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MANUFACTURE OF COKE AND COMBUSTIBLE GAS AND APPARATUS THEREFOR

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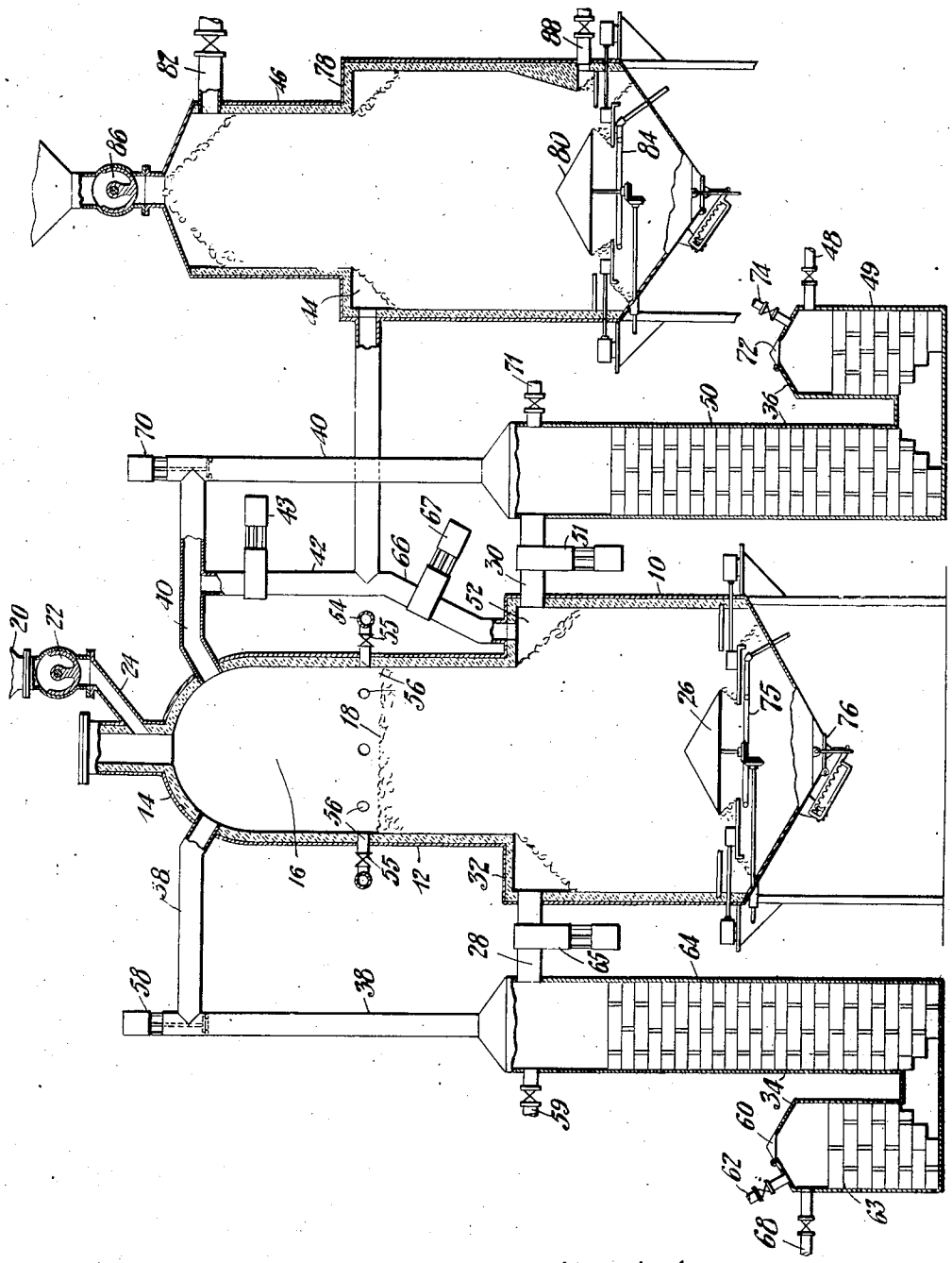

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MANUFACTURE OF COKE AND COMBUSTIBLE GAS AND APPARATUS THEREFOR

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This invention relates to the manufacture of coke and combustible gas, and more particularly to an improved method of and apparatus for making enriched water gas and high grade coke from caking bituminous coal.

Several processes for making high quality fuel gas have been developed in which the calorific value of a low B. t. u. gas, such as producer gas, blast furnace gas or water gas, is raised by passing the gas from its generator through a previously heated "carbonization preheater" to be superheated and thence in direct heat transferring relationship with a bed of bituminous fuel to carbonize the fuel and carry off the volatile components distilled from the fuel for its enrichment. It is necessary to impart a high degree of superheat to the current of low B. t. u. gas in order to effect the carbonization of the raw fuel. According to the above processes the preheat of the gas is supplied by at intervals alternating the gas superheating and fuel carbonizing operation with a heat regenerating operation during which the temperature of the "carbonization preheater" is elevated by burning exhaust blast gases or other low B. t. u. gases therein. When water gas is employed as a heating and carbonizing medium, by which bituminous fuel is carbonized and its volatile components are driven off, the primary blast gases produced in the water gas generator during periods of air blasting are burned in the preheater, and between periods of air blasting the make gas is passed through the highly heated preheater and thence through the bed of bituminous fuel in the carbonizing shell.

The primary object of the present invention is to provide an improved method and apparatus of the type above referred to by which large yields of high quality fuel gas and high grade coke can be simply, economically and effectively manufactured from caking bituminous coal.

Another object of the invention is to reduce the number of pieces of apparatus from that normally employed and the loss of heat normally resulting from radiation to the atmosphere when water gas is employed as the sole heat transferring medium for carbonizing bituminous fuel.

In accordance with these objects one feature of the invention contemplates discontinuing the use of a "carbonization preheater" as employed in the above described processes, and passing the gas "carbonizing medium" directly from the gas generator into a bed of fuel to be carbonized.

Another object of the present invention is to provide a method and apparatus by means of which water gas can be effectively and economically manufactured and enriched with the volattile products of carbonization of bituminous caking coal.

In accordance with this object another feature of the invention contemplates using the sensible heat carried by water gas and the potential heat carried by primary blast gases at the time they leave the bed of fuel in the water gas generator to impart sufficient superheat to the water gas to make it effective as the sole heating medium for carbonizing bituminous fuel and driving off volatile hydrocarbons therefrom for its enrichment.

Another object of the invention is to provide a method and apparatus by means of which the enrichment of water gas with the volatile products of fuel carbonization can be carried out with a more efficient utilization of heat.

Accordingly, another feature of the invention contemplates burning blast gases with secondary air as they leave the top of the fuel bed in the water gas generator, storing the heat liberated by the secondary combustion as radiant energy within the generator and fuel bed, and utilizing the heat thus stored to impart superheat to the water gas within the generator and immediately before it enters the bed of raw bituminous fuel in the carbonizing shell.

With these and other objects and features in view the invention consists essentially in the improved method of and apparatus for making enriched water gas and high quality coke hereinafter described and particularly defined in the claims.

The various features of the invention are illustrated in the accompanying drawing,

which shows in vertical section the arrangement of apparatus embodying the preferred form of the invention.

In the apparatus illustrated in the drawing 10 represents a water gas generator of the Doherty shaft type equipped with a refractory lining 12 and a superimposed radiation arch or dome 14. The arch 14 is raised above the normal fuel charging level of the generator to form a combustion chamber 16 beneath the roof of the generator and above the normal top layers 18 of the charge. Fuel is charged into the generator from a hopper 20 through a charging gate 22 and a charging neck 24. A movably mounted discharge mechanism 26 in the lower portion of the shaft serves to support the charge in a column and to discharge unconsumed fuel and ash from the base of the column. Conduits 28 and 30 connect the interior of the generator at a point immediately beneath a circumferential arch or rackback 32 to corresponding sets of compound regenerator units 34 and 36. Other conduits 38 and 40 lead from the tops of the respective regenerators 34 and 36 into the top of the generator 10 and combustion chamber 16. A gas main 42 comprises the chief conduit for conducting superheated make gases from the top of the generator into a circumferential passage 44, which surrounds a column of raw bituminous fuel in the carbonizing shell 46.

The method of manufacturing high quality fuel gas and high grade coke which comprises the preferred form of the present invention is carried out in the apparatus illustrated in the drawing substantially as follows: Primary air is admitted periodically through a valved inlet 48 into the top of an auxiliary chamber 49 of the regenerator unit 36, the regenerator unit having been first preheated by the combustion of blow gases therein. As the primary air passes downwardly through the hot checker brick lining of the auxiliary chamber and upwardly through the lining of a primary chamber 50, it absorbs preheat from the hot lining of the regenerator chambers, and is then passed by hot valve 51 through conduit 30 into a circumferential inlet 52 in the generator 10. The circumferential inlet 52 is formed beneath rackback 32 and between the lining of the generator and the expanding surface of the column of fuel advancing therethrough. After entering the fuel bed through the inlet 52 the preheated air rises upwardly through the column and as it reacts with the carbon of the fuel to produce low B. t. u. or primary blast gases, the temperature of the fuel bed adjacent the circumferential blast inlet 52 is rapidly raised to incandescence. Secondary air, with or without preheat, is simultaneously admitted to the generator from a distributor 54, through valves 55 and a number of circumferentially placed nozzles 56, the volume of secondary air admitted being regulated by valves 55 to either partially or completely consume the current of primary blast gases rising through the top of the fuel bed into the combustion chamber 16. Heat liberated by the combustion of these primary blast gases is projected by the refractory roof and walls of the chamber 16 as radiant energy downwardly into the upper layers of the fuel bed, wherein it is stored to be subsequently utilized during the next gas making run. The products of secondary combustion exit from the top of the combustion chamber through conduit 38 and are passed by hot valve 58 into and through the checker brick linings of the two sections of regenerator unit 34. Any of the primary blast gases which are unconsumed at the time they leave the combustion chamber 16 are burned by admitting a regulated volume of secondary air into the top of the regenerator 34 through a valved inlet 59. The checker brick lining of the regenerator unit absorbs the sensible heat of these products of secondary combustion, and accordingly they are exhausted through stack valve 60 at a relatively low temperature.

After the temperature of the fuel bed has been raised sufficiently to support water gas reactions, blast air entering through inlet 48 is cut off and the air blow is followed by a gas making run during which water or steam is admitted through a valved inlet 62 into the auxiliary chamber 63 of the regenerator unit 34, which has just been previously heated by the exhaust blast gases. Any water admitted through the inlet 62 is rapidly vaporized by absorption of heat from the hot checker brick lining and as the steam thus produced passes downwardly through chamber 63 and upwardly through a primary chamber 64 of the regenerator unit 34 it absorbs superheat from the hot checker brick lining of the two chambers. The superheated steam is then passed into the generator and fuel bed either by a hot valve 65 in the conduit 28, or by hot valve 58 in the conduit 38. When hot valve 58 is opened and hot valve 65 is closed, steam enters the generator at the top of the combustion chamber 16 and the manufacture of water gas is conducted on a "down run." When valve 58 is closed and valve 65 is opened the steam enters the fuel bed at the base of the incandescent zone, and the gas making run resembles the "up run" of normal practice. The gas making run may be varied by at intervals changing the direction of flow of the steam through the upper portion of the fuel bed. During the period in which steam is admitted into the generator through conduit 28 and the circumferential passage 52, i. e. the "up-run" period, the water gas thereby made rises through the hot upper layers of the fuel bed into combustion chamber 16 and consequently takes on a high degree of superheat by ab-

sorption of heat stored as radiant energy in the hot walls of the chamber and in the top layers of the fuel bed. This "up-run" water gas leaves the top of the generator through conduit 42, and is passed by a hot valve 43 directly into the circumferential passage 44 in the carbonizing shell 46. During this "up-run" hot valve 58 in conduit 38 is closed. During the "down-run" hot valve 58 is opened, hot valve 65 in conduit 28 is closed, and the make gases are withdrawn through circumferential passage 52 and are passed by hot valve 67 and conduit 66 into the circumferential passage 44 in the carbonizing shell. During the period in which steam is passed into the top of the generator through conduit 38 and combustion chamber 16 it takes on additional superheat and is substantially completely decomposed by absorption of radiant heat from the top layers of the fuel bed and from the walls and roof of the combustion chamber before it enters the blast zone. Accordingly, larger volumes of water gas can be produced during the "down run" and this "down run" gas leaves the fuel bed in a substantially dry condition and generally carries sufficient superheat to carbonize a proportionate amount of fuel in the carbonizing shell.

After the temperature of the fuel bed has been lowered below that at which the water gas reaction proceeds effectively the steam is cut off at inlet 62 and the gas making run is followed by another air blow during which air is admitted through a valved inlet 68 at the top of the auxiliary chamber 63 of the regenerator 34, such regenerator having served during the make cycle for imparting superheat to the make steam. During this blow the blast air and primary blast gases pass through the apparatus in the reverse direction to that taken by the air and blast gases during the preceding blow, and accordingly the waste blast gas products of the secondary combustion in combustion chamber 16 during this cycle exit from the generator through conduit 40 and are passed by a hot valve 70 into and through the checker brick linings of the regenerator unit 36. Sufficient secondary air is admitted through a valved inlet 71 in regenerator 36 to complete combustion of any unburned gases, and during the passage of the products of combustion through the linings of chamber 50 and chamber 49 substantially all the sensible heat of these waste gases is taken up by the checkerbrick and they exit through stack valve 72 at the top of the auxiliary chamber 49 at a relatively low temperature.

After the temperature of the fuel bed has again been raised to incandescence by the blow cycle just described the air is cut off at inlet 68 and during the next gas making run water or steam is admitted through a valved inlet 74 into the top of the auxiliary chamber 49 of regenerator unit 36. The superheated steam enters the generator during the down run through conduit 40 and during the up runs through the conduit 30. During the up runs valve 51 will be opened and valve 70 will be closed. Likewise during the down run valve 70 will be opened and valve 51 will be closed. The superheated water gas produced during the down runs is passed by hot valve 67 through conduit 66 into the carbonizing shell, and the gas produced during the up runs is passed by valve 43 through conduit 42 into inlet 44 in the carbonizing shell.

Regenerators 34 and 36 are equipped with air and steam inlets and auxiliary gas conduits as shown by means of which they can be used alternately for preheating blast air, for regenerating the sensible heat of the waste blast gases and for generating and superheating the make steam. Each of the air and steam inlets and the various gas connections to the regenerators is equipped with valves by means of which the direction of flow of air, steam and other gases through the entire apparatus can be periodically reversed. Likewise the generator 10 is equipped with valved offtakes by means of which the direction of flow of make steam through the fuel bed can be periodically reversed to produce "up-run" or "down-run" water gas. Hot valves 51 in conduit 30, 70 in conduit 40, 58 in conduit 38 and 65 in conduit 28 afford the means of controlling the admission of steam from the two sets of regenerator units into the upper or lower portions of the generator, and these valves also afford the means of admitting blast air from the regenerator units into the generator and for removing waste blast gases from the generator into the regenerator units.

According to the preferred method of operation above described fuel is advanced through generator 10 continuously at about the rate at which it is consumed by the air and steam admitted during the periods of air blowing and gas making. The fuel may be admitted at regular intervals, but it is preferably charged only during the gas making runs, in order that any volatile components which are rapidly liberated at the time the raw fuel strikes the hot upper layers of the fuel bed, may be carried off by the make gases as enriching agents and their valuable qualities thereby utilized rather than lost, as would would be the case if they are liberated and removed by the primary blast gases during periods of air blasting. The mixture of ash, clinker and any unconsumed fuel which passes the high temperature gasification zone of the generator is expanded into an enlarged chamber below the rack-back 32, wherein it is cooled and quenched by a current of steam or other heat transferring gas before being removed from the base of the charge by discharge mechanism 26. Steam

for cooling the charge is admitted through an inlet and distributing coil 75 below the discharge mechanism, and waste material such as ash and clinker which has been discharged from the base of the fuel bed is removed at intervals from the bottom of the generator through a sealed discharge door 76.

Although the water gas produced in the regenerator during "down-runs" does not receive a subsequent superheating treatment such as that imparted to the "up-run" gas, it it nevertheless carries a relatively high degree of superheat by reason of the fact that the make steam admitted at the top of the combustion chamber 16 during the "down-run" absorbs a much higher degree of superheat and enters the fuel much more completely decomposed than does the make steam admitted through circumferential inlet 52 during the "up-run." The water gas which enters the carbonizing shell 46 during both the up-and down-runs carries a sufficient degree of superheat to make it very effective as the sole agent for carbonizing charges of coking bituminous coal.

After leaving the gas generator the superheated water gas enters the fuel bed in the carbonizing shell through the circumferential passage 44 and beneath a rackback 78 which resembles in its construction the rackback 32 in the gas generator. A charge of bituminous fuel such as coal and the like which is to be carbonized and the volatile components of which are to serve as enriching agents for increasing the calorific value of water gas produced in the generator, is supported in the carbonizing shell in a column by means of a discharge mechanism 80, mounted in the base of shaft 46. This charge of fuel may be either held in a stationary position during its carbonization or may be continuously advanced through the shaft at about the rate at which its carbonization is completed. In either case the superheated water gas produced in the generator enters the column of fuel at about its mid portion, and where the fuel is advanced continuously through the carbonizing shaft, the superheated gas entering through inlet 44 is allowed to rise and distribute itself through each cross section of the downwardly advancing column. The temperature of the gas gradually drops as it rises, by direct heat transfer with the cooler portion of the freshly charged fuel adjacent the top of shaft, and at the time the current of water gas leaves the top of the carbonizing shell through an offtake pipe 82, its temperature as well as the temperature of the volatile constituents distilled from the fuel and carried along in the gas current, has been reduced to a relatively low point (rarely exceeding 500° F.). The mixture of water gas and volatile components distilled from the fuel is preferably passed from offtake 82 directly to condensing and scrubbing apparatus (not shown).

No air is admitted into the carbonizing shell during the carbonization of the fuel, and accordingly the temperatures which are maintained in that portion of the bed of fuel adjacent the circumferential inlet 44, while higher than those in any other portion of the shell, are nevertheless much lower than the temperatures which are normally maintained in the air blast zone of the gas generator. As a result of these relatively low temperatures the volatile components distilled from the bituminous fuel and carried out of the shaft by the water gas carbonizing medium are never subjected to temperatures much in excess of those at which they are liberated from the fuel. Consequently they undergo little decomposition and the portions precipitated in condensing and scrubbing the gas are the very finest grade of primary tar oils. When the fuel is advanced through the carbonizing shell at about the rate at which its carbonization is completed, the carbonized fuel (coke) which has advanced beyond the rackback 78 is gradually expanded into an enlarged chamber below the inlet 44, and the coke in this chamber is gradually cooled by heat transfer with a counter-current circuit of steam or other cooling gas introduced at the base of the shaft through an inlet and distributing coil 84. Coke is continually discharged from the base of the column by the operation of the discharge mechanism 80, and at the same time fresh fuel is admitted in small portions to the top of the shell by a charging gate 86.

The present process is not necessarily limited to the use of a gas generator, carbonizing shell, and auxiliary preheaters and regenerators of the type illustrated and described, although the arrangement described and illustrated embodies the preferred form of apparatus. The standard type of water gas generator can be adapted with slight alteration to serve the purpose of the invention admirably, both as a gas generator and as a fuel carbonizing shell. Thus by raising the top of the standard generator and installing secondary air inlets above the normal fuel charging level as particularly described in my co-pending application, on the manufacture of water gas, Serial No. 5,245 filed January 28, 1925, the altered generator would function in much the same way as the more specialized type of Doherty shaft generator illustrated and described as the preferred form. The standard type of generator will serve without any substantial alteration as a fuel carbonizing-shell.

As previously indicated, it is not essential that fuel be passed continuously through the carbonizing shell, and in operations directed primarily to the manufacture of high grade coke and primary tar oils it is often advantageous to hold the charge of bituminous fuel

in the carbonizing shell in a stationary position during the period in which it is undergoing distillation by heat transfer with the current of superheated water gas.

In operations where the fuel undergoing carbonization is maintained stationary, it is often advantageous to pass all or a portion of the superheated gas carbonizing medium downwardly through the column of fuel and to remove the gas and volatile products of fuel carbonization from the lower portion of the shell through an auxiliary gas offtake 88. By conducting the fuel carbonization in this manner the bed of fuel serves much more efficiently as a screen for removing dust from the current of water gas and the water gas drives ahead of it heavy tar oils which have a tendency to condense out of the heating gas current as the gas cools and which in normal "up-run" operations sometimes obstruct the flow of heating gas through the fuel body. The principal advantage in holding the fuel in a stationary position during carbonization is of course that the coke produced is not broken up and disintegrated to the extent that it is in cases where it is advanced continuously through the carbonizing shell, so that the yield of high grade coke is large and the volume of fines or breeze produced is correspondingly small.

One of the chief advantages of the present invention is that the primary blast gases produced in the generator are burned and a large proportion of their potential heat is liberated and stored within the generator and fuel bed at a point where it is immediately available for superheating the make gases and supporting complete decomposition of make steam. As a result the make water gas is superheated before it leaves the generator and there is substantially no loss of sensible heat from the make gases and from the blow gases by radiation to the surrounding atmosphere. By passing the waste blast gases through the preheaters or regenerators 34 and 36 substantially all of the potential heat of the primary blast gases is recovered, and can be subsequently returned to the generator in the form of preheated blast air and superheated make steam. Thus the combination of "radiation arch generator" and carbonizing shell, with auxiliary preheaters or regenerators such as those described, gives an apparatus by means of which the manufacture of high quality fuel gas, i. e., enriched water gas, high grade coke and primary tar oils, can be carried on very economically, with an extremely high thermal efficiency, and on a substantially balanced thermal cycle.

It is apparent that the degree of superheat imparted to the water gas carbonizing medium, the degree to which fuel in the carbonizing shell is coked, the degree to which the make steam is decomposed, and the degree to which the water gas is enriched with volatile hydrocarbons may all be regulated by controlling the volume of secondary air entering the top of the gas generator through valves 55 and nostrils 56. Likewise, these several operations may be regulated by controlling the rate at which the superheated water gas is passed through the bed of fuel in the carbonizing shell and by controlling the rate at which the fuel is advanced through the shell.

While the invention is directed primarily to the production of high quality fuel gas and high grade coke, together with primary by-products, and consequently bituminous coal is the preferred fuel, the process and apparatus may be adapted with minor alterations to the treatment of anthracite coal, lignite, peat and oil shales.

By using two or more gas generators such as those described, equipped with radiation arch combustion chambers and auxiliary preheaters, in combination with one or more fuel carbonizing units, it is possible to carry on a continuous fuel carbonizing and gas enriching operation. Thus where two generators are employed they can be operated alternately on gas making runs and on air blast cycles to maintain a continuous flow of superheated water gas through the bed of fuel in the carbonizing shell.

Having thus described my invention, what I claim as new is:

1. The method of making high quality fuel gas and coke which comprises passing air and steam alternately through a bed of highly heated, solid carbonaceous fuel in a water gas generator to produce blow gases and water gas in turn, introducing secondary air into the generator immediately above the fuel bed and thereby burning the blow gases therein, superheating the said water gas within the generator by absorption of heat liberated as radiant energy from the combustion of the blow gases, and passing the superheated water gas from the generator in direct heat transferring relationship through a body of bituminous fuel in a carbonizing shell thereby carbonizing the bituminous fuel and carrying off its volatile components.

2. The method of producing high quality fuel gas and coke which comprises blasting a bed of highly heated, solid carbonaceous fuel alternately with primary air and superheated steam thereby generating blow gases and water gas in turn, introducing secondary air into the generator above the fuel bed and thereby burning the blow gases, projecting heat thus liberated as radiant energy into the upper layers of the fuel bed, passing water gas through the upper layers of the fuel bed to absorb superheat therefrom, and conducting the superheated water gas into and through a body of coking bituminous coal thus carbonizing the coal and enriching

the water gas with volatile hydrocarbons distilled therefrom.

3. The method of producing high quality fuel gas and coke which comprises passing air and steam alternately through a bed of highly heated, solid carbonaceous fuel in a water gas generator thereby producing water gas and blow gases in turn, introducing secondary air into the generator and thereby burning the blow gases, projecting heat liberated by their combustion as radiant energy into the top of the generator and the upper layers of the fuel bed, passing water gas through the upper layers of the fuel bed to absorb superheat therefrom, and passing the superheated water gas in direct heat transferring relationship with a body of solid bituminous fuel in a carbonizing shell thereby carbonizing the bituminous fuel and enriching the water gas with volatile hydrocarbons distilled therefrom.

4. The method of producing high quality fuel gas and coke which comprises periodically introducing primary air peripherally into the mid-portion of a bed of highly heated, solid carbonaceous fuel in a water gas generator, introducing secondary air into the generator above the fuel bed and thereby burning the primary blast gases, regenerating heat liberated by combustion of blow gases in the upper layers of the fuel bed and in preheaters during passage therethrough, passing steam in a reverse direction through the preheaters to absorb superheat and thence longitudinally through the fuel bed to generate water gas, passing the water gas through the upper layers of the fuel bed to absorb superheat, and passing a current of the superheated water gas into and through a bed of coking bituminous coal in a carbonizing shell thus carbonizing the coal and driving off volatile components distilled therefrom.

5. The method of producing combustible gas and coke which comprises passing primary air and superheated steam alternately through the upper portion of a bed of highly heated, solid carbonaceous fuel in a shaft water gas generator, introducing secondary air into the generator above the fuel bed and thereby burning the blow gases, projecting heat liberated by the combustion of the blow gases into the upper layers of the fuel bed as radiant energy, regenerating the sensible heat of the products of combustion in preheaters and subsequently passing blast air and make steam through the preheaters to absorb superheat, passing the make steam through the upper layers of the fuel bed to absorb further superheat and to produce superheated water gas, and passing the superheated water gas through a body of solid carbonizable fuel in a carbonizing shell thereby carbonizing the carbonizable fuel and enriching the gas with volatile hydrocarbons distilled therefrom.

6. The method of producing high quality fuel gas and coke which comprises blasting a bed of highly heated, solid carbonaceous fuel in a water gas generator provided with a radiation arch alternately with primary air and superheated steam thereby forming blow gases and water gas in turn, introducing secondary air into the upper portion of the generator thereby burning the blow gases, passing the make gases from the steam blast through the upper portion of the generator and fuel bed to superheat the gases by absorption of radiant heat liberated from the combustion of the blow gases and from superheated water gas, passing the superheated water gas through a bed of bituminous fuel in a carbonizing shell thereby carbonizing the bituminous fuel and enriching the gas with its volatile components, and controlling the degree to which fuel is carbonized and gas is enriched in the carbonizing shell by regulating the volume of secondary air admitted into the radiation arch generator during periods of air blasting.

7. The method of producing combustible gas and coke which comprises periodically basting primary air into the midportion of a bed of highly heated, solid carbonaceous fuel in a water gas generator thereby producing blast gases, introducing secondary air into the generator above the fuel bed and thereby burning the primary blast gases, regenerating heat liberated by combustion of the blast gases in the upper portion of the generator and fuel bed and in preheaters during passage therethrough, passing steam in a reverse direction through the preheaters and thence through the upper portion of the generator and into the fuel bed to absorb superheat and decompose the steam, passing the resultant superheated gaseous mixture through the said mid-portion of the fuel bed to generate water gas, and passing a current of the superheated water gas directly into and through a bed of bituminous fuel in a carbonizing shell, thus carbonizing the bituminous fuel and enriching the gas with volatile components distilled therefrom.

8. An apparatus for making enriched water gas and coke comprising a gas generator and a carbonizing shell connected in series for functional co-operation, a radiation arch combustion chamber in the upper part of said generator, fuel charging devices at the top of the generator and carbonizing shell and fuel discharging devices mounted in the base of each, a pair of preheaters, means connecting the preheaters and a circumferential blast inlet in the mid-portion of the generator, similar means connecting the preheaters and gas offtakes at the top of the generator, valves in these connections for controlling the introduction of preheated blast air and

superheated make steam from the preheaters respectively into the mid-portion of the generator and into the top thereof and for regulating the removal of primary blast gases and products of combustion from the generator through the preheaters, secondary air inlets in the upper portion of the generator, valves for controlling the admission of secondary air into the generator through these inlets to burn a regulated amount of blow gases in the radiation arch combustion chamber, and means for conducting water gas produced in the generator and superheated in the upper portion of the generator into and through the carbonizing shell.

9. An apparatus for making combustible gas and coke comprising a water gas generator having a circumferential blast inlet in its mid-portion, means for introducing preheated blast air and superheated steam alternately into the generator through said inlet, an inlet for secondary air in the upper portion of the generator, means for controlling the combustion of primary blast gases with secondary air admitted through said inlets, a radiation arch at the top of the generator arranged to project heat liberated by the combustion of the blow gas as radiant energy downwardly in said generator, preheaters and means connecting the latter with a circumferential blast inlet in the mid-portion of the generator, the said preheaters being adapted for regenerating sensible heat from the products of secondary combustion, and means for conducting water gas through the generator to absorb superheat and thence into and through a carbonizing shell to carbonize the fuel and drive off its volatile components.

10. An apparatus for making high quality fuel gas and coke which comprises a water gas generator and a fuel carbonizing shell, a radiation arch combustion chamber at the top of the gas generator, means for introducing secondary air into the combustion chamber to burn blow gases produced during periods of air blowing, and means for passing water gas upwardly in said generator and combustion chamber to absorb radiant heat liberated by combustion of the blow gases and thence into and through the carbonizing shell, means for removing enriched water gas from the top of the carbonizing shell, and means for discharging coke from the base of the shell.

11. An apparatus for making high quality fuel gas and coke comprising a gas generator having a radiation arch combustion chamber at its top, a fuel carbonizing shell, blast air and make steam inlets in the lower portion of the generator and a secondary air inlet in the upper part of the generator but substantially below the radiation arch therein, regenerators connected to the blast air and make steam inlets and to exhaust gas offtakes in the top of the generator, valves in the blast inlets and gas offtakes for reversing the direction of flow of blast air, steam, and waste blast gases through the regenerators and generator, and means for conducting superheated water gas from the gas generator directly into and through a bed of fuel in the carbonizing shell.

12. An apparatus for making combustible gas comprising a water gas generator and a fuel carbonizing shell, a radiation arch combustion chamber at the top of the gas generator, means in the lower portion of the combustion chamber for introducing secondary air therein to burn blow gases produced in the generator during periods of air blowing, means for introducing steam into the top of the combustion chamber to absorb radiant heat liberated by combustion of the blow gases, means for conducting the thus superheated steam downwardly through the gas generator to generate water gas, means for passing the superheated water gas directly from the generator into and through the carbonizing shell, and means for controlling the degree to which steam is superheated and decomposed and the degree of superheat imparted to water gas in the gas generator.

13. The method of producing high quality fuel gas and coke which comprises the steps of passing air through a column of highly heated, solid carbonaceous fuel in a water gas generator thereby producing blow gases, introducing secondary air into the generator immediately adjacent the surface of the fuel bed and thereby burning the blow gases and radiating heat to the generator and the fuel bed, thereafter passing steam through the said bed of fuel to produce water gas, superheating the water gas by absorption of the said radiated heat from the generator and fuel bed, at intervals changing the direction of flow of the steam passing through a portion of the said fuel bed, and passing the superheated water gas from the generator in direct heat exchange relationship with a body of bituminous fuel in a carbonizing shell thus carbonizing the bituminous fuel and carrying off its volatile components.

14. The method of producing high quality fuel gas and coke from solid carbonizable material, which comprises providing a mass of said material and a mass of solid carbonaceous fuel in separate chambers, inducing combustion in said fuel, thereby heating it to incandescence, passing steam through the incandescent mass for making water gas, superheating the water gas, passing the superheated water gas through said material thus carbonizing the same, and controlling the direction of flow of the superheated water gas through the last-named mass.

15. The method of producing high quality fuel gas and coke from solid carbonizable material, which comprises superheating water gas, and continuously passing the super-

heated water gas through a moving mass of the said material in a carbonizing shell, thereby carbonizing the mass, and controlling the direction of flow of the superheated water gas through the said mass during such carbonization.

In testimony whereof I affix my signature.

ALFRED JOHNSON.