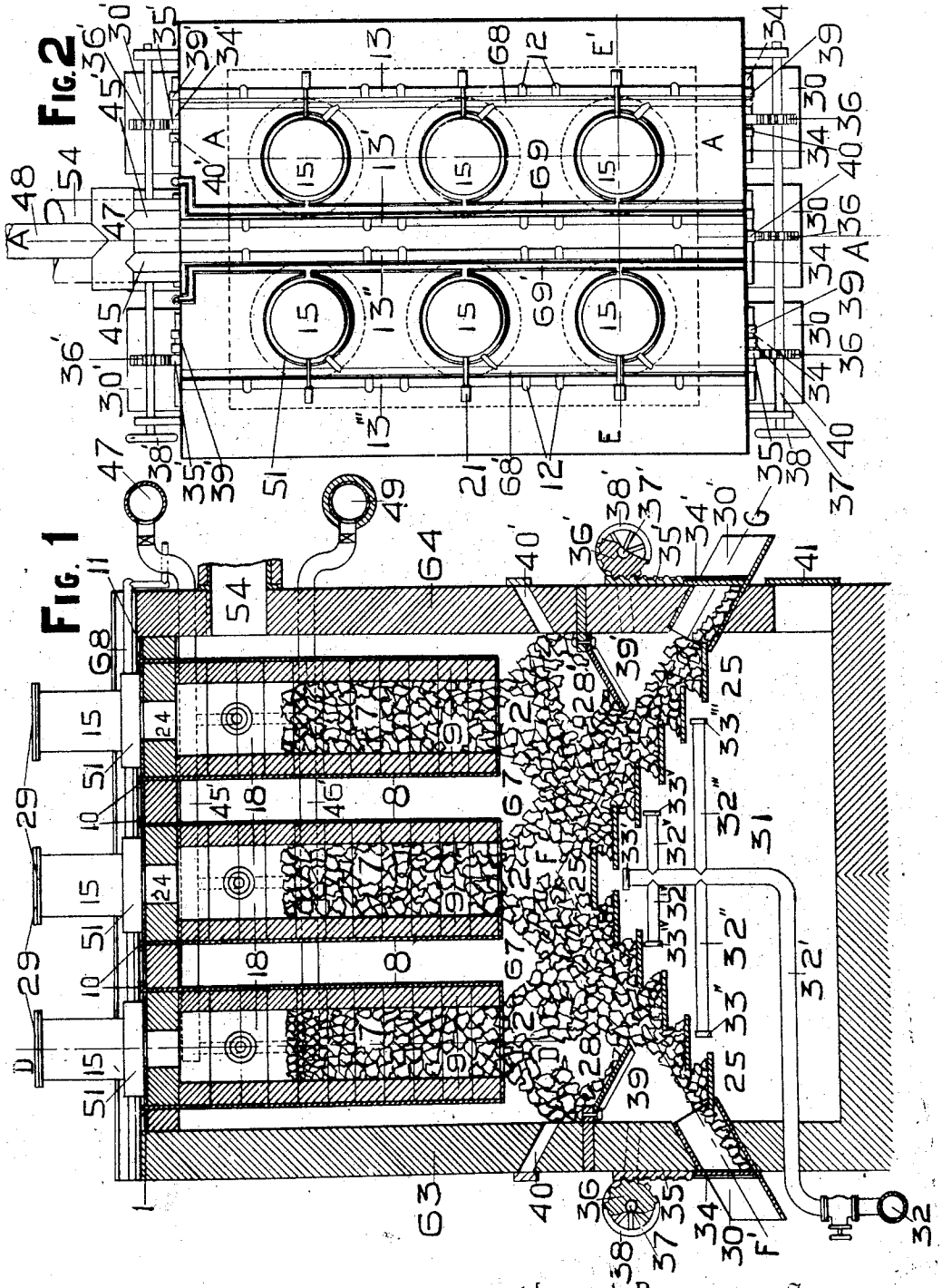
H. L. DOHERTY.

PROCESS OF COKING COAL AND PRODUCING GAS.

APPLICATION FILED JUNE 22, 1909.

1,034,214. **Patented July 30, 1912.**

4 SHEETS—SHEET 1.



Witnesses:
Fred B. Mulock
Thos. I. Carter

Henry L. Doherty, Inventor
By his Attorney Frank S. Young.

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4 SHEETS—SHEET 2.

FIG. 4

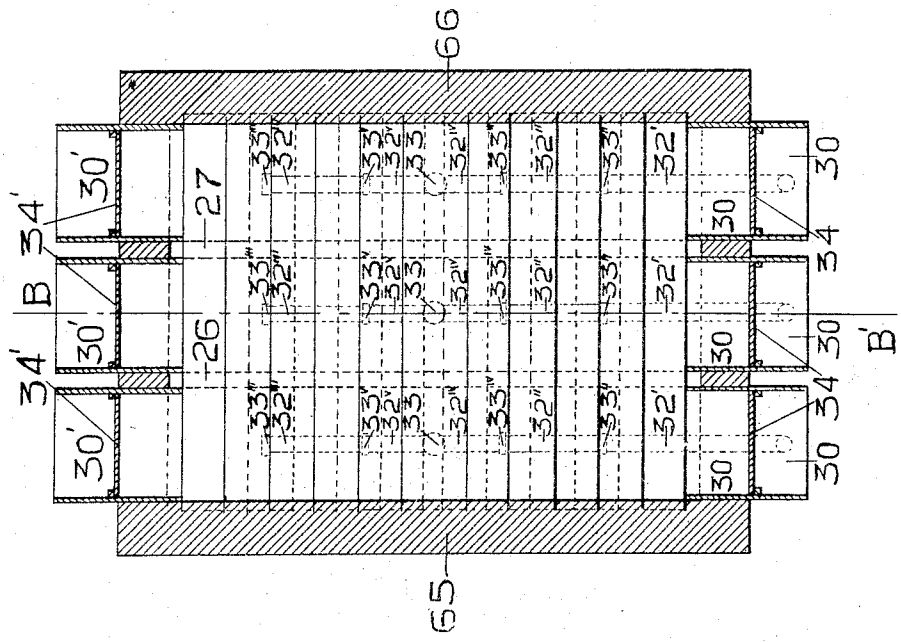
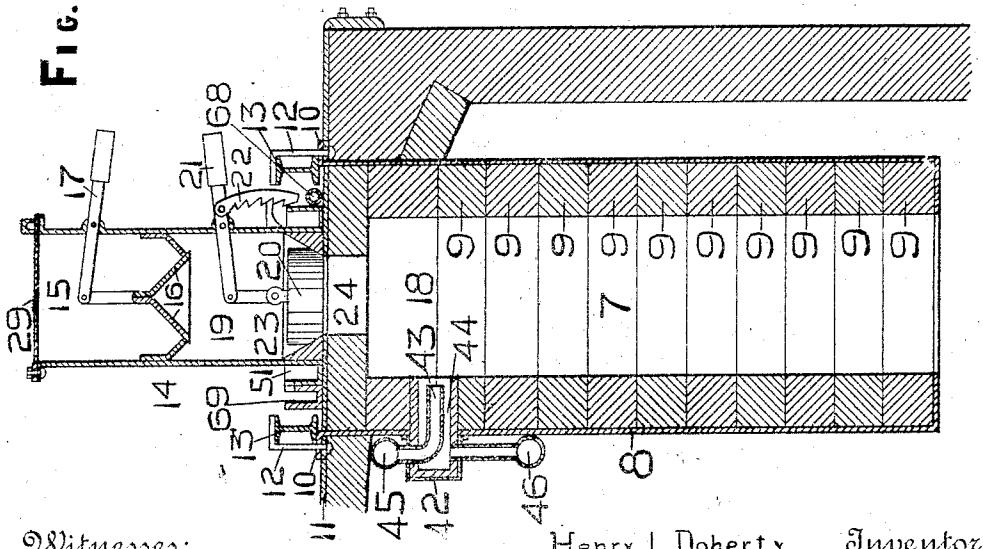


FIG. 3



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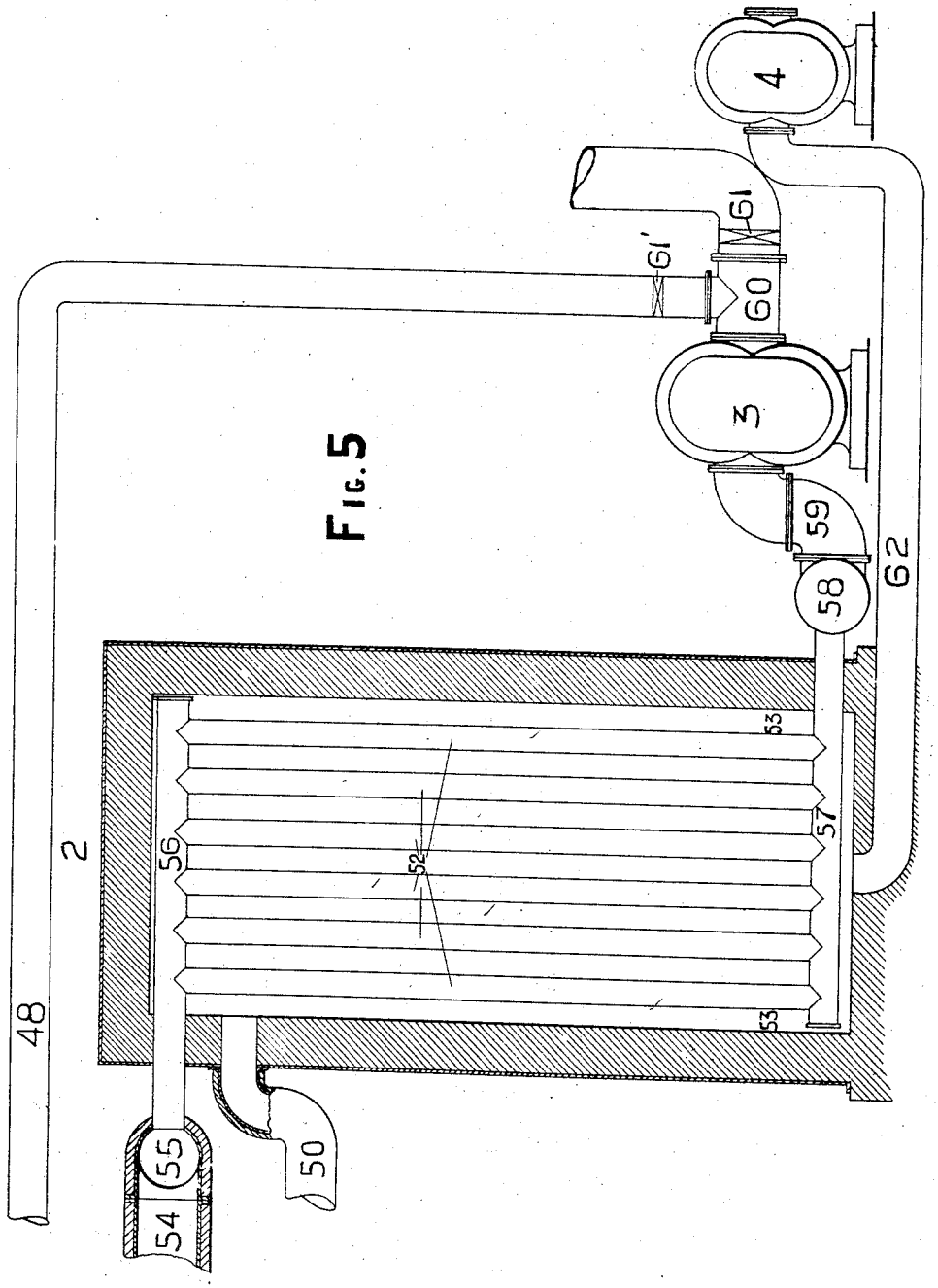

FIG. 5

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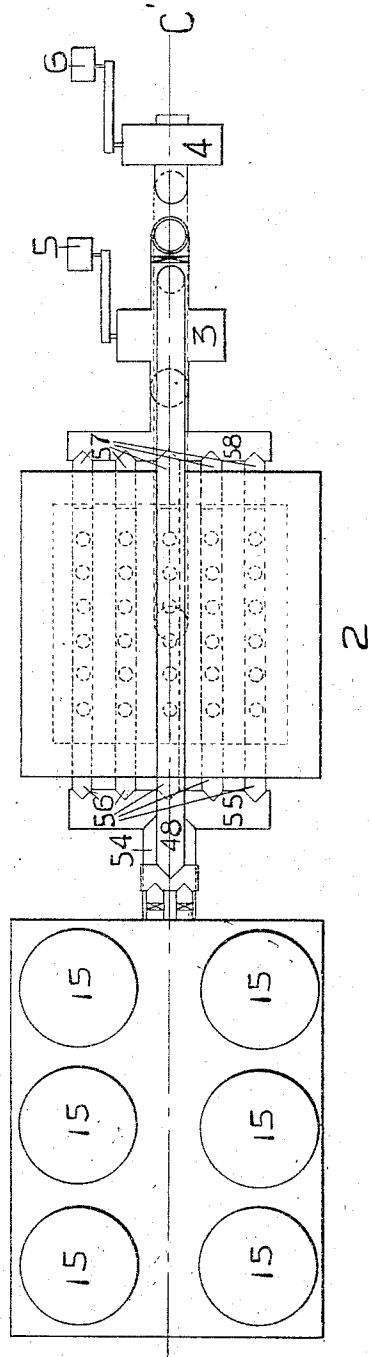
4 SHEETS—SHEET

FIG. 6



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UNITED STATES PATENT OFFICE.

HENRY L. DOHERTY, OF NEW YORK, N. Y.

PROCESS OF COKING COAL AND PRODUCING GAS.

1,034,214. Specification of Letters Patent. Patented July 30, 1912.

Application filed June 22, 1909. Serial No. 503,733.

To all whom it may concern:

Be it known that I, HENRY L. DOHERTY, a citizen of the United States, residing at New York city, in the county of New York and State of New York, have invented new and useful Improvements in Processes of Coking Coal and Producing Gas, of which the following is a specification.

This invention relates to processes for carbonizing slack coal, and producing gas, and, in particular, to such processes where the heat for the carbonizing of the coal is derived from the combustion of a portion of the gas formed during the treatment of a previous portion of the coal.

The objects of my invention are the furnishing of a process, whereby, the slack coal may be continuously carbonized or coked with the expenditure, in the coking process, of a minimum proportion of the total heat of the original coal and a large proportion of the volatile nitrogen of the coal recovered as ammonia, and in apparatus of such design that great flexibility of control over the coking process may be exercised, whereby the quality of carbonized coal or coke produced may be varied at will, and the coking carried on with the expenditure of a minimum amount of labor.

In the hereinafter described process, I accomplish the above objects by subjecting the raw coal to a flame of burning producer gas and air preheated by the sensible heat of the gases leaving the oven, the products of such combustion being passed in contact with the carbonizing coal and the hot carbonized coal or coke in one direction, while the steam from the quenching of the coke is passed in the opposite direction, also in contact with the coke, the gases resulting from the reaction of the reactive constituents of the combustion gases and the coke, and from the reaction of the water vapor and coke, being drawn off from the coke-oven in a common current and passed through a recuperator for preheating the air, the gas required for the coking being returned to the coke-oven.

In the accompanying drawings, I have shown a form of apparatus suitable for applying my process, but any form of apparatus which will permit of the carrying out of the essential steps of my process may, of course, be substituted for the one shown.

Figure 1 is a vertical longitudinal section through the coke-oven proper on the line A A′, of Fig. 2 and B B′ of Fig. 4. Fig. 2 is a top view of the coke-oven and connections. Fig. 3 is a vertical cross section through a retort or coking chamber and its feed-hopper and gas burner on the line D D′ of Fig. 1 and line E E′ of Fig. 2. Fig. 4 is a horizontal projection of a section by two inclined planes whose traces on Fig. 1 are shown by the lines F F′ and F G. Fig. 5 is a part section through the recuperator on a vertical plane through the line C C′ of Fig. 6, the air and gas blowers being shown in side elevation. Fig. 6 is a diagrammatic plan of the apparatus.

In the drawings, 1, designates the coke-oven proper, 2 the recuperator, 3 the gas blower, 4 the air blower, 5 and 6 motors for driving the blowers.

67 is a chamber inclosed by the outer walls, 63, 64, 65 and 66, of the oven, in which are suspended coking chambers or retorts, 7. In Fig. 3 is shown a section through one of the retorts. The retorts have a steel jacket 8, with a thick lining built up of thick ring-shaped blocks of fireclay, 9. The steel-shell has a flange 10 at its top which rests on a heavy steel plate 11. Heavy hangers, 12, are fastened to the plates 11 and suspended from the I-beams 13 and 13′ and 13″ and 13‴. These beams are supported on the walls of the oven. The weight of the coking chambers is thus borne by the walls of the coke-oven and not by the arch of the same. Appropriate buck-staves bind the walls together.

The charging apparatus, 14, of each of the retorts 7 is superimposed upon the retort. It consists of a coal hopper, 15, closed at the bottom by a charging cone, 16, actuated by the counterpoised-lever mechanism 17, and having a cover 29. An air-chamber, 19, separates the coal hopper 15 from the top of the retort. This air chamber is closed at the bottom by a movable plug of fireclay, 20, which is elevated or lowered by the lever mechanism 21. A suitable device, 22, is provided for keeping the

plug 20 raised while the cone 16 is being lowered. A water jacket, 51, is provided for the bottom of 19 to protect it from the high temperature in the combustion chamber 18. The hopper-bottom, 23, of 19 opens directly into the opening 24 in the cover of the retort. A stepped-grate, 25,—which is itself supported by the stepped-walls 26 and 27 and the side walls 65 and 66 of the oven,—together with the inclined plates 28 and 28′, supports the mass of coke in the oven. Sets of chutes—one set for each end of the oven— designated by 30 and 30′, are arranged to receive the coke as it discharges from the grate 25.

The portion of the oven, 31, below the plates 28 and 28′ may be called the quenching chamber of the oven. The quenching device consists of a system of water pipes terminating in spray nozzles. A separate system, connected with the same main water pipe 32, is placed in each of the compartments formed by the side walls 65 and 66 and the walls 26 and 27. The arrangement of the nozzles for the middle compartment is shown in Fig. 1. The pipe 32′ leading off from 32 has a number of branches, 32″, 32‴, 32′ᵛ, 32ᵛ, respectively terminating in spray nozzles, 33′, 33″, 33‴, 33′ᵛ, 33ᵛ. The number of nozzles used should be sufficient to give a uniform distribution of the water. While I may use any suitable form of nozzle, the one that I prefer is that revealed and claimed in my Letters Patent No. 901,597 dated Oct 20, 1908. This form of spray has a solid head perforated with fine holes, or passages, bored at an angle with the axis of the spray-head and so arranged in position and angle that the fine streams discharging through the said inclined passages intersect and impinge on each other, whereby, a very fine spray or fog is produced.

The sets of chutes, 30 and 30′, are closed by sets of gates, 34 and 34′, arranged with sets of racks, 35 and 35′, gearing with pinions 36 and 36′. The pinions 36 are mounted on a common shaft 37 and so are operated in unison by turning the hand wheel 38. The pinions 36′ are similarly mounted on a shaft 37′ operated by the hand wheel 38′.

Sets of poke-holes, 39 and 40 and 39′ and 40′, permit of access to the bed of coke for the purpose of barring down, when the coke hangs and will not discharge by gravity upon the rising of the gates 34 and 34′. Doors 41 are provided, furnishing a means of access to the compartments beneath the grate, 25.

The retorts are each provided with one or more burners 42, which consist of short tubes of fire-clay, or other refractory material, closed at their outer ends and having their inner ends in free communication with their corresponding combustion chambers 18. The burners 42 have an interior axial tube 43 which extends to the outside of the burner, and leaves an annular passage 44, between itself and the walls of the burner. The tubes 43 in connection with each row of retorts are connected with a gas-distributing pipe, 45, while the annular passages, 44, are connected with an air-distributing pipe, 46. The burners of the other row of retorts are similarly connected to similar gas and air-distributing pipes 45′ and 46′, respectively. The gas-distributing pipes of each oven are connected, through the cross-pipe 47, to a common gas-supply-pipe 48 which conducts the gas back from the exhauster 3 to the oven. The air-distributing pipes, 46, are correspondingly connected, through the cross-pipe 49, to a common air supply-pipe, 50.

The recuperator may be of any suitable design. In the one shown in the drawings, it consists, simply, of a system of vertical pipes, 52, located in a chamber, 53. The gas is drawn off from the oven through the conduit 54, and is distributed through the cross-pipe 55 to the horizontal header-pipes 56. From 56 the gas is distributed to the vertical tubes 52. Horizontal header-pipes 57 connect the tubes at the bottom of the recuperator, and the pipes 57 are, in turn, connected with the cross-pipe 58. The suction pipe 59 of the exhauster-blower 3 opens out of 58. Set in the discharge-pipe 60 of 3, is the by-pass 48 leading back to the oven. A valve, 61, is also provided on 60, and another, 61′, on 48. By manipulating 61 it is evident that the gas may be supplied to 48 at any pressure desired within the capacity of the blower 3. The pipe 60 may be connected to a holder or directly to a distributing main, as may be desired.

The air for the combustion in the retorts is compressed by the blower 4 and passes through the pipe 62 to the bottom of the chamber 53, through 53 in contact with the gas pipes 52 and discharges from the upper part of 53 through the pipe 50, through which it passes to the coke-oven.

Heat insulating jackets are, preferably, provided for the various pipes conducting the hot gas and air from the recuperator to the coke-oven.

In starting the oven in operation, I charge cinder or coke on to the grate until a bed has been built up well above the apex of the grate 25. A fire is then kindled and coke gradually charged on the ignited bed until a bed of fuel has been built up to the bottoms of the retorts. During this operation the doors 41 are left open and the exhauster 3 run at a slow speed. When a sufficient thickness of ignited coke has been built up the gas passing through the exhauster 3 has become a fairly good producer gas. The valve 61′ which was at first closed is now

opened and part of the gas passes back to the burners 42, where it is ignited and burned by means of air supplied by the blower 4. Coke is now gradually charged into the retorts until the proper fuel level has been attained. When the retorts and contents have been brought up to a suitable carbonizing temperature the doors 41 are closed. During the preliminary firing, sufficient water, if necessary, is sprayed onto the grate 25 to prevent damage to the same from the high heat in the fuel bed. The combustion gas from the burners in passing downward through the columns of hot coke in the retorts is changed to producer gas by the, now, well known reaction revealed in my Letters Patent 829,105 of Aug. 21, 1906. Material—cinder or coke according to which was used—is now withdrawn at the bottom of the oven and, as the charges in the retorts settle, raw coal is charged in at the top. This is immediately subjected to the carbonizing and coking action of the flame and the hot walls of the retort, and is soon coked, the volatile matter distilled off mixing with the combustion gases from the burners and passing down through the retorts in contact with the ignited coke. The result is that the heavy vapors which, ordinarily, simply distil off from the coke unchanged, are cracked up into compounds of lower molecular weight, such as methane, ethylene, etc., with free hydrogen. At the same time most of the CO_2 formed in the combustion at the burners reacts with the ignited coke according to the reaction,

$$(a) \quad CO_2+C=2CO.$$

The result is that the gas issuing at the bottom of the retort is a mixture of producer gas and distillation gases; the richness of the mixture depends upon the quantity of gas burned in the retorts relative to the quantity of coal carbonized, or—put in another way—upon the temperature of carbonization. When a hard coke is desired, a high temperature in the retorts is necessary. Consequently, more gas must be burned in the retorts for the same quantity of coal coked, than when a low-temperature product, such as coke of a quality corresponding to that known commercially as "coalite", is made; and, as a result, the ratio of producer gas to distillation gas is increased.

When coal is coked in the present used types of externally heated retorts or ovens, an amount of heat equivalent to about ten to twenty per cent. of the total heat of the raw coal is required for coking. This is due to several reasons. In the first place, the high temperature (1800–2000° F.) required to form a hard coke necessitates the use of a highly refractory material such as fireclay in the construction of the retorts or ovens. This material has a comparatively low tensile strength and as a result it is necessary to make the walls of the carbonizing chamber very thick. The heat conductivity of fireclay is also low. The coke itself also possesses quite a low conductive power. Now, in coking in externally fired chambers all the heat necessary for the coking operation must pass to the coal through the highly resistant walls of the chamber and is then transmitted to the interior of the mass in the chamber through the outer shell of the coke which is first formed in contact with the hot walls of the chamber. Owing to the low heat conductivity of the materials mentioned, it is absolutely necessary to have a very high temperature in the combustion chamber in order to obtain a sufficient difference of heat potential to drive the heat into the interior of the charge at a rapid rate. This, of course, means that the products of combustion must be allowed to leave the combustion chamber at a temperature considerably above that of the walls of the coking chamber, or, say, 2000° to 2300° F. This means that a large portion of the total heat developed is ordinarily wasted so far as the coking operation is concerned. Besides, the higher the temperature, the greater is the amount of radiation loss from the oven, since, according to Stefan's law, the radiation varies as the fourth power of the absolute temperature of the body. In the ordinary methods of coking the heat losses by radiation and conduction to the air amount to more than 20% of the total heat developed in the operation. On the other hand, by my method of coking, the heat is developed in actual contact with the raw coal, and the gases of combustion pass through the mass enveloping each individual fragment of the same. The greatest distance that the heat must pass by conduction through a solid is measured by the shortest distance that the center of the largest fragment is from the exterior surface of the lump—say three inches. In such an oven as the ones at present usually used the heat must be transmitted through 4½ inches of fireclay and about 9 inches of coal or coke to get to the interior of the charge. Further, since the temperature in the mass is only high enough to insure the desired coking action, the radiation losses are reduced to a minimum. This latter loss is further reduced in the apparatus which I have shown, by the fact that the coking chambers are surrounded by an outer inclosed chamber. The heat radiated from the coking chambers is principally taken up in the gaseous atmosphere surrounding the coking chambers and so passes to the recuperator, from which it is returned to the oven through the medium of the air supplied for the combustion. For reasons explained below, the temperature in the main

oven chamber is comparatively low. For all of these reasons the heat losses in my method of coking are comparatively low—only a fraction, in fact, of the customary losses in coking. I am therefore able to carry out the coking operation with the expenditure of a comparatively small proportion of the total heat of the raw coal. Instead of 10%, I can so operate my apparatus that I may use less than 5% of the total heat of the original coal, in the coking. This would correspond to the gasification by semi-combustion of, approximately, 5 to 6% of the carbon of the raw coal treated. Since this gasified carbon is, in large part, in the form of carbon-monoxid and the major part of the sensible heat of the gas is recovered in the recuperator and returned to the carbonizing chambers, nearly three-quarters of the original potential heat of the gasified carbon remains in an available form in the gas formed from it.

An important and novel feature of this invention is the method I use to reduce the temperature of the heating gases (combustion gases from the burners 42) and of the hot coke before they leave the coking chambers. I do this by utilizing the cooling effect of the mutual reaction between the CO_2 of the combustion gases and the carbon of the coke.

When a fresh charge of raw coal has been introduced into a coking chamber, the high temperature gases from the carbonizing flame cause an extremely rapid distillation of the volatile matter of the coal. The temperature of the coal, however, remains at a comparatively low point until most of the volatile matter has been driven off. This is due to the fact that the distilling vapors carry off the heat from the coal as fast as the latter can pick it up from the combustion gases. It is only when the distillation has progressed to a considerable degree, that the coal gains heat faster than the distillation gases can carry it off, and the temperature tends to rise to a high point. Since the reaction,

$$(a)\quad CO_2+C=2CO,$$

requires a considerable time of contact for its completion, the cooling effect of the reaction on the fresh charge which is under the direct influence of the flame is scarcely appreciable. The low conductivity of the coking coal and the comparatively low velocity of the reaction, mentioned, permits the combustion gases, which are initially at a temperature of from 2500° F. upward, to penetrate a considerable distance into the fuel bed before their temperature has been reduced below that necessary to successfully complete the coking of the coal. This temperature may be taken as about 2000° F. for the harder qualities of coke. The coke is therefore subjected to a good finishing heat before the temperature of the combustion gases has fallen so low that the cooling action, in reference to the coke, of the reaction mentioned, predominates. Below this level in the carbonizing chambers, the coke is in process of cooling, the reaction proceeding at the expense of the remaining sensible heat of the combustion gases and the coke. I aim to make my carbonizing chambers of such a depth, in relation to the speed of driving, that the combustion gases shall remain in contact with the coke for a sufficient length of time to reduce the temperature of the latter to near the point at which the reaction ceases. In other words, I prefer to so design my apparatus that the coke may be cooled by reaction (*a*) to as low a temperature as is practically so attainable, say 1300° F. To complete the cooling of the coke I bring in the action of water. The water as it is sprayed onto the coke on the grate is, in part, immediately vaporized, while the portion not so vaporized is carried as a dense fog by the initially formed vapor farther into the bed of coke. The quantity of water used is restricted to that which can be vaporized in, say, the lower third of the coke bed. As the vapor passes up through the hotter coke above, which it discharged from the coking chambers onto the bed at a temperature of about 1400–1500° F., the water vapor is decomposed by reaction with the carbon by either,

$$(b)\quad 2H_2O+C=2H_2+CO_2,$$

or

$$(c)\quad H_2O+C=H_2+CO.$$

The gases resulting from these reactions, and any undissociated water vapor, pass out of the coke bed and mingle with the current of mixed, producer gas proper, and distillation gas from the retorts.

Owing to the small quantity of heat which I have to develop to carry on the carbonization by my herein-revealed method, the normal producer gas may be restricted to less than double the volume of the distillation gas. Since the distillation gas would have a calorific value about five times that of the producer gas proper, a resultant mixed gas may be produced having a calorific power of about 2⅓ times that of ordinary producer gas. Since the water gas may be made having about the same calorific value as the mixed gas, it does not materially modify the calorific power of the entire mixture.

Where the recovery of the volatile nitrogen of the coal becomes an object, I modify the working of my apparatus to correspond with the conditions favorable to the formation of ammonia. These are, a moderate temperature in the fuel bed and the rapid removal of the gases from contact with the

incandescent coke. I secure these conditions by introducing a proper proportion of combustion gases into the air current supplied to the gas burners of the coking retorts. This modification of my present invention I have revealed and claimed in my application Ser. No. 534,693, filed December 23rd, 1909.

When I desire to produce a soft coke retaining a considerable proportion of volatile matter—a product corresponding to that commercially known as "coalite"—I restrict the relative quantity of gas burned in the coking chambers, and increase the speed of driving—*i. e.*, both "draw" and "charge" at more frequent intervals. On the contrary, to produce a hard coke, I increase the proportion of gas burned in the coking chambers, and decrease the speed of driving, whereby the coke formed remains much longer under the influence of the high temperature flame.

It is to be understood that the phrase "substantially all of the carbon dioxid and water vapor" as used in the following claims refers to the dissociation of substantially all of that portion of said constituents which is reducible under the conditions of temperature and pressure which prevail in the operation of my coke oven. As is well known to those skilled in the art, there is always a certain partial pressure of carbon dioxid and water vapor which is necessary for the equilibrium of the reacting system. I, of course, do not claim that I can dissociate the carbon dioxid and water vapor beyond the proportion corresponding to this equilibrium pressure. The residual CO_2 may be taken as corresponding to the practical minimum in gas producer practice, say 4 to 5 per cent. by volume.

The apparatus shown and described herein I claim in my application Ser. No. 533,734, filed June 22nd, 1909.

It is, of course, to be understood that I do not limit my invention to the treatment of true caking coals, which produce a true coke after carbonization, but use it in the carbonizing of any quality of coal that it may be desirable to treat. For example, my invention may be applied to carbonizing lignite, although this material will not yield a true coke. The process of treatment, however, remains substantially the same as when treating caking coals, the principal difference being that the product of the operation is with lignite not a true coke.

Having described my invention, what I claim is:—

1. The process of coking coal and producing gas which comprises subjecting the coal in an inclosed chamber to the direct action of a gas flame; passing the products of combustion from said flame in contact with a mass of previously formed coke in said inclosed chamber, the depth of said mass of previously formed coke being sufficient to insure the reaction with carbon of substantially all of the carbon-dioxid and water vapor formed by the combustion in said gas flame, spraying the coke with water after the said coke has been contacted with the products of combustion from said gas flame, withdrawing from the inclosed chamber the gases resulting from the contact of the combustion gases and the hot coke and the water and hot coke, and withdrawing the quenched coke from said chamber, substantially as described.

2. The process of carbonizing coal and producing gas which comprises heating coal in an inclosed chamber in direct contact with a heating flame to form distillation gases and carbonized coal, passing the combustion gases from said flame and the gases distilled from the said coal in contact with a mass of previously formed incandescent carbonized coal in said inclosed chamber, the depth of said coke mass being sufficient to insure the conversion by reaction with carbon of substantially all of the carbon-dioxid and water vapor formed from the combustion in said gas flame, to carbon monoxid and hydrogen, quenching the carbonized coal after it has been contacted with the said gases, withdrawing from the inclosed chamber the gases formed by reaction between the combustion and distillation gases and the carbon of the carbonized coal and the gases from the quenching operation, in a common current, and withdrawing the quenched carbonized coal from the inclosed chamber, substantially as described.

3. The process of carbonizing coal and producing gas which comprises heating the coal in an inclosed chamber in direct contact with the heating flame to form distillation gases and carbonized coal, partially quenching the carbonized coal so-formed by contacting the same with the combustion gases from the heating flame and the distillation gases from the coal, the contact between the said gases and said carbonized coal being sufficient to effect the conversion by reaction with carbon of substantially all of the carbon dioxid and water vapor in said gases into carbon-monoxid and hydrogen; completing the quenching of said carbonized coal by spraying the partially quenched carbonized coal with water, withdrawing from the said chamber the gases formed by the reaction between the said combustion and distillation gases and the hot carbonized coal and the gases formed by the final quenching in a common current, and withdrawing the quenched carbonized coal from said chamber, substantially as described.

4. The process of carbonizing coal and producing gas which comprises introducing

said coal into an inclosed chamber, introducing into said chamber gas from the carbonizing of a previous portion of coal and heated air, burning said gas and heated air in contact with said coal, whereby said coal is carbonized, removing said carbonized coal from direct contact with the flame of burning gas when the carbonizing action has proceeded to the desired degree, partially quenching the so-formed carbonized coal by contacting therewith the combustion gases from said flame and the gases distilled from a succeeding charge of coal, the mass of carbonized coal exposed to the quenching action of said gases at any given time being sufficient to convert substantially all of the carbon dioxid and water vapor of said combustion and distillation gases to hydrogen and carbon monoxid, completing the quenching of said carbonized coal by spraying the same with water, withdrawing the gases formed in the two quenching operations in a common current, passing the said gases through a recuperator, whereby the major portion of the sensible heat of said gases is transferred to the air current which sustains the combustion of the gas in the carbonizing chamber, substantially as described.

5. The process of carbonizing coal and producing gas which comprises charging said coal onto a column of previously carbonized coal in an inclosed chamber, introducing into said chamber gas from the carbonizing of a previous portion of coal and heated air, burning the said gas and said heated air in contact with said coal, whereby the volatile matter of said coal is distilled therefrom, and the said coal carbonized, charging a second portion of coal onto the carbonized coal from the first portion of coal, when the coking operation has proceeded to the desired degree, whereby the said carbonized coal is removed from the direct action of the flame of burning gas, partially quenching the said carbonized coal by contacting therewith the combustion gases from said flame, and the distillation gases from succeeding charges of coal, the mass of carbonized coal which is at any given time subjected to said quenching action being sufficient to provide enough contact surface to effect the conversion by reaction with carbon of substantially all of the carbon dioxid and water vapor of said combustion and distillation gases to carbon monoxid and hydrogen, removing from contact with the partially quenched carbonized coal the combustible gas resulting from the reactions between the reactive constituents of the said combustion and distillation gases and the hot carbonized coal, completing the quenching of the partially quenched carbonized coal, by spraying the same with water, withdrawing the combustible gases formed by reaction between the water and the partially quenched carbonized coal, passing the combustible gases from the first quenching operation and the combustible gases from the second quenching operation through a recuperator, whereby the major portion of the sensible heat of the said gases is transferred to the air current supplied for sustaining the combustion in the carbonizing chamber, removing the quenched carbonized coal from the said chamber, and charging a fresh portion of raw coal onto the bed of carbonized coal in said chamber, substantially as described.

6. The process of coking coal and producing gas which comprises charging said coal onto a column of previously coked coal in an inclosed chamber, introducing into said chamber gas from the coking of a previous charge of coal, and heated air, burning the said gas and heated air in contact with said coal, whereby the volatile matter of said coal is distilled therefrom and the said coal converted into coke, charging a second portion of coal onto the coke from the first charge of coal, when the first charge has been coked to the desired degree, whereby the coke from the first charge is removed from the direct action of the flame of burning gas, partially quenching the said coke by contacting therewith the combustion gases from said flame and the distillation gases from the succeeding charges of coal, the mass of coke that is contacted with the said gases at any time being such that the major portion of the carbon dioxid and the major portion of the water vapor of the said gases are converted by the incandescent carbon of the coke to carbon monoxid and free hydrogen, and heavy hydrocarbon vapors of the distillation gases are also dissociated into permanent gases of lower molecular weight, withdrawing the gases resulting from the contact of the combustion and distillation gases and the coke from contact with the latter, withdrawing the partially quenched coke from the coking chamber onto a bed of coke on a grate in a quenching chamber, spraying water onto the lower part of said bed of coke, contacting the water vapor so formed in the lower part of said bed of coke with the hot coke in the superincumbent layers, whereby more or less of such water vapor reacts with a portion of the carbon of said coke to form combustible gas, withdrawing the combustible gases formed from the reactions between the combustion and distillation gases and the coke and the water vapor and the coke from the coke oven and passing them through a recuperator whereby the major portion of the sensible heat of such gases is transferred to the current of air supplied to said coking chamber to support the combustion therein, returning to said coking chamber a portion

of the combustible gases after they have passed through said recuperator, withdrawing the quenched coke from said fuel bed, and charging a fresh portion of coal onto the top of said fuel bed, all substantially as described.

7. The process of carbonizing coal and producing gas which comprises subjecting the coal in an inclosed chamber to the direct action of a flame of burning gas to carbonize said coal, passing the products of combustion from said flame in contact with a mass of previously formed carbonized coal in said chamber, spraying the carbonized coal with water, after the said carbonized coal has been contacted with the products of combustion from said flame, withdrawing from the inclosed chamber the gases resulting from the contact of the combustion gases and the hot coke and the water and hot coke, and withdrawing the quenched coke itself, substantially as described.

8. The process of carbonizing coal and producing gas which comprises charging the said slack coal onto a column of previously formed carbonized coal in an inclosed chamber, subjecting the said coal to the direct action of a flame of burning gas, the gases of said flame being under sufficient pressure to insure their penetrating of the layer of freshly charged slack coal, conducting the combustion gases from said flame through the said column of carbonized coal, withdrawing from contact with the carbonized coal the gases resulting from the reaction of the carbon of the same and the said combustion gases, spraying the lower portion of the column of carbonized coal with water, whereby the carbonized coal in the said lower portion of the chamber is quenched and the said water vaporized, conducting the so-formed water vapor through a portion of the superincumbent column of carbonized coal and withdrawing the gases formed by the contact of the said carbonized coal and water vapor and the contact between the carbonized coal of the upper portion of said column and the combustion gases from said inclosed chamber, substantially as described.

9. The process of carbonizing coal and producing gas which comprises subjecting the said slack coal in an inclosed chamber to the direct action of a flame of gas burning above the surface of the coal bed, the gases of said flame being under sufficient pressure to insure their penetration of said mass of slack coal, passing the combustion gases from said flame in contact with a body of previously formed carbonized fuel, and withdrawing the finished carbonized fuel and the gases produced by the said operations from the inclosed chamber, substantially as described.

10. The process of coking coal and producing gas which comprises charging the slack coal onto a mass of coke from previously coked slack in an inclosed chamber, introducing under pressure into the top of said chamber above the surface of the slack coal a current of combustible gas and a current of air, whereby the said slack coal is subjected to the direct action of a flame of burning gas, conducting the combustion gases from said flame through the upper portion of said mass of coke, spraying the lower portion of said mass of coke with water, whereby the said water is partly vaporized, conducting the so-formed water vapor and the residual liquid water through the lower portion of said mass of coke, and withdrawing the quenched coke and the gases formed by said operations from the inclosed chamber, substantially as described.

11. The process of coking coal and producing gas which comprises repeatedly charging portions of said slack onto a column of ignited coke maintained in an inclosed chamber, introducing under pressure above the surface of the freshly charged slack, preheated air and a portion of the gas previously withdrawn from said inclosed chamber, the pressure under which the said fluids are introduced being sufficient to insure the penetration of the charge of fresh slack by the flame of burning gas, conducting the combustion gases from said flame through the upper portion of said column of coke, contacting the lower layers of said column with misted water, whereby a portion of said water is vaporized in contact with said lower layers, conducting the water vapor bearing the residue of the misted water through the portion of the said coke column superincumbent to said lower layers, whereby the residue of said water is also converted into vapor and the water vapor caused to react to a greater or less extent with the hot coke to form principally carbon monoxid and hydrogen, continuously withdrawing from an intermediate level of said coke column the gases formed therein, and repeatedly withdrawing portions of the quenched coke from the bottom of said column, substantially as described.

12. The process of carbonizing coal and producing gas which comprises maintaining a body of fuel in an inclosed chamber, maintaining a flame of burning gas in contact with the surface of said fuel body to carbonize said fuel, passing the products of combustion from said flame in contact with a mass of previously formed carbonized fuel in said chamber, whereby carbon dioxid of said combustion products is caused to react with a portion of the carbon of said carbonized fuel, advancing said fuel body through said chamber at a rate materially greater than the rate of consumption of said fuel therein, spraying the carbonized fuel advanced beyond the combustion re-

gion of said chamber with water, to cool said fuel, to vaporize said water, and to form water gas, withdrawing from said chamber the gases resulting from the contact of the combustion gases with the carbonized fuel and the gases resulting from the contact of the water and carbonized fuel, and withdrawing the quenched coke.

Signed at New York city, in the county of New York and State of New York, this 21st day of June 1909.

HENRY L. DOHERTY.

Witnesses:
FRED B. MULCOX,
THOS. I. CARTER.