of such a producer would be $\frac{50}{100} = \frac{1}{2}$, or 50 per cent.

The heat given out by the gas may be divided into sensible heat and heat of combustion, and the efficiency of the producer will vary, according as the former is or is not included in the calculation. The cold-gas efficiency considers the gas to be at the temperature of the air, while in the calculation of hot-gas efficiency the sensible heat of the gas is taken into account. The direct method of finding the efficiency of the producer would be to measure the quantity of gas made from a given quantity of coal and burn samples of each in a calorimeter. This method is not usually feasible at works, and generally we have to calculate from the analysis of gas and coal how far the producer is working efficiently. Mr. Jenkins* proposes the following formula for calculating the efficiency of producers:—

$$\text{Cold-gas efficiency} = \frac{M \times K \times G}{H}$$

M = { Heat of combustion of gas per kilogram of Carbon contained in it (calculated from analysis of gas with the aid of Table xxi. given below).

K = Proportion of Carbon in coal.

G = " of Carbon made into gas.

H = Heat of combustion of kilogram of coal (determined by experiment).

The calorific power (the heat of combustion per unit volume) of a gas divided by the weight of Carbon in a cubic metre gives the heat of combustion of the gas per kilogram of Carbon—i.e., M (or figure of merit).

The calorific powers of gases given by different authorities vary considerably, but any of the following tables are sufficient for all practical purposes, and Mr. Jenkins, in his paper, uses that of Messrs. Winkler and Lunge:—

TABLE XX.—CALORIFIC POWER OF DIFFERENT GASES.

	Calories per Cubic Metre.		
	Faure and Silbermann.	Julius Thomsen.	Winkler and Lunge.
CO,	3,014	3,044	3,066
H,	2,389	2,631	2,581
CH ₄ ,	8,498	8,417	8,697
C ₂ H ₄ ,	14,009	13,848	14,045

The following table gives the amount of Carbon in one cubic metre of different gases:—

TABLE XXI.

Gas.	Kilogrammes of Carbon per Cubic Metre.
Carbon Dioxide (CO ₂),	0.5376
Carbon Monoxide (CO),	0.5376
Marsh Gas (CH ₄),	0.5376
Olefiant Gas (C ₂ H ₄),	1.0752
Hydrogen and Nitrogen,	0.0000

In the above equation M is sufficient to measure the quality of the gas, if only one kind of coal is used. K depends on the quality of coal, * Efficiency of Gas Producers, *Min. of Proceedings of Inst. Civil Engineers*, vol. cxxiii., p. 328.

its percentage of ash, &c. G measures the grate efficiency—in other words, the percentage of Carbon passing away unburnt with the ashes.

The cold-gas efficiency considers the gas as leaving the producer at the temperature of the air, and the hot-gas efficiency may be obtained from it by means of the following formula:—

$$\text{Hot-gas efficiency} = \text{cold-gas efficiency} \times \left\{ 1 + \frac{\text{Sensible heat per cubic metre of the gas}}{\text{Calorific power of the gas}} \right\}$$

The sensible heat per cubic metre = (temperature of gas - temperature of the atmosphere) × "volumetric specific heat of the gas."

By the volumetric specific heat is meant the heat required to raise the quantity of gas 1° C. which, at standard temperature and pressure, would occupy 1 cubic metre.

The following tables * give specific heats of the different gases, all of which, except CO₂ (whose specific heat at different temperatures is given separately), are constant for different temperatures:—

TABLE XXII.—VOLUMETRIC SPECIFIC HEAT OF DIFFERENT GASES.

Gas.	Calories per Cubic Metre per Degree C.
Oxygen (O ₂),	0.313
Hydrogen (H ₂),	0.305
Nitrogen (N ₂),	0.306
Carbon Monoxide (CO),	0.306
Marsh Gas (CH ₄),	0.425
Olefiant Gas (C ₂ H ₄),	0.506

TABLE XXIII.—VOLUMETRIC SPECIFIC HEAT OF CARBONIC ACID AT DIFFERENT TEMPERATURES.

Temperature (t).	Mean Calories per Cubic Metre of Gas per Degree between 0° C. and t° C.
t = 400	C _p - t = 0.467
t = 500	" = 0.487
t = 600	" = 0.507
t = 700	" = 0.525
t = 800	" = 0.544
t = 900	" = 0.562
t = 1,000	" = 0.580
t = 1,100	" = 0.598
t = 1,200	" = 0.615

C_p - t indicates the mean value of specific heats at constant pressure between 0° C. and t° C.

In the above formula no account is taken of sensible heat carried over by any steam in the gases, and if necessary a correction must be made for this, the percentage of steam being first determined by experiment by aspirating a given quantity of gas through a drying tube. The correction is, however, of very small importance, unless the amount of steam is

* Calculated by Mr. Jenkins from figures given by Professor Akerman, *Beitrag zur Entwicklung der Frage der Heizgasgewinnung.*

abnormal, and is rarely worth making, involving as it does a special test of the gas, and a very troublesome and lengthy calculation.

The following is a numerical example of the calculation of the efficiency of a producer from the Jenkins formula:—

Example of Calculation of Efficiency.

A Rectangular Brick Producer giving poor gas.

$$\text{Cold-gas efficiency} = \frac{M \times K \times G}{H}$$

Proportion of Carbon in coal, = 0.750 = K.
 " " made into gas, = 0.964 = G.
 Heat of combustion of coal, = 8.000 calories per kilogram = H.

M is found as follows:—

Volumetric Analysis of Gas.	Calorific Power.	Carbon in Gases.
Per cent.		Per cent.
CO ₂ , 7.5	...	7.5 × .5376
CO, 18.5	18.5 × 3.066 = 566	18.5 × .5376
CH ₄ , 0.7	0.7 × 8.607 = 60	0.7 × .5376
H, 10.4	10.4 × 2.581 = 268	...
N ₂ , 62.9	...	...
100.0	894	$\frac{26.7 \times .5376}{100} = 0.144 \text{ kg. Carbon}$

$$\therefore \text{Figure of merit} = \frac{894}{0.144} = 6,210 \text{ or } M.$$

$$\text{Cold-gas efficiency} = \frac{M \times K \times G}{H} = \frac{6,210 \times 0.75 \times 0.964}{8.000} = 0.562.$$

Temperature of gas = 1° C.

Hot-gas efficiency is found as follows:—

Vol. sp. heats.	
CO ₂ , 7.5 × 0.580	= 4.35
CO, 18.5 × 0.306	= 5.66
CH ₄ , 0.7 × 0.425	= 0.30
H, 10.4 × 0.305	= 3.16
N ₂ , 62.9 × 0.306	= 19.25

} = 0.3272 (mean specific heat).

$$\text{Sensible heat per cubic metre of gas} = 1000^\circ \times 0.3272 = 327.2.$$

$$\text{Hot-gas efficiency} = 0.562 \left(1 + \frac{327}{894} \right) = 0.756.$$

Nothing is probably of greater importance in fuel economy than keeping a regular and systematic check upon the working of the producer by frequent analyses of the coal used, the ashes, and the evolved gas, as it is not an uncommon thing to find producers working under similar conditions as regards fuel varying in efficiency from 50 to 66 or 75 per cent., which means that one producer is burning 70 tons of fuel to produce the same amount of heat as the other is producing from only 50 tons. In some American works, samples of the gas are taken from the producer once or twice every twelve hours, an average sample from the main gas culvert every two hours, and the whole results tabulated and plotted each week. The cost of this is only equal to a few tons of fuel per week, and if this example, combined with frequent analyses of ashes, &c., were followed in

all our English works, the saving in fuel would probably astonish some of our steel makers.

Under normal conditions of work when an average amount of steam is used, as in the Siemens, Wilson, or Dawson type of producers, carbonic acid should average about 5 per cent. and should never exceed 7 per cent. A higher percentage than this, especially if the gas has a high temperature on leaving the producer, may be taken as a sure indication of bad working

The following are fairly typical analyses of gas from producers when working well:—

TABLE XXIV.

	Wilson.	Dawson.	Siemens.	Talbot.*	American Producer Gas.	Forced Blast without Steam.
Carbon Dioxide, .	5.10	5.50	4.80	2.91	5.20	3.80
Carbon Monoxide, .	23.42	22.90	24.80	33.35	22.8	27.00
Hydrogen, .	12.00	11.55	8.70	13.86	8.5	7.60
Marsh Gas, .	2.90	3.10	2.30	...	2.4	3.60
Olefiant Gas, .	0.40	0.30	...	...	0.4	0.35
Nitrogen, .	56.18	56.65	59.6	49.90	60.3	57.65

The calorific power of a gas is of great importance, as although the percentage of Carbon Monoxide, Hydrogen, &c., for producers working under similar conditions, may indicate the heating value of the gases, if taken alone, and compared with the gas from producers working under different conditions, with varying percentages of steam, erroneous conclusions may be drawn.

In the following Table xxv. are summarised the results obtained by Prof. Bone and Dr. R. V. Wheeler † during an important investigation on the use of steam in gas producer practice. For these experiments a producer of the Mond type was used, and trials extending over a full week were made under each set of conditions examined. The first series of trials was made with a depth of incandescent fuel of 7 feet, and in the second series this depth was reduced to 3 feet 6 inches: this thickness of fuel not only permits of very high rates of gasification, and keeps clinkering difficulties within easily manageable proportions, but is also sufficient to accomplish the decomposition of nearly all the steam introduced in the blast (i.e., with a saturation temperature not exceeding 60° C.), and to reduce the amount of Carbon Dioxide in the gas to 5 per cent. or even less. The influence of successive increments of steam, with consequent lowering of the temperature of the incandescent fuel is that the reaction $C + 2H_2O = CO_2 + 2H_2$ comes more and more into play at the expense of the reaction $C + H_2O = CO + H_2$, and the equilibrium points of the reversible reactions $CO + H_2O \rightleftharpoons CO_2 + H_2$ and $2CO \rightleftharpoons C + CO_2$ shift more and more to the right hand. Thus, successive increments of steam in the blast increase the percentage of Carbon Dioxide and Hydrogen, but reduce the percentage of Carbon Monoxide in the resulting gas.

* This is the average of five analyses kindly supplied me by Mr. Mannaberg, of Frodingham, where a Talbot producer is working. The hydrocarbons were not determined separately, but are included in the CO and H, which makes these higher than they would otherwise be.

† *Iron and Steel Inst. Journ.*, 1907, vol. i., p. 126; 1908, vol. iii., p. 206.

TABLE XXV.—EFFECT OF INTRODUCTION OF DIFFERENT QUANTITIES OF STEAM ON THE COMPOSITION OF PRODUCER GAS.

Average depth of incandescent fuel,	3 feet 6 inches.					7 feet.				
	45°	50°	55°	60°	70°	60°	65°	70°	75°	80°
Average rate of gasification (day shift) per hour per producer, .										
Steam saturation temperature, .										
Percentage Composition of Gas.										
Carbon Dioxide, .	2.35	2.50	4.40	5.10	9.25	5.25	6.95	9.15	11.65	13.25
Carbon Monoxide, .	31.60	30.60	28.10	27.30	20.85	27.30	25.40	21.70	18.35	16.05
Hydrogen, .	11.60	12.35	15.45	15.50	19.75	16.60	18.30	19.65	21.80	22.65
Methane, .	3.05	3.00	3.00	3.05	3.45	3.35	3.40	3.40	3.35	3.50
Nitrogen, .	51.40	51.55	49.05	49.05	46.70	47.50	45.90	46.10	44.85	44.55
Total combustibles, .	46.20	45.95	46.6	45.85	44.05	47.25	47.10	44.75	43.50	42.20
Yield of gas, cubic feet at 0° C. and 760 mm. per ton of coal, .	133,700	132,500	132,700	135,000	...	138,250	134,400	141,450	145,800	147,500
Steam added to blast, lbs. per lb. of coal, .	0.2	0.21	0.32	0.45	...	0.45	0.55	0.80	1.10	1.55
Percentage steam decomposed, .	All	All	All	76.0	...	87.0	80.0	61.0	52.0	40.0

Under ordinary conditions of producer work it is important that the amount of steam in the gas, as it leaves the producer, should not be high, as it carries with it a comparatively large amount of sensible heat, which is lost if the gas is used cold, and partially lost if the gas is used hot.

The low efficiency of a producer may result from various causes, amongst the most common being the burning of gas in the producer itself, due probably to careless stoking, so that air channels are formed in the bed of fuel; or, possibly, defective construction of the producer may cause the same result. The gas produced under these conditions will be high in Carbon Dioxide, and low in Carbon Monoxide and Hydrogen, and will, of course, have a very low calorific power. The following is an analysis representing a very bad case* :—

Carbon Dioxide (CO ₂),	10.20 per cent.
Carbon Monoxide (CO),	11.80 "
Marsh Gas (CH ₄),	2.40 "
Hydrogen (H),	8.80 "
Calorific Power,	790

One of the surest indications of burning of the gas in the producer is a high and rapidly varying temperature of the gas; and there is probably no better way of controlling the working of the producer in this respect than to have an automatic record of the temperature of the gas as it leaves the producer. This, now that pyrometers of the Le Chatelier type are being used in all our leading works, could be arranged in many cases without any difficulty. A pyrometer in the gas culvert, as near as possible to the producer, and

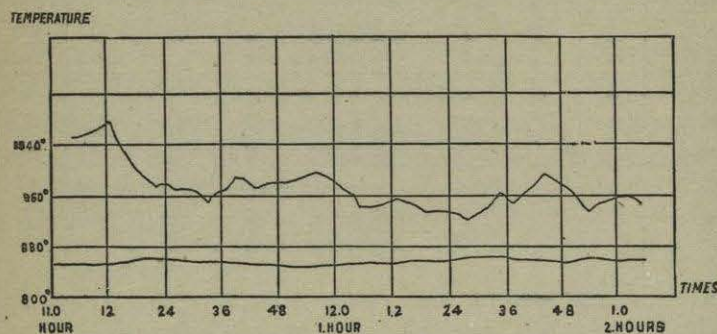


Fig. 111.—Temperature Variations in Producer Gas—Upper curve when working badly; lower curve when working well.

connected with a recorder, would give perhaps a better regular indication of the continuous working of the producer over a period of time, than even frequent analyses, and would be an excellent check on irregular stoking. It is, however, advisable to have analyses as well, as by considering the temperature and the analysis of the gas together not only are we able to form a definite opinion as to the working of the producer, but apart from this, the actual calorific value of the gas can be calculated from the analysis. Under ordinary conditions the temperature of the gas leaving the producer should not exceed 750° to 850° C., and the variations should be slight. From information received by the author, he is of the opinion that the best results are obtained when the gas is about 750°, although it will vary somewhat with the fuel used. The diagram (fig. 111), by Mr. Jenkins, shows the variation in temperature of the gas from a producer when working badly and when working well.

* Jenkins, *loc. cit.*, p. 341.

Taking Samples.—The advantage of obtaining fair average samples of the coal, gas, and ashes need not be dwelt upon, but in each case, to get reliable results, they should be the mean of 6 or 7 samples taken over a period, say, of one week. In taking the gas samples, Stead's* gas sampler is extremely handy, samples should be collected every two or three hours, and the average of 6 or 8 samples taken to represent the gas for the particular 24 hours.

Water Gas.—As stated previously, when steam is passed through a bed of red-hot Carbon it is decomposed, with formation of Carbon Monoxide and Hydrogen, reactions which are endothermic, or attended with absorption of heat, so that unless heat is supplied from an outside source the incandescent Carbon is rapidly cooled, and the reactions cease. Provided no air is injected with the steam a gaseous mixture, consisting almost entirely of Carbon Monoxide and Hydrogen, is obtained, and this is known as water gas, which is most useful for certain metallurgical operations, where great local intensity of heat is required. In preparing this gas on a large scale, it is usual to raise the fuel to a state of incandescence by the injection of air, which produces ordinary producer gas, and then to shut off the air and inject steam through the incandescent Carbon, generally in the reverse direction. It is customary to blow up with air for about eight to ten minutes, and then to inject steam for about four minutes, and by this means we get an alternate production of producer and water gas. As for most operations it is necessary to have a continuous supply of gas, whether it be producer or water gas, it is generally essential to have two gasholders, one for storing each gas, so that they can be used as required. Water gas has been tried at several works, for open hearth steel furnaces, but, with the exception of one or two small furnaces for making steel castings, has not been a success, and attempts to use a mixture of the water and producer gas, although tried at various works, have not been so successful as to lead to its general adoption.

For special work, such as tube welding, etc., water gas is most useful, but for open hearth practice it is not suitable, as the great intensity developed by its combustion is not essential to the process, and leads to great expense for repairs due to unnecessary wear and tear on the furnace. It is, therefore, more economical to use good producer gas, which gives all the heat required, and can be supplied continuously from the producer, without any storing in holders, or mixing with other gas. It should be borne in mind that the great intensity of the flame produced by combustion of water gas is not due to the specially high calorific intensity of Hydrogen present, but to the fact that it is not diluted by an inert gas like Nitrogen, and consists entirely of combustible gases. Even in works where there is a demand for both producer and water gas, the former made by blowing up the producer is generally so saturated with water vapour that its thermal value is very low, making it useless for many purposes, where high temperatures are required, unless all the water vapour is first condensed. Apart from the intermittent supply the comparatively small amount of water gas, compared to the amount of producer gas made in a given time, has been a most serious drawback to its general adoption in metallurgical works, and although many attempts have been made to produce water gas continuously, they have only comparatively recently been attended with success.

It will be remembered that when Carbon is burnt to Carbon Dioxide, more than three times as much heat is produced as when it is burnt to Carbon

* *Iron and Steel Inst. Journ.*, 1884, vol. i., p. 187.

Monoxide, and if the fuel in the producer could be burnt so that the gas left the producer as Carbon Dioxide instead of Carbon Monoxide, three times as much heat would be accumulated in the fuel, and be available for the decomposition of steam, and consequently the quantity of water gas would be correspondingly increased. This is what has been effected in the process known as the Dellwik, or Dellwik-Fleischer. We have seen that under ordinary circumstances in a producer Carbon is burnt to Carbon Monoxide (CO); how then is it possible to burn Carbon to Carbon Dioxide (CO₂), and prevent its reduction to Carbon Monoxide during its passage through a thick bed of fuel? Messrs. Dellwik and Fleischer have shown that this can be effected by working at a higher pressure of blast, so that in a given space of time each unit of Carbon is brought into contact with more Oxygen than usual. In this way the conditions of chemical equilibrium for the particular temperature are changed, and the point where Carbon combines with only one atom of Oxygen is moved upwards, so that even at 1,000° or 1,200° C. Carbon Dioxide (CO₂) is formed, and is not reduced again to Carbon Monoxide (CO), because the excess of Oxygen enveloping it presents other conditions than those present in former cases considered. With this process it is only necessary, therefore, to blow up the producer with air for 1½ minutes, as against 10 minutes with ordinary water gas process, and steam can be injected for 8 to 10 minutes for gas making,

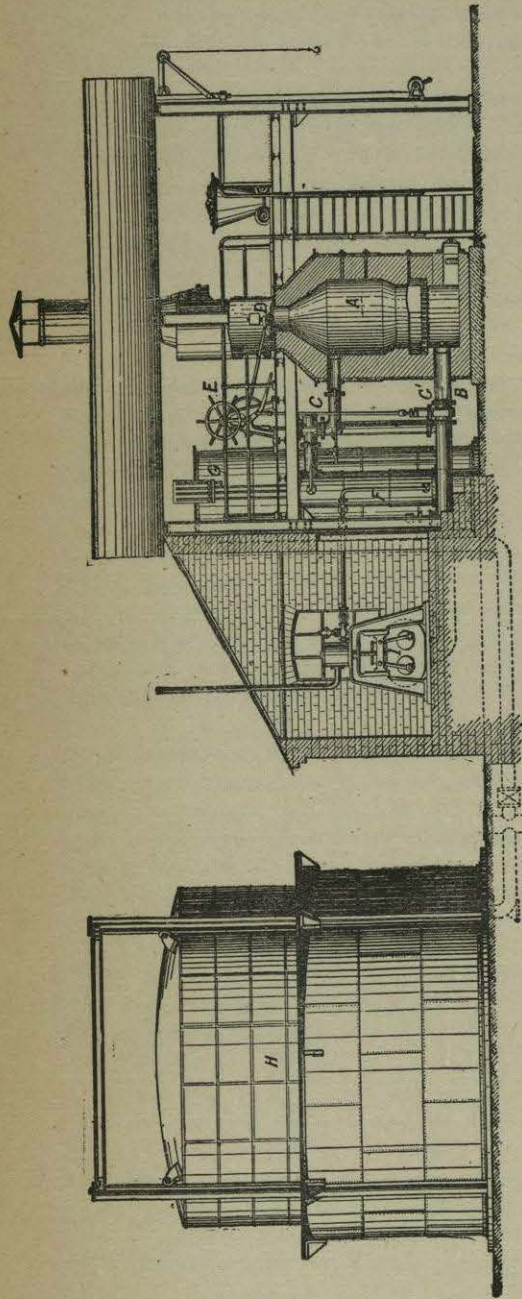


Fig. 112.—The Dellwik-Fleischer Water-Gas Plant. A, generator; B, blast inlet; CC', gas outlets (the lower, C', behind the blast pipe); D, stack and charging valve; E, interlocking valve gearing; F, steam superheater; G, scrubber; H, gasholder; I, blower and engine.

as against 5 minutes. The time of blowing and injecting steam will vary with the class of fuel used, and the author has private information respecting two plants in England, in one of which they blow up for 80 seconds and inject steam for 10 minutes; in the other the blowing lasts 1 minute, and steam injection 8 minutes. The gas from blowing up does not contain appreciable quantities of CO, but from 17 to 18 per cent. of Carbon Dioxide (CO₂), and 1 to 2 per cent. of oxygen, and is, of course, allowed to escape out of the stack. The water gas has the following composition:—

CO,	. . . . .	39.65
H,	. . . . .	50.80
CH ₄,	. . . . .	0.82
C _n H _{2n},	. . . . .	0.05
CO ₂,	. . . . .	4.65
O,	. . . . .	0.20
N,	. . . . .	3.83
		100.00

As the result of numerous experiments it has been found that 30 to 33 lbs. of coke produce 1,000 cubic feet of water gas, as against 45 to 50 lbs. required by the best of the old processes, and give a utilisation of 65 to 70 per cent. of the fuel, as against 45 per cent., only 30 per cent. being lost by radiation, and carried away by the gases escaping to the stack.

Fig. 112 illustrates the latest form of the Dellwik-Fleischer producer, in which A is the generator, fitted with fire-bars near the bottom, and lined with fire-brick, B is the blast-pipe which admits the air-blast below the fire-grate, C and C' are gas outlets, the upper one, C, being in use when the steam is admitted at the bottom, and the lower one, C', not seen in the sketch, being in use when the steam is admitted at the top; D is the stack for the outlet of waste gases during the heating up with air, this also shows the charging arrangement; E represents the interlocking valve gearing used for reversing the direction of the steam and the water-gas at intervals; F is the steam superheater, from which two conducting pipes enter the generator, one near C and the other near C'; G is the scrubber, through which the water-gas passes on its way to the gasholder H; I is the blower and engine. In use, the steam is alternately blown in at the top and bottom, the water-gas being drawn off at the bottom or top as the case may be.

Natural Gas.—In certain localities in America and elsewhere, in boring for oil, vast reservoirs of gas, under great pressure have been tapped. This gas is now carried immense distances in pipe lines, and distributed to the various works for steel making and other purposes. The pressure at which

	Pittsburg. Natural Gas.	Pennsylvania.*	
Hydrogen,	22.00	22.50	6.10
Marsh Gas,	67.00	60.27	75.44
C _n H _{2n} gases (olefiant gas),	6.00	6.80	18.12
Carbon Monoxide,	0.60	Trace.	Trace.
Nitrogen,	3.00	...	...
Carbon Dioxide,	0.60	2.28	0.34

* Sir Boverton Redwood, *Petroleum and its Products*, vol. i., p. 223.

the gas escapes varies from 100 to 200 lbs. on the square inch, and enables it to be taken great distances. It gives excellent results in steel making, being practically free from non-combustible gases, and of such high calorific power, that no regeneration of the gas is necessary, the air only being superheated. The foregoing table gives typical analyses.

Unfortunately we have not so far discovered any large stores of natural gas in this country, and we have to rely entirely upon gas made from coal or coke for steel manufacture, and in this respect are seriously handicapped in competing with American manufacturers.

CHAPTER VII.

THE OPEN HEARTH OR SIEMENS PROCESS.

THE process of manufacturing steel in the open hearth regenerative furnace, which we owe chiefly to the genius of Sir William Siemens, is the only process which has in any way proved a serious rival to that of Bessemer. The difficulty of obtaining a sufficiently high temperature to maintain a large quantity of decarburised iron in a fluid condition was the chief obstacle to the solution of the problem, and it was only after many experiments, involving great expense and labour, that the efforts of Sir Wm. Siemens and his brother were crowned with success. They first gasified the fuel in a separate furnace called a producer, and then raised this and the air necessary for its combustion to a high temperature by means of the waste heat derived from the previous combustion stored up in fire-brick checkered chambers, which they called regenerators. They then conducted the superheated gas and air by separate flues to the hearth of the furnace, where combustion took place with the production of an extremely high temperature. Great difficulties were experienced in the early days in obtaining for the roofs of the furnaces refractory materials which would both withstand the high temperature and the contraction and expansion; but these were gradually overcome, and in 1867 to 1868 the success of the process was demonstrated at an experimental works at Birmingham, large quantities of steel being made from old rails and similar material. Gradually the problem of desiliconising and decarburising pig-iron, with and without steel scrap, by means of iron ore as the oxidising agent, was worked out, and in 1868 the Landor Steel Company was started. In France, Messrs. P. & E. Martin also attacked the problem; but, instead of using ore, they worked with steel scrap and pig-iron alone, dissolving the scrap in a bath of molten pig until, by the diluting down of the impurities combined with their partial removal by oxidation, they produced a steel of the required grade. This process was known as the Siemens-Martin, as distinguished from the Siemens process, in which ore and pig alone were used; but the distinction has long ceased to be of any importance, the almost universal practice now being to use both ore and scrap with the pig, especially in this country.

The original furnaces built at Landore were only of 3 to 4 tons capacity, but now it is by no means uncommon to find furnaces working charges from 40 to 50 tons, and some metallurgists anticipate that the 100-ton furnace will be the one of the future. Furnaces of a larger capacity than this are now in operation working the Talbot process, which is a modification of the Siemens process.

General Description of Furnace.—The Siemens furnace consists of a large hearth built of refractory material, upon which the metal is melted without contact with any solid fuel. At each end are arranged two chambers filled with checker fire-bricks, through which the air and gas pass on their way into the furnace, and through which the products of combustion pass at the other end on their way to the stack. One of these regenerators on each side is called the gas, and the other the air regenerator, and they are