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C. ELLIS.

ART OF GENERATING GAS.

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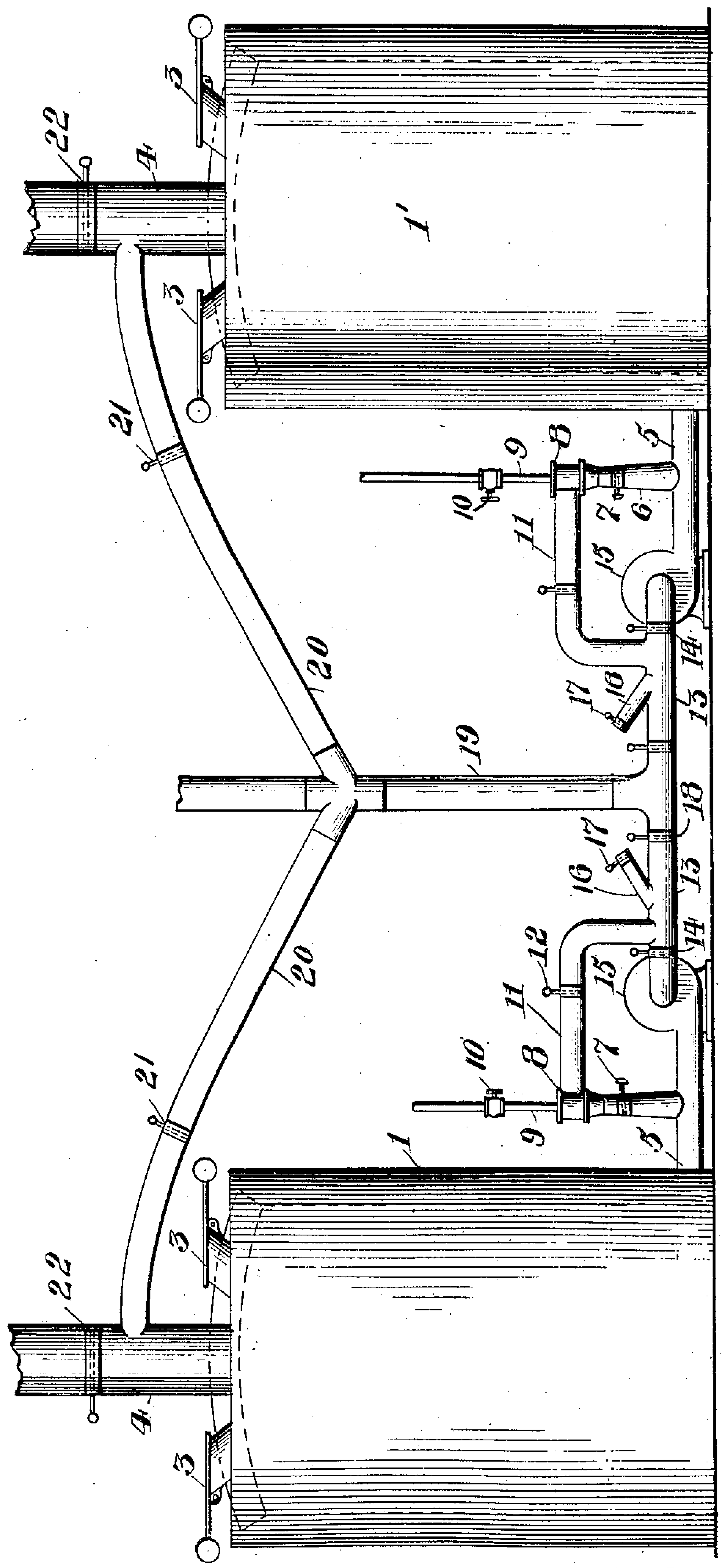

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ART OF GENERATING GAS.

No. 835,506. Specification of Letters Patent. Patented Nov. 13, 1906.

Application filed July 1, 1905. Serial No. 267,921.

To all whom it may concern:

Be it known that I, CARLETON ELLIS, a citizen of the United States, and a resident of New York city, in the county of New York and State of New York, have invented certain new and useful Improvements in the Art of Generating Gas, of which the following is a specification.

This invention relates to processes of making gas; and it consists in a method of producing a complete partial combustion of the fuel in a gas-producer of the ordinary type, converting the fuel wholly into gaseous fuel without the generation of completely-burned products, all as more fully hereinafter set forth, matters of novelty being particularly pointed out in the appended claims.

The invention relates more especially to that branch of the art wherein the gas-generator is functionally remote from the gas-consuming apparatus, although independence of structure is not absolutely necessary to the practice of my method, it being possible to unite gas-producing and gas-consuming apparatus into a single structure, provided the organization is such as to permit the application of the principles hereinafter laid down.

Gas-producers are structures wherein various mixtures of gases are led through a bed of hot or glowing fuel and the combustible gaseous products formed are collected and delivered for consumption. In the ordinary operation of a gas-producer containing a sufficiently thick bed of fuel to insure normal reactions upon the gases going therethrough, there is a certain balance obtaining between the carbon dioxid and the other bodies in the gaseous products obtained. Under the phase rule or law of mass action its concentration or partial pressure relative to other gaseous and vaporous bodies will always be a certain definite amount in the normal running of a given producer at given temperatures and under other given conditions. This amount is independent of the composition of the gases fed to the producer. In one such producer I have found, for instance, that the gas delivered contains about five per cent. of carbon dioxid. While the producer is running at the same temperatures, &c., this five per cent. will be produced whether the entering air used to support combustion in the producer contains five per cent. of carbon dioxid, ten per cent., or none, or whether it contains steam or does not, so long as the body of reacting fuel in the producer is sufficiently deep to insure completeness of contact of the gases passing through or is brought into thorough contact with said gases in any other way.

In the complete combustion of carbon, speaking broadly, of every one hundred units of heat generated about thirty are due to the partial combustion to carbon monoxid and the remaining seventy to the further combustion of the monoxid to the dioxid. It is evident that the heat of formation of dioxid in the producer is wasted, as it appears as sensible heat in the gas produced and must generally be removed before use, and it is further detrimental in that it embarrasses the working of the producer by causing undue temperatures, clinkering, &c. It is also evident that the carbon the dioxid contains is also wasted so far as any useful effect in the gas is concerned, and therefore represents so much fuel thrown away. In the prior practice of this art there has been an effort to control the undue temperatures mentioned by an addition of steam to the entering gases, though I believe it has never heretofore been sought to obviate the wastes mentioned. Steam reduces the temperature, its reaction with glowing carbon being endothermic; but it does not obviate the waste of heat from the formation of carbon dioxid nor the waste of fuel to which it corresponds. The heat of formation of the dioxid is merely diluted, not done away with.

Producers are ordinarily run with air or steam, or mixtures. With steam alone it is necessary to blow up the producer with air occasionally to restore the temperature of the carbon, this being the well-known water-gas process. With air alone at the high temperatures prevailing in a pure-air blow the oxygen is converted into carbon dioxid by the undermost layers of glowing fuel, thereby liberating a great deal of heat on the grate, where it is very detrimental, and the carbon dioxid in its upward passage through the fuel is converted partly into the monoxid—the useful ingredient in the gas produced. This conversion, however, as stated, is never complete, a certain proportion of dioxid inevitably remaining in the gas. With steam a certain amount decomposes with the hot carbon, forming carbon monoxid. Another portion forms dioxid, and still another portion goes through unchanged, the relative proportions in the gas of monoxid, dioxid, hydrogen, and steam depending on the laws of mass action.

It has never hitherto been possible to burn the coal in the producer to carbon monoxid without production of carbon dioxid.

It is the object of my invention to achieve this result.

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) $C+O_2=CO_2$	The principal reaction in the lower part of the producer.
(2) $CO_2+C=2CO$	The reaction of reduction occurring at 600° centigrade and upward.
(3) $2CO=2C+O_2$	The dissociation reaction investigated by Maillard and Le Chatelier. This occurs at temperature varying from 300° to 800° centigrade.
(4) $2C+O_2=C+CO_2$	
(5) $2CO+C=CO_2$	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 two left-hand members of the Equation 2 divided by the square 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 absolute amounts of the reacting bodies, but on the concentration or relative amounts 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 in the normal operation of the producer, I have found it feasible to provide from an external source the carbon dioxid necessary to create this partial pressure, thereby causing all the reactions in the producer to do useful work.

My invention consists in the institution by external means of the desired partial pressure of carbon dioxid in the gas-producer—that is to say, the normal balance. 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 of the coal to carbon monoxid.

In the accompanying drawing I have illustrated more or less diagrammatically one form of apparatus of the many adapted to be used in my process.

In the illustration, 1 and 1′ are two gas-producers of identical structure to be used independently or alternately, according to the modification of my process adopted. Each producer is provided with the usual coal-inlets 3 and gas-outlets 4. (Shown broken away.) Pipe 5 communicates with the twyers. This pipe is provided with a branch pipe 6, having a valve 7 and an inductor 8. Into 8 opens steam-pipe 9 with valve 10 and also another pipe 11 with valve 12. Pipe 11 joins pipe 13. Pipe 13 is provided with valve 14 and is connected with pipe 5 through fan 15. Into it opens an air-inlet pipe 16, provided with valve 17. Beyond the air-inlet is another valve 18 and a connection with a pipe 19 leading to a source of products of combustion. (Not shown.) Pipe 19 is further connected with a pipe 20, leading from gas-outlet 4 of the producer and provided with valve 21. Said gas-outlet 4 is provided with valve 22.

In operation, where a mixture of steam, products of combustion, and air is desired for the draft-current, steam from 9 is used to draw in a mixture of products of combustion from 19 and air from 16, valves 10, 12, 17, and 18 being properly adjusted to control the proportions and valve 14 closed to throw the fan out of circuit, or with valve 14 open and valve 12 closed the draft may be caused by the fan and slight amounts of steam added by opening 10. When the steam is not to be used, valve 7 is closed and a mixture of products of combustion from 19 and air from 16 is caused to flow by the fan.

When producers 1 and 1′ are to be used alternately, as in processes where an air-blow alternates with gas production, products of combustion from said air-blow may be drawn through pipe 20, valves 21 and 22 being properly adjusted. In making the air-blow it is obvious that by closing valve 18 and opening valve 17 a pure-air draft-current may be induced by the fan.

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, (and steam, in case the latter is desired.) 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........	5 per cent.
Carbon monoxid......	20 per cent.
Hydrogen	15 per cent.
Hydrocarbons...	3 per cent.
Nitrogen	52 per cent.
Steam	5 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 generator. 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, or five per cent. CO_2 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 forty-five parts carbon monoxid. The carbon completely burned, as shown by the 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 represented 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.

It will be understood that the example set forth above is considered only for the purpose of elucidating the points which I desire to make evident—namely, that the percentage of carbon dioxid stands as a measure of efficiency of a gas-generator intended for the production of a gas rich in combustible matter and that a very substantial economy may be effected by means which tend to reduce the amount of carbon dioxid formed from the fuel. I have therefore shown theoretically why it is that the institution by external means of the desired partial pressure of carbon dioxid will result in economy owing to the production of the maximum quantity of carbon monoxid.

In certain cases where the generator 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. In other cases the determination of the amount of carbon dioxid required 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 practically 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. For the precise determination of the normal partial pressure p_a of carbon dioxid scientific measurements of a high degree of refinement and complexity must be resorted to. So exact an adjustment is unnecessary and, in fact, in practice is scarcely possible. When steam in considerable quantity passes unchanged through the fuel-bed and the gas is not cooled immediately on evolution, the following reaction occurs: $CO+H_2O=CO_2+H_2$ This reaction gives rise to carbon dioxid in greater or less degree, and if not taken into consideration misleading data are obtained. Carbon dioxid arising from this reaction should be corrected and allowed for in accordance with the theoretical part of the present disclosure.

It is the object of my invention, as heretofore stated, to produce from a given amount of fuel a maximum of combustible gas, and therefore my process is scarcely applicable to such gas-making operations as those which normally give rise to a by-product gas very low in combustible matter and which have primarily as their object the production of distillation or decomposition products—such, for instance, as ammonia.

As a source of carbon dioxid the products of combustion or waste gases from any suitable furnace may be employed. These contain, beside carbon dioxid, ordinarily oxygen, nitrogen, water-vapor, and, in small amount, carbon monoxid. The products of combustion of producer-gas generally are the most convenient sources of carbon dioxid for producer operation, as the gas is usually burned in furnaces located near the producer. When the presence of nitrogen is not objectionable, water-gas generators may often be supplied with carbon dioxid from the "air-blow," waste gases, or from a steam-boiler furnace. The waste gases evolved in the calcination of lime or cement are especially suited for this purpose, owing to their high content of carbon dioxid. Waste gases containing large quantities of dust may be filtered before use. When the generator is used for the operation of internal-explosion engines, the products of explosion of the engine may be entered into the producer in such an amount as will suffice to regulate the combustion in the desired manner. In the manufacture of producer-gas a cooling medium, such as steam, may be introduced into the fuel-bed, whereby on contact with ignited carbon an endothermic action occurs and the producer temperature is lowered. It is furthermore often desirable when the products of combustion are derived from a furnace at a high temperature to subject these to a cooling influence prior to introduction into the generator, for at high temperatures the velocity of reaction of oxygen with carbon is greatly accelerated over that at normal temperatures, and the oxygen may combine so rapidly with carbon as to produce excessively high or clinkering temperatures in the lower portion of the fuel-bed.

In applying my new process to the manufacture of water-gas I use in general the ordinary methods, such as the blasting of hot fuel with mixtures of air and steam, with the former in amounts sufficient to keep up the heat, or the alternate blasting with steam and with air; but in each case I inject, together with the steam, an amount of carbon dioxid or of products of combustion containing the same that will suffice to supply the amount of carbon dioxid normal to the gas formed in the producer. With the mixed air-steam blow the amount of steam can of course be as great or as little as desired, though where it exceeds a certain amount an occasional interruption of the process to restore heat to the fuel by an air-blow will be necessary. Where the alternating blast is employed, the products of combustion to be supplied with the steam can be very conveniently derived from the air-blow.

In the manufacture of water-gas by my process the loss of fuel ordinarily incurred by the formation of carbon dioxid in the producer is obviated, the inevitable amount of carbon dioxid in the gas being supplied from products of combustion which cost practically nothing. The gas is richer in combustible elements, and it is far more uniform in quality than prior water-gas, for the reason that one variable reaction in its formation is eliminated.

I regard my process as generally applicable to any producer-gas method blowing gases or vapors or mixtures of both through glowing fuel for the manufacture of combustible gas. I have found it particularly applicable to making water-gas by the described method and also to making producer-gas by air injection alone; though the latter specific process I do not herein claim, as it forms the subject-matter of Patent No. 795,790, granted me July 25, 1905, upon a copending application, Serial No. 240,626, filed January 11, 1905.

Briefly stated, my invention consists, broadly, in the art of semi-oxidizing carbon in a gas-producer without production of carbon dioxid therein or the complete oxidation of the carbon by supplying to the draft-currents sent through such a producer the amount of carbon dioxid normal to gas issuing therefrom, thereby suppressing completely the formation of such dioxid or completely-oxidized carbon in the producer itself. These draft-currents may be oxygen, air, steam, or mixtures thereof within purview of my broad invention.

What I claim is—

1. The process of making gas which consists in contacting with a bed of hot fuel a carbon-oxidizing draft-current containing an amount of carbon dioxid equal to that normally present in the gas from said fuel.

2. The process of making gas which consists in contacting with a bed of hot fuel a carbon-oxidizing draft-current containing products of combustion in quantity sufficient to furnish an amount of carbon dioxid equal to that normally present in the gas from said fuel.

3. The process of semi-oxidizing carbon without formation of carbon dioxid therefrom which consists in contacting with said carbon in a heated state a draft-current of air containing endothermic agents in quantity sufficient to repress undue rise in temperature, said endothermic agents comprising a quantity of carbon dioxid equal to that normally found in the gas resulting from the contact of carbon and said draft-current.

4. The processs of manufacturing gas

which consists in contacting with a bed of hot fuel a draft-current containing air, steam and carbon dioxid, the carbon dioxid being equal in amount to that normally present in the gas from said fuel.

5. The process of manufacturing gas which consists in contacting with a bed of hot fuel a draft-current containing air, steam and products of combustion, said products being contained therein in amount sufficient to furnish an amount of carbon dioxid equal to that normally present in the gas from said fuel.

6. The process of manufacturing gas which consists in contacting with a bed of hot fuel a draft-current comprising steam and carbon dioxid, the carbon dioxid being equal in amount to that normally present in the gas from said fuel.

7. The process of manufacturing gas which consists in contacting with a bed of hot fuel a draft-current comprising steam and products of combustion, said products being contained therein in quantity sufficient to furnish an amount of carbon dioxid equal to that normally present in the gas from said fuel.

Signed at New York city, in the county of New York and State of New York, this 29th day of June, A. D. 1905.

CARLETON ELLIS.

Witnesses:

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JAS. K. CLARK.