

May 5, 1942.

M. W. DITTO ET AL
FUEL GAS PRODUCTION

2,281,562

Filed Dec. 15, 1939

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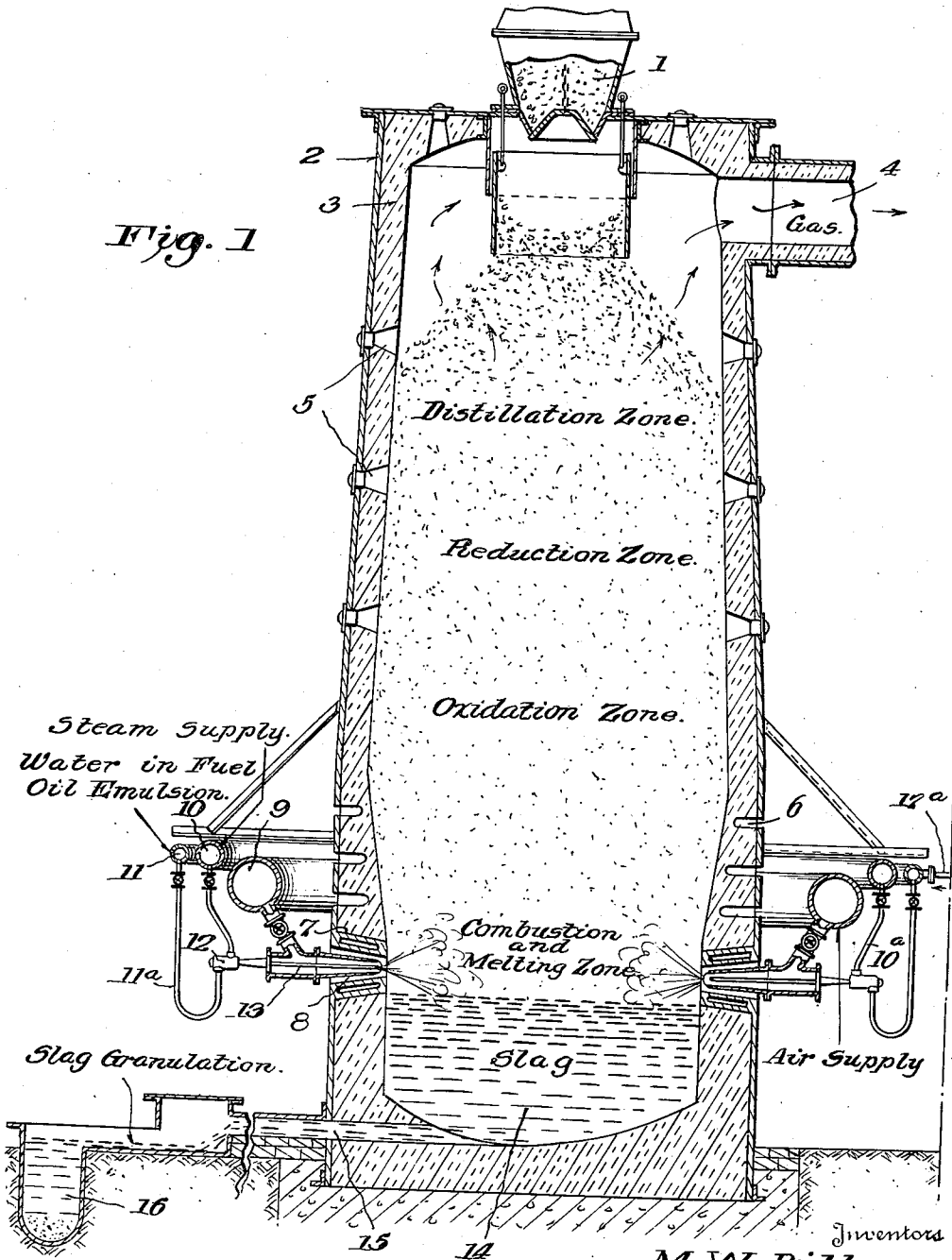


Fig. 1

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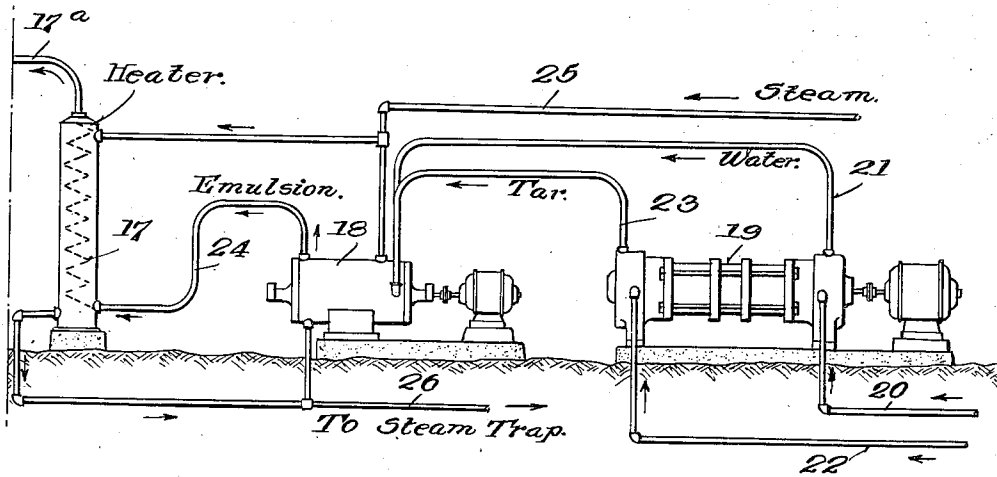
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2 Sheets-Sheet 2

Fig. 2



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UNITED STATES PATENT OFFICE

2,281,562

FUEL GAS PRODUCTION

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Application December 15, 1939, Serial No. 309,504

13 Claims. (Cl. 48—200)

This invention relates to the production of gas and more particularly to the production of combustible gas such as used in metallurgical plants for heating purposes in open hearth furnaces, soaking pits, etc.

One of the objects of the invention is to provide an improved method of producing gas having a high calorific value by the operation of a slag type producer. Slagging type producers are well known but it has been impractical to operate them with the addition of steam because of the high demand for heat made upon the incandescent zone, as the steam causes rapid cooling and therefore retardation or cessation of the slagging. In accordance with our invention an emulsified liquid fuel is injected into the incandescent zone of the producer, such fuel having sufficient water incorporated therein to supply the oxygen-hydrogen demand when combined with the steam used for atomization. Due to the heat generated by the combustion of the emulsified fuel, we can meet the extra thermal demand necessary for the reaction of steam with the incandescent charge. This permits a higher rate of gasification of the coal and the use of any other suitable solid carbonaceous material such as coke, anthracite coal, bituminous or sub-bituminous coal, as the method operates regardless of the fusion point of the ash derived from such material because sufficient heat is generated to liquefy the ash and to allow the ash and clinker-forming material to be discharged as liquid slag. It will therefore be understood that it is another object of the invention to supply a method by which higher calorific gas may be manufactured partially from relatively cheap substantially solid carbonaceous materials.

A further object is to furnish a method for producing combustible gases in slagging ash producers by utilizing residual tar or its equivalent in combination with solid carbonaceous material.

Other objects of the invention will appear from the following description taken in connection with the accompanying drawings in which:

Fig. 1 is a vertical sectional view partly in elevation of a gas producer in accordance with our invention.

Fig. 2 is a side elevation of an apparatus employed in manufacturing and preheating an emulsified liquid fuel, which is utilized in the producer.

Such apparatus will be described in conjunction with the method of operating the same. The coal or other suitable solid carbonaceous material, from which gases are to be obtained, is

introduced into the upper end of the producer through a charging apparatus 1 and a conventional seal and charging bell. The producer itself consists of a suitable steel shell 2 having a refractory lining 3 and an upper gas outlet 4. Conventional poke holes 5 are arranged in the shell and lining at various elevations. The producer has a Bosch angle similar to a blast furnace and behind which there are the Bosch coolers 6. Water-cooled tuyères 7 are radially disposed around the stack or tower below the Bosch angle to accommodate nozzles 8 which receive air under pressure from a bustle pipe 9. 10 designates a steam manifold and 11 an emulsified fuel manifold. 12 indicates a steam fuel mixing valve, and 13 a fuel nozzle extending from each mixing valve into one of the air nozzles. Valved tubes 10a convey steam from the manifold 10 to the mixing valves, and valved tubes 11a convey the emulsified fuel from the manifold 11 to such valves. 14 designates a slag crucible at the bottom of the stack; 15 a slag tap-hole; and 16 any suitable slag disposal means.

Referring now to Fig. 2, 17 designates an emulsified fuel heater from which the preheated fuel is conducted through a pipe 17a to the manifold 11.

18 designates an emulsification mill preferably of the type disclosed in the patent to M. W. Ditto, No. 2,169,338 or No. 2,169,339.

19 indicates a proportioning pump preferably at the type disclosed in the M. W. Ditto patent application Serial No. 230,480, filed September 17, 1938, as such pump is capable of simultaneously pumping water and oil and permitting the proportion of water to oil to be varied at any time, even during the operation of the pump. Water is introduced into one end of the pump through a pipe 20 and is forced from the latter under superatmospheric pressure through a pipe 21 into the emulsification mill. Residual tar or any other suitable fuel oil is introduced into the opposite end of the pump through a pipe 22 and is forced under pressure by the pump through a pipe 23 into the emulsification mill. The mill acts to finely disperse the water in the oil, and the resulting emulsion passes under pressure through a pipe 24 into the heater 17. The latter is of the heat exchange type and it, as well as the jacket of the dispersion mill, may be heated by steam introduced through a pipe 25 and discharged through a conduit 26.

Our producer is a refractory lined cylindrical structure approximately 25 feet in height, the bottom portion of which is a dolomite lined slag

crucible. Just above this crucible, which is approximately 3 feet in depth, are a series of tuyères and above this there is a slight Bosch angle similar to a blast furnace, to compensate for the reduction in volume of the coke after the coal has been carbonized. This oxidation zone, which is approximately 4 feet in height, is water cooled. Above this the furnace structure is straight and is equipped at the top with an automatic coal feeder. The gas off-take is situated at the top and side of the furnace structure. The air is introduced through tuyères at pressures ranging from 5 to 15 pounds per square inch and in the necessary quantity in order to gasify up to 200 pounds of coal per square foot of furnace area, at the Bosch line, per hour. The emulsion is introduced through the tuyères by means of special steam atomizing burners supplying enough steam beside the water contained in the emulsion to react with the carbon in the coal. Emulsified tar containing from 25 to 65% of water is introduced at the rate of from 10 to 100 gallons per ton of coal charged, depending on the amount of tar or fuel oil available and the desired calorific value of the gas.

In operation, coal or any suitable carbonaceous material is introduced into the top of the producer, and forms a column within the stack, the column being burned from the bottom up. After ignition is started in any suitable way, the material within the stack will form superposed zones which may be referred to as the slag zone, combustion and melting zone, oxidation zone, reduction zone and distillation zone, the last-mentioned zone being, of course, at the top of the column. While the combustion zone is in incandescent condition, hydrocarbon liquid and water in suitable proportions are forced by the pump 19 into the steam jacketed emulsifying mill 18 where a fine dispersion of the water in the oil takes place. The emulsion from the mill is passed through the heater 17 at a pressure of approximately 200 pounds per square inch, and at the time it leaves the heater it is at a temperature of about 260° F. The preheated emulsion is conducted from the heater through the manifold 11 which conducts it to the tubes 11a leading to the various mixing valves 12 which are distributed around the producer. In the mixing valves, the emulsion is thoroughly mixed with high pressure steam and discharges with the same through the nozzles 13 which introduce atomized emulsion into the blast air in the nozzles 8. Sufficient air is introduced through the tuyères to gasify approximately 200 pounds of coal per square foot of hearth area.

The amount of emulsified fuel or tar employed varies from 10 to 100 gallons per ton of coal gasified. The air introduced through the tuyères into the incandescent bed of devolatilized coal, rapidly raises the temperature within the combustion zone of the stack, as the oxygen in the air combines with the carbon of the fuel to form CO₂. The emulsion introduced with a large excess of air, combined with the high temperature of the combustion zone, causes rapid flame propagation, resulting in very rapid heat release. This tends to maintain an extremely high temperature in the combustion zone at the place where fusion of the ash takes place, and consequently the slag present in the crucible 14 is maintained in a liquid condition. Obviously the water and steam are highly superheated both from the combustion of the emulsion and the rapid oxidation of the carbon of the charge by

the air. The gaseous products of combustion and the water vapor pass up through the column of fuel until all the oxygen has reacted to form CO₂. As soon as there is no free oxygen present, reduction of C plus H₂O to CO plus H₂ starts, and the reaction of C plus CO₂ to 2CO takes place. Above the reduction zone, the high sensible heat of the gases causes distillation and partial carbonization of green coal in the absence of air, and the gaseous products of the distillation and partial decomposition mix with the rising gases to form the final gas which passes off through the discharge conduit 4.

The operation of the unit is so balanced that sufficient water vapor is derived from the water of the emulsion and the atomizing steam to amount to practically 0.4 to 1.5 pounds of water vapor per pound of coal gasified. This results in the production of gas having a higher calorific value with lower nitrogen dilution, because the sensible heat created within the producer is utilized through the endothermic reaction of the decomposition of the water vapor and the reduction of the CO₂ from the combustion of the emulsion to form CO. The decomposition of the water vapor takes place more efficiently than in ordinary producer practice because of the fact that the high rate of gasification results in high combustion temperatures plus the fact that combustion of the emulsion is so balanced to release sufficient heat that the endothermic demand to decompose the water vapor does not cool the ash, at the slag line, below its fusion point.

There are a number of grateless gas producers now in existence. In general they resemble a small blast furnace. As the air is introduced into such producers at relatively high pressures, very high gasification rates are possible. The rapid combustion rate makes it possible to fuse the ash, though ordinarily some fluxing material is introduced with the coal, such as blast furnace slag, sand, lime or the like. The gas produced by such grateless producers contains essentially CO and N₂ and is of low calorific value due to the nitrogen dilution, as it has not been found practical to use steam or water vapor with the blast air due to the fact that the high endothermic demand to decompose the water would interfere with the slagging of the ash.

It is recognized that a slagging ash producer can be operated to advantage on coals having low fusion ash as they tend to limit the rate at which ordinary producers can be operated but the objection to the operation of the slagging ash producers has been the low calorific value of the gas as a result of the operation without water vapor, combined with the fact that fluxing material must be added to the coal in order to cause efficient slagging of the ash. By our method of operation we eliminate these objections while also producing producer gas of higher calorific value. Besides we produced such gas while utilizing residual tar or other liquid hydrocarbons as fuel.

We have found in practice that the ignitibility and combustibility of emulsified fuel oils or tars even when saturated with as high as 65% water, is suitable for our purposes, because a sufficient quantity of air can be introduced into the producer at or adjacent to the point or points of introduction of the emulsified fuel, to take advantage of the reaction of large quantities of steam with the primary gas making material. Consequently, we can gasify the solid carbonaceous material at rates which would be prohibitive in

using apparatus which requires operating temperatures below the fusion point of the ash.

Most gas producers used in the United States today are of the pre-fusion type with grates so arranged that the ash can be eliminated in dry unfused condition. Such producers are limited to very low rates of gasification per square foot of hearth area. Besides they necessitate careful selection of coal to be used so that proper fusion temperatures of ash do not throw the operating reactions out of gear. In pre-fusion type producers, both air and steam are used, the steam acting as gas making material and at the same time holding the temperature of the ash below the fusion point. Obviously our method also eliminates the objections to pre-fusion type producers.

By our procedure it is possible to produce a gas of higher calorific value containing illuminates, hydrocarbons, hydrogen and carbon monoxide, in which the ratio of nitrogen to the combustible matter contained in the gas is lower than the ratio contained in producer gas obtained by other slagging type producers.

From the foregoing it is believed that our method of producing gas may be readily understood but by way of recapitulation, and for further disclosure we make the following statement.

The purposes of our method of operation are three in number.

1. Making it possible to operate gas producers with coal with low fusion ash at extremely high rates; the ash being tapped out as slag, sufficient temperature being maintained in the thermal decomposition chamber to maintain the ash in a liquid condition.

2. The utilization of heavy gas-tars or other residue hydrocarbons in the producer to act as an enriching agent by converting this material into a fixed gas by high temperature thermal decomposition; reacting with water vapor and then the reduction of these products of combustion into carbon monoxide, hydrogen and other hydrocarbon gases.

3. Owing to the fact that the oxidation zone will operate at very high temperatures due to both the rapid rate of oxidation of the carbon of the charge at very high gasification rates and the fact that emulsion will be burned in the blast air stream, the temperature of the primary and secondary reduction zones will be maintained at elevated temperatures, due to the sensible heat contained in the highly preheated products of combustion. A large percentage of sensible heat will be recovered owing to the reduction reactions and a large amount of the balance of the sensible heat will be extracted due to the thick bed of green coal above the reduction zone. There will be little loss due to the secondary oxidation in the upper gas zone, known as Neuman reversion, as a result of oxidation of CO by undecomposed water vapor. Large amounts of water vapor can be used per pound of coal because of the higher oxidizing zone temperatures which will tend to decompose more efficiently the water vapor present.

Fuel gas is normally formed by the passage of a stream of steam and air through the thick bed of coal; primarily the reactions take place in three steps. The air and steam entering the incandescent bed of carbon above the ash line, causes a rapid increase in the temperature. Due to this reaction, O_2 plus $3.76 N_2$ equals CO_2 plus $3.76 N_2$, the steam being preheated to the temperature of the oxidizing zone. This CO_2 , nitrogen and superheated steam then passes into the primary re-

duction zone where the carbon has been devolatilized as a result of high temperature; the carbon immediately starts reducing the water vapor and CO_2 by the following reactions: C plus CO_2 plus $3.76 N_2$ equals $2CO$ plus $3.76 N_2$; C plus H_2O equals CO plus H_2 . None of the reduction reactions, of course, will take place until all of the oxygen present has been consumed. These reactions also occur but at a reduced rate in the secondary reduction zone and above this zone, the hot gases will come in contact with the green coal that is being continuously fed into the producer, and as a result, the sensible heat contained in these gases distills off the volatile constituents from the coal. Inasmuch as these volatiles are being distilled in the absence of air, they contain materials for enriching the resulting gases.

In the event where this gas is being used hot or as so-called smoked gas, these products of distillation are carried over with the gas and burned. But where these gases must be cleaned and cooled, such as in the operation of gas engines or heating coke ovens, the extracted tar becomes a problem. Also unless recuperative apparatus is installed, the sensible heat from the gas at the final producer temperature is lost. The operations of these coal gas producers are limited at the present time by the following factors.

The rate at which the coal may be gasified ranges from 8.9 to about 100 pounds of coal per square foot of grate per hour. This is determined by the fusion temperature of the ash in the coal as the producers are only equipped to dispose of unfused ash. Fusing of ash causes extreme difficulty from clinker formation. Fuel bed depth varies from 3.75 to 7 feet and pounds of steam per pound of coal varies from .28 to 1.57. Theoretically it would be best to use the amount of steam that would give the maximum efficiency of decomposition and therefore a minimum of dilution of the resulting gas with undecomposed steam. Under present operating conditions this cannot be done practically.

An excess of steam is generally used in order to reduce the possibility of fusion of the ash and to obtain a larger percentage of decomposed steam. This usually defeats its own purpose because the reduction of steam being an endothermic reaction, the more steam used the lower the temperature of the reduction zone and therefore the lower percentage of the total steam decomposed. There is also the disadvantage of having undecomposed steam in the final gas, as secondary oxidation of CO to CO_2 occurs as a result of water vapor being present when the temperature is high.

By our method of operation we eliminate most of the above operating difficulties and make it possible to convert all of the by-product tar into gas.

In the case where washed or cleaned gas is desired, suitable regenerators or recuperators may be provided so that the incoming air may be preheated in order to recover a large percentage of the sensible heat contained in the manufactured gas. The coal charge may have either low or high fusion ash and be either bituminous or anthracite. The operation of this unit generally is as follows; due to the introduction of air through tuyères at high pressure there is formed a combustion zone between the top of the slag and the under part of the coal charge. The emulsion being introduced at high velocity through a series of burners radially disposed around the wall of the producer, results in an

extremely high combustion temperature. The radiant heat from this combustion being thrown off at right angles tends to maintain the slag in molten condition and to cause fusion of any ash being released from the combustion zone of the coke. The combustion of the emulsion also tends to preheat all the incoming air, as sufficient excess air must be supplied to get the necessary amount of heat release from the combustion of the carbon of the charge to form the CO₂ necessary to react in the upper zone.

The incoming steam and water in the emulsion by passing through the body of this flame, is highly preheated and then is further preheated by passing through the oxidation zone of incandescent carbon. These combined products of combustion highly preheated are then carried into primary reduction zone where due to the high temperature and the absence of oxygen reduction of the CO₂ and water vapor occur. It is generally supposed that approximately 10% of the uncombined hydrogen also reacts with the carbon to form CH₄. These hot gases then pass through the secondary reduction zone where some further reduction occurs and are then passed through a thick bed of coal so as to cause distillation of the volatiles (if present) and a reduction in the sensible heat of the gases. The lower the final gas temperature can be carried, still maintaining high enough temperature to completely carry off the products of distillation, the more efficient the operation will be, as there will be a saving in the sensible heat of the gas plus the fact that the lower the temperature, the less secondary oxidation there will be from the oxidizing effect of the undecomposed steam.

It can easily be seen that complete gasification of coal can be efficiently carried out by this method of operation because of the fact that the fusion point of the ash in the coal will not be a limiting factor. Insofar as the rate of gasification is concerned this is made possible by the simultaneous burning of emulsified tars or fuel oils imparting enough heat, at what would normally be the ash zone, to maintain the ash in a liquid state. There is also the interesting fact that ash contains large amounts of iron oxide and silica with traces of titanium oxide, aluminum oxide, calcium oxide and magnesium. It is well known that iron, titanium, calcium and magnesium at highly elevated temperatures react catalytically to promote water gas and hydrogenation reactions. Inasmuch as all the liquid hydrocarbons, used for enriching, are passed through this zone of extreme high temperature and are in some cases, due to the high velocity of the incoming air, carried through the bed of incandescent coke, while still partly burned, complete thermal destruction takes place resulting in complete conversion to fixed gases of all of the liquid hydrocarbons charged. The slag can be periodically tapped out and disposed of.

In the foregoing description, we have set forth in considerable detail the manner in which our improved method will preferably be carried out in connection with the type of apparatus illustrated in the drawings, but the same is by way of illustration only, and all changes and variations are contemplated that come within the scope of the appended claims.

What we claim and desire to secure by Letters Patent is:

1. In the production of combustible gas, introducing a mass of green substantially solid carbonaceous material into the upper portion of a

stack and feeding the mass successively through a distillation zone, a reduction zone, an oxidation zone, and an incandescent zone, in the order named, maintaining the incandescent zone in a state of incandescence by blowing air into the lower portion of the mass, injecting an intimate mixture of water and fuel oil in atomized condition into the incandescent zone, burning the fuel oil and some of the resulting combustible gases in said incandescent zone, passing hot gases upwardly from the incandescent zone through said mass and thereby subjecting carbonaceous material above the zone of incandescence to distillation and partial combustion, and discharging the resulting gases from the upper portion of said distillation zone.

2. In the production of combustible gas, introducing a mass of green substantially solid carbonaceous material into the upper portion of a stack and feeding the mass successively downward through a distillation zone, a reduction zone, an oxidation zone, and an incandescent zone, in the order named, maintaining the incandescent zone in a state of incandescence by blowing air into the lower portion of the mass, injecting an intimate mixture of steam, water and fuel oil in atomized condition into the incandescent zone, burning the fuel oil and some of the resultant gases in said incandescent zone, passing other gases upwardly from the incandescent zone through said mass and thereby subjecting carbonaceous material above the zone of incandescence to distillation and to partial combustion, and discharging the resultant gas from the upper portion of said distillation zone.

3. In the production of combustible gas, introducing a mass of green substantially solid carbonaceous material into the upper portion of a stack and feeding the mass downwardly successively through a distillation zone, a reduction zone, an oxidation zone, and an incandescent zone, in the order named, maintaining the incandescent zone in a state of incandescence by blowing air into the lower portion of the mass, injecting an intimate mixture of water and fuel oil in atomized condition into the incandescent zone, burning the fuel oil and some of the resulting combustible gases in said incandescent zone, passing hot gases upwardly from the incandescent zone through said mass and thereby subjecting carbonaceous material above the zone of incandescence to distillation and partial combustion, and discharging the resulting gases from the distillation zone, the air introduced being sufficient to constantly maintain the lower portion of said zone incandescent and the ash in liquid condition.

4. In the production of combustible gas, introducing green carbonaceous material into a passageway at one point, feeding said material in the passageway successively through a distillation zone, a reduction zone, an oxidation zone, and an incandescent zone, in the order named, discharging slag in liquid condition from the passageway at another point remote from the first one and adjacent to the incandescent zone, raising a portion of the mass of carbonaceous material in the incandescent zone to a state of incandescence by blowing air into the incandescent zone, injecting an intimate mixture comprising water and fuel oil in atomized condition into the zone of incandescence, burning the fuel oil and some of the resulting combustible gases in the said incandescent zone, passing hot gases from the incandescent zone through the mass in a direction toward

the point where the green carbonaceous material is introduced and thereby subjecting another portion of said carbonaceous material to distillation and partial combustion, and discharging the resulting gases from the mass at a point adjacent to that where the green carbonaceous material is introduced into the passageway.

5. In the production of combustible gas, introducing substantially solid carbonaceous material into the upper portion of a stack and feeding the material successively through a distillation zone, a reduction zone, an oxidation zone, and an incandescent zone, in the order named, before discharging slag in liquid condition from the lower portion of the stack, raising a portion of the mass of carbonaceous material adjacent the point of discharge of the slag, to a state of incandescence by blowing air into the incandescent zone, injecting a water-in-fuel oil emulsion in atomized condition into the zone of incandescence under super-atmospheric pressure, burning some of the emulsion in said incandescent zone, passing hot gases from the incandescent zone through the mass in a direction toward the point where the green carbonaceous material is introduced and thereby subjecting another portion of said carbonaceous material to distillation and partial combustion, and discharging the resulting gases from the mass at a point adjacent to that where the green carbonaceous material is introduced into the mass.

6. In the production of combustible gas introducing a mass of green carbonaceous material into the upper portion of a stack and feeding the mass successively through a distillation zone, a reduction zone, an oxidation zone, and an incandescent zone, in the order named, maintaining the incandescent zone in incandescent condition by blowing air into the incandescent zone, injecting a liquid fuel comprising an intimate mixture of water and fuel oil in atomized condition into the incandescent zone, burning the fuel oil and some of the resulting combustible gases in the incandescent zone, passing hot gases upwardly from the incandescent zone, through the oxidation zone, reduction zone and distillation zone and thereby subjecting carbonaceous material above the incandescent zone to distillation and partial combustion, and discharging the resulting gases from the distillation zone.

7. In the production of combustible gas introducing a mass of green carbonaceous material into the upper portion of a stack and feeding the mass successively through a distillation zone, a reduction zone, an oxidation zone, and an incandescent zone, in the order named, maintaining the incandescent zone in incandescent condition by blowing air into the incandescent zone, injecting a liquid fuel comprising an intimate mixture of water and fuel oil in atomized condition into the incandescent zone, burning the fuel oil and some of the resulting combustible gases in the incandescent zone, passing hot gases upwardly from the incandescent zone, through the oxidation zone, reduction zone and distillation zone and thereby subjecting carbonaceous material above the incandescent zone to distillation and partial combustion, and discharging the resulting gases from the distillation zone, the air introduced into the incandescent zone being sufficient in quantity to maintain ash discharged from the incandescent zone, in liquid condition.

8. As an improvement in the art of manufacturing combustible gas, passing air upwardly through an incandescent mass of substantially solid carbonaceous material and a super-incum-

bent charge of fresh substantially solid carbonaceous material arranged in superposed oxidation, reduction and distillation zones, injecting a water-in-fuel oil emulsion in atomized condition into the incandescent body and burning the emulsion therein, passing hot gases from the incandescent body upwardly through said super-incumbent charge and thereby subjecting carbonaceous material of the charge to distillation and partial combustion, and discharging the resulting gases from the distillation zone.

9. As an improvement in the art of manufacturing combustible gas, passing air upwardly through an incandescent mass of substantially solid carbonaceous material and a super-incumbent charge of fresh substantially solid carbonaceous material arranged in superposed oxidation, reduction and distillation zone, injecting a water-in-fuel oil emulsion in atomized condition into the incandescent body and burning the emulsion therein, passing hot gases from the incandescent body upwardly through said super-incumbent charge and thereby subjecting carbonaceous material of the charge to distillation and partial combustion, and discharging the resulting gases from the distillation zone, the amount of air introduced into the incandescent body being sufficient to cause the ash discharged to flow therefrom in liquid condition.

10. As an improvement in the art of manufacturing combustible gas, passing air upwardly through an incandescent mass of substantially solid carbonaceous material and a super-incumbent charge of fresh substantially solid carbonaceous material arranged in superposed oxidation reduction and distillation zones, injecting a water-in-fuel oil emulsion in atomized condition into the incandescent body and burning the emulsion therein, passing hot gases from the incandescent body upwardly through said super-incumbent charge and thereby subjecting carbonaceous material of the charge to distillation and partial combustion, and discharging the resulting gases from the distillation zone, the emulsion containing from approximately 25% to 65% water.

11. In the production of combustible gas maintaining a column of substantially carbonaceous material in a stack having superposed distillation, reduction, oxidation and incandescent zones, raising the lower portion of the column to a state of incandescence by blowing air into the lower portion of the column, injecting a water-in-residual tar emulsion in atomized condition into the incandescent zone of the column, the water in the emulsion ranging from approximately 25% to 65%, burning at least some of the emulsion in said zone, passing hot gases upwardly from the incandescent zone successively through said oxidation, reduction and distillation zones and thereby subjecting the carbonaceous material above said incandescent zone to distillation and partial combustion, and discharging the resulting gases from the distillation zone.

12. In the production of combustible gas, introducing fresh coal into the upper portion of a stack and feeding the same downwardly in the stack successively through distillation, reduction, oxidation and incandescent zones, maintaining the incandescent zone in incandescent condition by simultaneously blowing air into the incandescent zone and injecting an intimate mixture of steam and a water-in-fuel oil emulsion in atomized condition, burning the fuel oil and some of the resulting combustible gases in the incan-

descent zone, passing hot gases upwardly from the incandescent zone successively through the oxidation, reduction and distillation zones, and thereby subjecting carbonaceous material above the incandescent zone to distillation and partial combustion, discharging resulting gases from the distillation zone, and discharging slag in flowable condition from the lower portion of the incandescent zone.

13. In a production of combustible gas, maintaining a substantially vertical column of substantially solid carbonaceous material in a stack, heating the bottom portion of the column to a state of incandescence by blowing air into the lower portion of the column, making a water-in-

5 fuel oil emulsion of predetermined quantities of water and fuel oil and injecting such emulsion in atomized condition into the lower portion of the incandescent zone of the column in intimate admixture with steam, burning the fuel oil and some of the resulting combustible gases in said zone, passing hot gases solely from said zone upwardly through said column and thereby subjecting carbonaceous material of the column above said zone to distillation and partial combustion, and discharging the resulting gases from the upper portion of said column.

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