UNITED STATES PATENT OFFICE.

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PROCESS OF PRODUCING GAS.

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To all whom it may concern:

Be it known that I, CARLETON ELLIS, of New York city, State of New York, have invented new and useful Improvements in Processes of Producing Gas, of which the following specification discloses an embodiment thereof which I believe one of the best of the various forms in which the principles of my invention may be applied.

This invention relates to the art of making gas by the producer process as distinguished from the retort and water-gas processes.

It relates particularly to that branch of the art wherein the gas-producer is functionally remote from the consuming apparatus, and may therefore be an entirely independent structure, although independence of structure is not absolutely necessary to the practice of my invention, and it is possible to combine the gas producer and consuming apparatus in a single structure, provided the organization be such as to preserve the essential functional characteristics.

In the practice of this art it has been necessary to employ a thick bed of incandescent coal, so that the carbon dioxid from the combustion in the lower layers may pass through the hot layers above, to be there reduced, as far as possible, to carbon monoxid, one of the atoms of oxygen of the carbon dioxid splitting off and joining with an atom of carbon of the coal, thus making two molecules of carbon monoxid from one of dioxid. This reduction is never complete. The combustible gas from a gas-producer always contains carbon dioxid, and many efforts have been made to reduce the amount in order to secure greater fuel efficiency; but these haphazard attempts up to the present time have been abortive, as certain principles connected with the law of mass action have not been realized.

I have discovered that the gases formed in or passing through a producer have a certain affinity or absorptive capacity for carbon dioxid which prevents its complete reduction. I believe that the principle involved has been heretofore noted in connection with certain laboratory experiments in connection with the theoretical investigations of Rathke; but I believe that I am the first to have discovered that this principle, heretofore apprehended theoretically, is of commercial importance in the practical art of making producer-gas. So far as I am aware, all of the makeshifts proposed have been founded on incorrect conceptions, not taking into account this principle, and for this reason, among others, they have not effected the end desired. By the application of the hereinafter-described chemical theory I have been enabled to solve the difficulty and to put the adjustment of the producer for highest efficiency upon an exact scientific basis.

The carbon dioxid found in the gas is derived by methods heretofore employed from the combustion of the coal in the producer. It is produced at the expense of fuel and without compensation, as a general rule, from steam dissociation. The coal in the producer therefore burns partly to carbon monoxid and partly to carbon dioxid; but up to the present time it has not been possible to burn this carbon completely to monoxid. In the combustion to carbon dioxid the full heat value of the fuel is evolved in the producer, where for obvious reasons it is of course not desired. Increase in carbon dioxid in the gas should mean increase in hydrogen when steam is used as the endothermic or cooling agent. This rarely proves to be the case. Therefore the content of carbon dioxid in the gas is generally taken as the index of efficiency or measure of waste. The object of my invention is to burn the carbon entirely to carbon monoxid and to thus overcome the waste now attendant on the complete combustion of a portion of the fuel to carbon dioxid. The reaction between carbon dioxid and carbon to form carbon monoxid is a reversible one and is expressed by

$$CO_2 + C \rightleftarrows 2CO,$$

in which the arrows indicate that the reaction may progress in either direction, according to circumstances. I determine this condition of reversibility from the following reactions:

(1.) $C+O_2=CO_2$.	(1.) The principal reaction in the lower part of the producer.
(2.) $CO_2+C=2CO$.	(2.) Reaction of reduction occurring at 600° centigrade and upward.
(3.) $2CO=2C+O_2$.	(3 and 4.) The reaction investigated by Mallard & LeChatelier. This occurs at temperatures varying from 300° centigrade to 800° centigrade.
(4.) $2C+O_2=C+CO_2$.	
(5.) $2CO=C+CO_2$	(5.) From reactions 3 and 4.

or the reaction may take place in either direction. In accordance with the laws of mass action the products of the partial pressures of the two left-hand members of the equation 2, divided by the square of the par-

tial pressure of the right-hand member, is a constant, or

$$\frac{p_a\, p_b}{p_c 2} = K,$$

where p_a is the partial pressure of carbon dioxid, p_b that of carbon, and p_c that of carbon monoxid. By the law of mass action this condition of equilibrium is dependent, not on the relative amounts of the reacting bodies, but on the concentration of these bodies. This explains, then, why it has been impossible to reduce carbon dioxid to an inconsiderable amount by any of the methods heretofore exploited. Finding the reduction in the concentration of carbon dioxid below the degree represented by the partial pressure p_a to be practically impossible, I have found it feasible to provide from an external source the carbon dioxid necessary to create this partial pressure. The determination of the amount of carbon dioxid required for the purpose may be found approximately by making a determination of the percentage of carbon dioxid in the gas produced by an air-blast containing no endothermically-reacting agent, care being taken that the bed of fuel during this determination is of such depth that no free oxygen passes through the fire unchanged. Under such conditions the percentage of carbon dioxid represents fairly well the partial pressure requirement of the gas for this constituent.

My invention consists in the institution by external means of the desired partial pressure of carbon dioxid in the gas-producer. I aim to secure an equilibrium between carbon monoxid and carbon dioxid in an artificial manner, and I thus suppress the natural tendency of a portion of the coal to depart from the producer as carbon dioxid. The net result is complete combustion to carbon monoxid.

Carbon dioxid from any suitable source—as, for instance, from waste products of combustion—is introduced into the producer in amount sufficient to create the partial pressure p_a along with air or oxygen. Striking the lower part of the fuel-bed the oxygen is burned to carbon dioxid, and the mixture passes up through the incandescent fuel, where reduction to carbon monoxid takes place down to that point where the partial pressure p_a is realized. Thenceforth no further reduction occurs, and the gas departs with its complement of carbon dioxid represented by the partial pressure or concentration p_a. In so far as the object of this invention is concerned any possible interreactions occurring before the concentration p_a in the gas is reached to the carbon dioxid introduced from external sources need not be considered. The final or net result of the process is the combustion of carbon entirely to carbon monoxid.

For example, a gas-producer affords a gas of the average composition: carbon dioxid, five per cent.; carbon monoxid, twenty per cent.; hydrogen, fifteen per cent.; hydrocarbons, three per cent.; nitrogen, fifty-two per cent.; steam, five per cent. The partial pressures of these constituents will be denoted hereinafter by the expression p_a, p_1, p_2, p_3, p_4, and p_5, respectively. The partial pressure of carbon dioxid or p_a I call the "partial-pressure-efficiency factor of the producer." The total pressure of the gas is P, and the partial-pressure equation for the gaseous constituents is

$$P_a + p_1 + p_2 + p_3 + p_4 + p_5 = P.$$

Now p_a, the partial pressure of carbon dioxid, provided no reaction producing carbon dioxid other than that embraced in these partial-pressure considerations exists, is represented by five per cent. in the above statement, and this five per cent. represents the "partial-pressure factor of efficiency" of the producer. The combustible matter of the gas consisting of carbon monoxid, hydrogen, and hydrocarbons heretofore shown and amounting to thirty-eight parts of the total will, if calculated in thermal value into terms of carbon monoxid, be equivalent to about forty-five parts of the latter. The thirty-eight parts of the total combustible matter in one hundred parts of the gas may therefore be expressed as equivalent to forty-five parts carbon monoxid. The carbon completely burned, as shown, to carbon dioxid is five parts, and this expressed in terms of carbon monoxid remains the same numerically—namely, five parts. The total fuel value is therefore representd by fifty parts carbon monoxid, and the fuel allowed to go to waste in this manner is five-fiftieths or ten per cent. of the total. By my process this fuel is saved. Endothermic reactions conducted in the producer with steam or otherwise do not succeed in converting the excess of heat developed in the formation of this carbon dioxid into latent gaseous energy as shown, by the fact hereinbefore mentioned that hydrogen does not increase in proportion as carbon dioxid increases.

In certain cases where the producer is efficiently designed, so as to largely complete reactions within the thick uniform fuel-bed, particularly where no steam is used or where the amount of steam is not too large, the partial pressure of carbon dioxid required in operating by my process may be obtained by the introduction of an amount of carbon dioxid which may be determined with approximate accuracy by making it equal in weight to the amount of carbon dioxid normally present in the combustible gaseous product.

What I claim is—

1. Process of generating combustible gas having a high content of carbon monoxid and a low content of carbon dioxid which consists in introducing into the gas-producing mass of fuel an air-blast containing as an endothermic constituent only carbon dioxid, approximately equivalent in amount to that produced by the passage through the fuel of an air-current containing no endothermically-reacting medium, and in thereby artificially creating within the fuel mass the carbon-dioxid partial pressure p_a, whereby a relatively large amount of fuel is converted into combustible gas.

2. Process for generating producer-gas rich in combustible matter which consists in introducing into the draft-current supplied to the gas-producing mass of fuel as an endothermic constituent only an amount of carbon dioxid approximating that produced by the passage through the fuel of an air-current containing no endothermically-reacting constituent; thereby instituting the necessary partial pressure p_a and converting a relatively large amount of the fuel into combustible gas.

3. Process for producing combustible gas having a relatively high content of carbon monoxid and a relatively low content of carbon dioxid which consists in injecting into the producer along with the air-draft as the endothermic constituent only an amount of carbon dioxid approximately equal to the amount of carbon dioxid present in the producer-gas, and under conditions which prevent the passage through the fuel-bed of free oxygen.

4. Process of manufacturing producer-gas containing a maximum of combustible elements in a producer constructed and designed to largely complete combustible-gas-generating reactions and to pass little or no unchanged steam, whch process consists in injecting into the producer along with the draft thereto as the endothermic constituent only an amount of carbon dioxid approximately the same as the amount of carbon dioxid normally present in the gaseous products of said producer.

5. The process of generating producer-gas rich in combustible matter which consists in supplying to the blast fed through the producer as the sole endothermic constituent the amount of carbon dioxid which would be normally formed by the action of the blast alone in said producer, thereby eliminating the formation of carbon dioxid in said producer and waste of heat thereby.

6. The process of generating producer-gas rich in combustible matter which consists in supplying to the air-blast fed through a producer as the sole endothermic constituent the amount of carbon dioxid which would be normally formed by the action of the air-blast alone in said producer, thereby eliminating the formation of carbon dioxid in said producer and waste of heat thereby.

7. The process of generating producer-gas rich in combustible elements which consists in determining the partial pressure p_a of the carbon dioxid in the gas furnished in the normal working of a gas-producer and thereafter supplying to the blast feeding the said producer from extraneous sources as the sole endothermic constituent an amount of carbon dioxid corresponding to the said partial pressure, p_a, substantially as described.

8. The process of enriching producer-gas which consists in determining the partial pressure, p_a, of the carbon dioxid in the gas furnished in the working of a gas-producer by a pure-air blast under conditions which prevent the passage through the fuel-bed of free oxygen, and thereafter supplying to the blast feeding the said producer from extraneous sources as the sole endothermic constituent the amount of carbon dioxid corresponding to said partial pressure, p_a, substantially as described.

9. In the art of making producer-gas having a relatively high content of carbon monoxid and a relatively low content of carbon dioxid, process for the substantially complete conversion of the fixed carbon of the fuel into carbon monoxid which consists in determining the partial pressure, p_a, of the gas formed in passing an air-draft containing no endothermic constituent through the fuel mass under conditions which prevent the passage therethrough of free oxygen; and in thereafter supplying to the blast feeding the said fuel mass from extraneous sources the amount of carbon dioxid corresponding to the partial pressure, p_a, and no other endothermic constituent, substantially as described.

10. In the art of making producer-gas having a relatively high content of carbon monoxid and a relatively low content of carbon dioxid, the process for the substantially complete conversion of the fixed carbon of the fuel into carbon monoxid, which consists in determining the partial pressure, p_a, of the gas formed in passing an air-draft containing no endothermic constituent through the fuel mass under conditions which prevent the passage therethrough of free oxygen, and in thereafter supplying a blast composed only of air and products of combustion, and in regulating the proportion of the latter with reference to its content of carbon dioxid to create the partial pressure, p_a, of carbon dioxid within the fuel mass.

Signed at New York city, in the county of New York and State of New York, this 10th day of January, A. D. 1905.

CARLETON ELLIS.

Witnesses:

MARY AGNES NELSON,

GEORGE C. DEAN.