

Aug. 22, 1950

E. G. BAILEY
PROCESS FOR THE HEAT TREATMENT OF
CARBON-CONTAINING FEED STOCK

2,519,340

Filed March 23, 1944

2 Sheets-Sheet 1

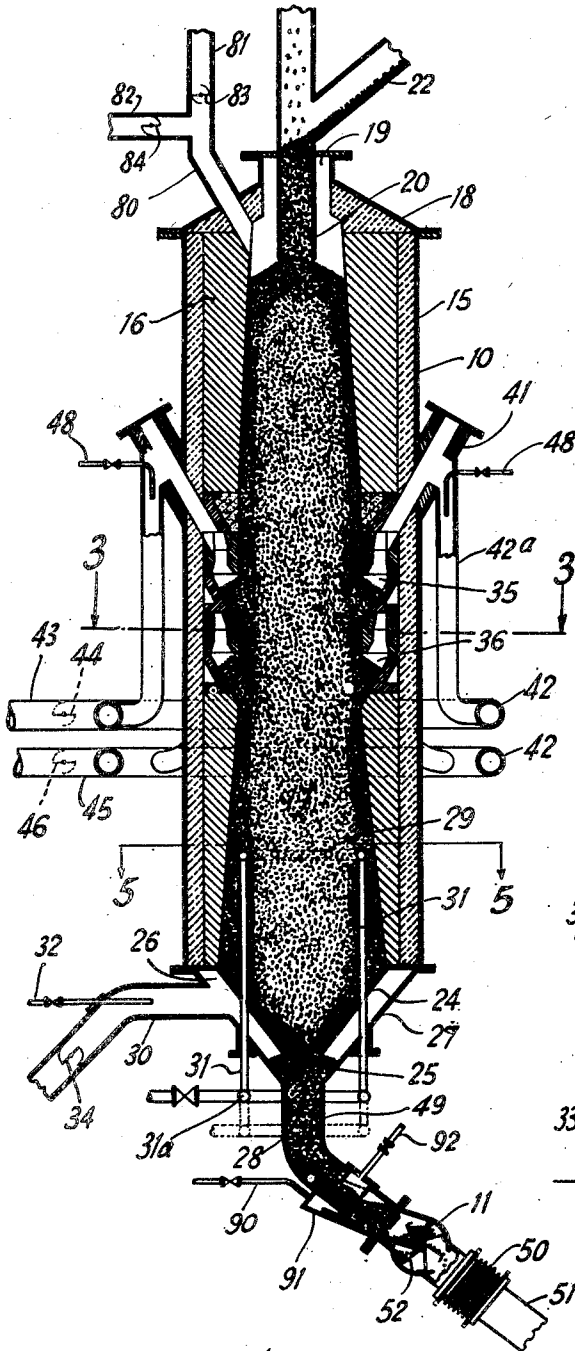


Fig. 2

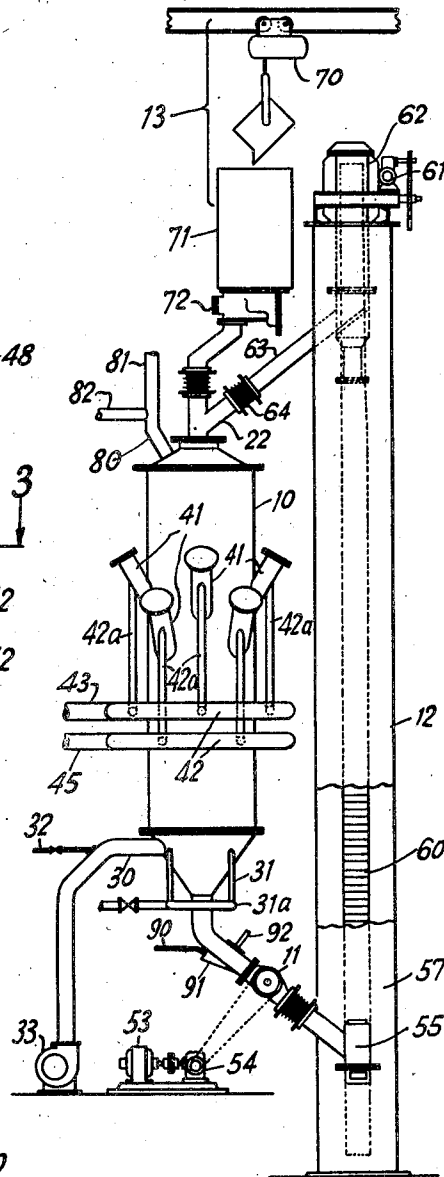


Fig. 1

INVENTOR
Errin G. Bailey
BY *J. P. Moran*
ATTORNEY

Aug. 22, 1950

E. G. BAILEY
PROCESS FOR THE HEAT TREATMENT OF
CARBON-CONTAINING FEED STOCK

2,519,340

Filed March 23, 1944

2 Sheets-Sheet 2

Fig. 3

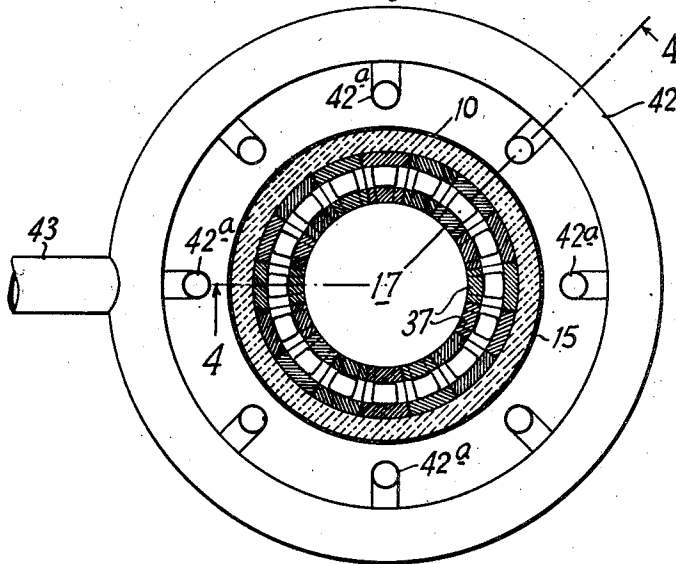


Fig. 4

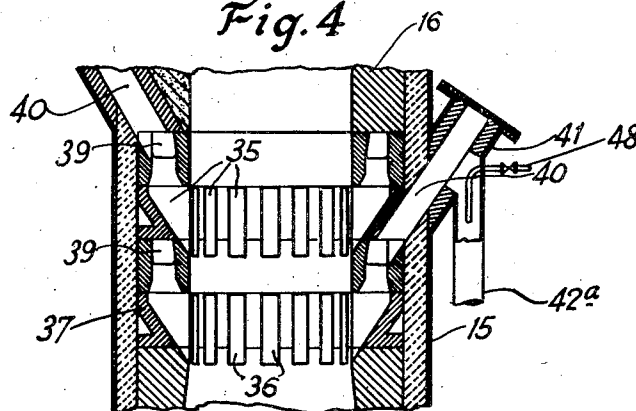
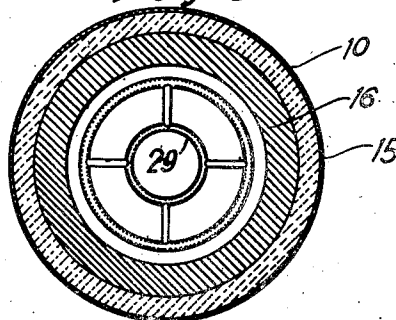


Fig. 5



INVENTOR
Ervin G. Bailey
BY *J. M. Moran*
ATTORNEY

UNITED STATES PATENT OFFICE

2,519,340

PROCESS FOR THE HEAT-TREATMENT OF
CARBON-CONTAINING FEED STOCK

Ervin G. Bailey, Easton, Pa., assignor to The Babcock & Wilcox Company, Rockleigh, N. J., a corporation of New Jersey

Application March 23, 1944, Serial No. 527,726

8 Claims. (Cl. 48—197)

1

The present invention relates to a process of and apparatus for the treatment of hydrocarbons and carbohydrates with heat, oxygen and steam to produce fuel gas of moderate heating value and also condensable hydrocarbons and other end products of a more valuable nature.

Gas producers heretofore available in which gaseous end products are produced by the reaction of air and steam with a body of hydrocarbon, usually in the form of a mass of solid fuel, such as bituminous coal, have been characterized by difficult and inefficient operation and the production of relatively low grade fuel gas and by-products (mainly troublesome tars) of little commercial value. The conversion of a solid fuel, such as raw bituminous coal, into such end products in a gas producer causes the volatile constituents of the fuel to be distilled under conditions adverse to the formation of valuable hydrocarbon compounds. Under the action of heat the coal melts or fuses into a state of relatively high viscosity and the presence of a melted tarry mass of coal in the producer bed tends to fill the voids in the fuel bed and preclude the free flow and distribution of the combustion air and steam supplied with the result that the combustible gases produced are of relatively low quality even with continual mechanical stoking and other troublesome operating procedures.

In accordance with the present invention, hydrocarbon and carbohydrate materials, preferably in a solid state, although such materials in a liquid or gaseous state may also be used as prime or supplemental feed stock, are subjected to a thermal decomposition or pyrolysis process in which the gasifiable constituents of the material being treated are continuously and completely gasified under controlled time and temperature conditions to bring about reactions which yield the maximum value of the combination of non-condensable gaseous end products and condensable end products suitable for further treatment to produce hydrocarbons suitable for motor fuels, aromatic hydrocarbons and other valuable products.

In operating the present process the hydrocarbon or carbohydrate feed stock to be treated is continuously supplied to the upper part of a vertically elongated retort through which is substantially continuously moving downwardly a fluent mass of solid heat transfer material capable of being heated in different zones to a wide range of temperatures, and substantially continuously discharged from the bottom of the retort and returned to the upper part thereof by

2

suitable external elevator or lifting provisions. The feed stock is introduced into the top of the retort chamber intermingled with pieces of heat transfer material at a sufficiently elevated temperature, e. g. 500–1000 F., and with a volumetric ratio of feed stock to heat transfer material sufficiently small, so that as the feed stock is heated by conduction and radiation from the hot heat transfer material to drive out any moisture present and leave the feed stock in a highly viscous condition, the feed stock will adhere to the pieces of heat transfer material but will not be in sufficient volume to completely fill the voids therebetween nor to congeal into an impervious mass which would otherwise prevent the heat transfer material and feed stock from passing downwardly in the retort chamber as a fluent mass or of gases flowing through the fluent mass in intimate contact with all portions thereof. The gases and condensable vapors driven off in this low temperature gasification zone flow through the interstices in the fluent mass and are continuously discharged from the retort at a predetermined elevation, depending upon the desired end products of the process.

The described low temperature heating continues for a time interval sufficient to convert the feed stock in the descending fluent mass into so-called "low-temperature" coke or char, which normally still contains some hydrocarbons, and in this condition the feed stock enters the lower or high temperature section of the retort chamber, from the upper part of which section all of the gaseous products produced therein can be withdrawn. The upper part of the lower section serves as a high temperature gasification zone, in which the residence time of the feed stock and the high temperatures to which it is subjected are such that desirable hydrocarbons are formed by further distillation of the feed stock and pyrolysis and synthesis of the various compounds and elements normally present in this section. In the lower part of the gasification zone, the descending high temperature fluent mass of coke or char and heat transfer material is contacted by superheated steam at a relatively high temperature and a water gas reaction takes place between some of the carbon and steam, forming hydrogen and carbon monoxide, which flow upwardly in the retort chamber and mix with the hydrocarbons produced in the upper part of the lower gasification zone.

The residual carbon remaining on or intermingled with the heat transfer material after passing through the water gas reaction zone

serves as the source of heat, when burned, for effecting the water gas and pyrolysis reactions in the higher sections of the retort chamber. For this purpose oxygen, either in the form of commercially pure oxygen or air, or a mixture of air and oxygen, is introduced into the lowermost part of the retort chamber along with or below the elevation at which the steam is introduced, for combustion of the residual carbon. The portion of the feed stock consumed, and amount of combustion air introduced, for combustion purposes is regulated in accordance with the desired temperatures in the different sections of the retort. The heating gases generated by the complete and/or partial combustion of the residual carbon flow upwardly through the interstices in the descending mass of heat transfer material and feed stock, and mixed with the other gases and vapors produced in the lower zone, are advantageously withdrawn from the upper part of that zone. The amount of carbon dioxide in the heating gases is substantially reduced by the high temperature reducing action thereon of the descending residual carbon to form carbon monoxide. The presence of substantial amounts of hydrogen and carbon monoxide at high temperatures and with a sufficient residence time in the upper part of the lower zone in intimate contact with the descending coke or char residue and gaseous hydrocarbons driven off is conducive to the formation therein of hydrocarbons of a more valuable composition. Other desirable hydrocarbon compounds may be formed by mixing the low temperature volatile gases distilled in the upper zone of the retort with the gaseous products in the high temperature gasification zone and withdrawing all or substantially all of the gases at an elevation near the mid-height of the retort. Alternately, the low temperature volatiles may be withdrawn from the retort chamber separately or with only a small portion of the gaseous hydrocarbons from the high temperature zone.

The descending heat transfer material on leaving the combustion zone is at a high temperature and the heat content thereof is partly utilized to preheat the incoming air and steam flowing to the combustion and gasification zones, and partly to provide sufficient heat therein for the distillation of the low temperature volatiles in the gasifiable feed stock entering the upper distillation zone, to which the heated heat transfer material is returned. The described process and apparatus are applicable to the gasification of a wide range of hydrocarbon and carbohydrate materials such as coal, lignite, peat, hogged wood, sawdust, bunker C or other heavy oil, oil shale, and mixtures of such materials.

The general object of the invention is thus the provision of an improved process and apparatus for continuously heat treating hydrocarbon and carbohydrate materials, in solid, liquid or gaseous form, under controlled reaction time and temperature conditions to produce condensable and non-condensable gaseous end products of greater commercial value than the material treated. Another object is the provision of a gasification process and apparatus in which the chemical compositions of the end products can be readily controlled over a relatively wide range by varying the reaction times and temperatures to which various constituents of the hydrocarbon or carbohydrate feed stock are subjected while undergoing treatment. A further and more specific object is the provision of a gas producing

apparatus and process of gasification which is characterized by the continuous production of high quality condensable and non-condensable end products, high capacity operation and complete utilization of the volatile and gasifiable constituents of the hydrocarbon or carbohydrate feed stock.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of my invention.

In the drawings:

Fig. 1 is an elevation, partly broken away and diagrammatic, of a retort and associated apparatus for carrying out the process of the invention;

Fig. 2 is a sectional elevation of the retort shown in Fig. 1;

Fig. 3 is a horizontal section taken on the line 3—3 of Fig. 2;

Fig. 4 is a vertical section taken on the line 4—4 of Fig. 3; and

Fig. 5 is a horizontal section taken on the line 5—5 of Fig. 2.

The apparatus illustrated is particularly designed for the gasification of crushed or coarsely pulverized solid hydrocarbons, such as a high volatile bituminous coal, and as shown comprises as its main elements a vertically elongated retort 10, a fluid sealing material discharge mechanism 11 receiving material from the lower end of the retort, elevating mechanism 12 receiving material from the discharge mechanism 11 and returning the same to the upper end of the retort, and provisions 13 for supplying feed stock to the upper end of the retort.

As shown in Figs. 2 and 3, the retort 10 is formed by a fluid-tight cylindrical steel casing 15 lined with suitable refractory material 16 to form a vertically elongated retort chamber 17 of upwardly tapering circular cross-section. The upper end of the retort chamber has a refractory lined top plate 18 provided with a normally closed central access opening 19, through which an inlet pipe 20 extends downwardly into the upper end of the retort chamber. The pipe 20 is connected to the feed stock supply system and has a branch pipe 22 leading from the elevating mechanism 12. The lower end of the retort chamber is formed by an inverted frusto-conical metallic plate 24 having a central discharge opening 25 at its lower end and perforated over the major portion of its height. The plate 24 forms the inner wall of a downwardly tapering annular inlet chamber 26, the outer wall of which is a second inverted frusto-conical plate 27 also terminating in a central discharge opening 28 below and in axial alignment with the discharge opening 25.

A fluid inlet pipe 30 opens horizontally into one side of the inlet chamber 26. The pipe 30 is connected to a forced draft fan 33, as shown in Fig. 1, with the air supply therefrom controlled by a valve 34 in the pipe 30. A valve controlled steam supply pipe 32 extends into the pipe 30 and terminates therein adjacent its entrance to the inlet chamber 26 for mixing purposes. The operation of the fan 33 permits the air flow to be controlled independently of the steam flow.

5

As shown in Figs. 2 and 5, a supplementary or alternative steam supply is provided by a spider 29 having connected concentric inner and outer perforated rings in the lower part of the chamber 17. The outer ring of the spider is connected by vertical pipes 31 to an external valve controlled steam supply ring 31^a. A capacity for vertical adjustment of the spider in the chamber 17 is indicated to permit variations in the entrance level of the steam supplied therethrough.

The center section of the retort is provided with upper and lower vertically spaced sets of circumferential outlets 35 and 36 respectively, each of which sets is formed, as shown in Figs. 2-4, by refractory blocks 37 shaped to provide a circular series of radially extending vertically elongated ports therein having inclined bottoms and opening at their upper ends into an annular outlet duct 39 within the superjacent portion of the retort wall. Each duct 39 is connected to a plurality of separate inclined outlet passages 40 in the refractory 16 and extending to form projecting pipes 41. The outlet pipes 41 are separately connected to a subjacent common annular bustle pipe 42 by downwardly extending discharge pipes 42^a. A discharge line 43 controlled by a valve 44 connects the upper bustle pipe to a storage point or associated apparatus, and a second discharge line 45 controlled by a valve 46 is similarly connected to the lower bustle pipe. A suitable gas quenching nozzle 48 is arranged to discharge into the upper end of each discharge pipe 42^a in intimate contact with the gases discharging therethrough.

In operation the retort chamber 17 is filled to approximately the level indicated in Fig. 2 with a fluent mass of material, a substantially continuous downward movement of which is effected without change in level by the substantially continuous introduction of material through the inlet pipe 20 and its discharge through the discharge openings 25 and 28. The discharge outlet 28 opens into a vertical discharge pipe 49, which is connected through an expansion joint 50 to an inclined pipe 51. The fluid sealing material discharge mechanism 11 is incorporated in the pipe 49 and as shown consists of a variable speed rotary pocket feeder 52 driven by an electric motor 53 through suitable speed reducing devices 54. The lower end of the pipe 51 opens into a box 55 having openings therein for the addition and withdrawal of circulating material. From the box 55, the circulated material drops into the elevator casing 57 of the elevating mechanism 12. The elevator casing is of welded gas-tight construction and encloses an elevator 60 driven by an electric motor 61. The elevator buckets empty into a discharge pipe 62 having a bottom outlet opening into an inclined pipe 63, which is connected to the upper end of the branch inlet pipe 22 through an expansion joint 64. With this arrangement a substantially continuous circulation of material can be maintained externally of the retort between the discharge opening 28 and inlet pipe 20 so that the mass or column of material within the retort chamber 17 will descend at a predetermined rate mainly dependent upon the speed of the feeder 52.

The supply system for the solid hydrocarbon feed stock in the arrangement illustrated comprises an overhead track and bucket conveyor 70 discharging into a storage bin 71 having a regulable discharge through a suitable feeder 72 into the upper end of the pipe 20. The operation of the feeder 72 is advantageously coordinated with the operation of the rotary feeder 52 to con-

6

trol the volumetric ratio of feed stock to heat transfer material entering the inlet pipe 20 and retort chamber and so facilitate the maintenance of desirable material and gas flow conditions in the retort chamber.

In accordance with the invention, an additional gas outlet pipe 80 is arranged to open through the top plate 18 above the normal level of the material in the retort chamber 17. The gas outlet pipe 80 has two branches 81 and 82 controlled by valves 83 and 84 respectively. The branch outlet 81 is normally closed except at starting-up and serves as a heating gas outlet during such periods. The branch outlet 82 serves as an auxiliary gas outlet for the upper and lower series of outlet ports 35, 36 in the mid section of the retort chamber, as is hereinafter described, and leads to associated gas treating apparatus.

A relatively wide range of materials can be used as the circulating solid material serving the dual function of a heat transfer medium and a solid diluent for the hydrocarbon or carbohydrate feed stock, the material chosen depending upon the particular set of operating conditions to be maintained. The material selected for this purpose must be capable of withstanding a rapid rate of temperature change over a substantial temperature range without fracturing or substantial erosion and have a high rate of heat conductivity. Such materials are preferably non-combustible refractories, although a combustible material such as sized pieces of a suitable coke could be used under certain conditions. Preferably however the heat transfer material consists of pellets of ceramic refractory or corrosion resistant alloy or alloy steel, as disclosed in my copending application with R. M. Hardgrove, Serial No. 502,580, now Patent No. 2,447,306. The pellets should be of a diameter small enough to minimize thermal shocks and impact stresses and particularly to provide a large amount of heat transfer surface, and yet large enough to withstand the desired gas velocities in the retort chamber without lifting.

In initially starting up apparatus of the character described, the system is filled with pellets of heat transfer material of the character described and the feeding and elevating mechanisms started. All of the gas outlet passages are closed, except the outlet 81. A fuel gas supply is temporarily introduced into the combustion zone of the retort through the outlet ports 35 and/or 36 and air supplied through the pipe 30 for combustion of the fuel gas. The circulating heat transfer material is heated in this manner sufficiently to bring its temperature at the outlet 28 to 500-1000° F. with the heating gases leaving through the gas outlet 81. The hydrocarbon or carbohydrate feed stock, such as raw bituminous coal crushed so that all of it passes through a medium sized screen, e. g. one-half inch mesh, is then introduced through the inlet pipe 20 along with the heated pellets from the elevator in the desired volumetric ratio of coal to pellets. As the mixture moves downwardly in the upper part of the chamber, heat is progressively transmitted by radiation and conduction from the heated pellets to the intermingled coal particles. The starting-up gas supply is continued until the desired operating temperatures throughout the retort chamber are reached and is then cut off. The heating gas outlet 81 is then closed by the valve 83 and the gas outlets 35, 36 and 82 opened or closed depending upon whether all of the gaseous end products are to be withdrawn through

the outlets 38 and/or 36, or partly through the gas outlet 32. The steam supply pipe 31^a is then opened and the fan 33 regulated to supply steam and air at predetermined rates to the bottom section of the retort chamber. The steam supply 32 is used first to dilute the air supply and to act as an inert cooling medium for the pellets adjacent the outlet 25 and later as it flows upward is used in the water gas reaction.

In normal operation, with the auxiliary outlet 32 closed and the series of outlets 35 and 36 open, the descending intermingled mass of coal and pellets will first move downwardly through the low temperature gasification or distillation zone where the heat transmitted by the pellets will raise the temperature of the coal particles enough to drive out the moisture and the rich low temperature volatile hydrocarbon constituents, which flow downwardly through the interstices in the fluent mass to the gas outlets 35. The low temperature heating in this zone is sufficient to rapidly fuse the intermingled coal particles into a melted tarry condition and most of the melted coal soon deposits on the surrounding pellets as a tarry layer. The low temperature heating continues for a period sufficient to convert the coal in the descending mass into so-called "low-temperature" coke by the time it reaches the upper series of outlets 35. Some higher temperature hydrocarbons are still present in the coke at this level.

The retort chamber and pellet temperatures sharply increase in the center outlet section of the retort due to the presence therein of high temperature gases from the lower sections. As the mass of coke-coated pellets moves downwardly through this high temperature zone, the remaining hydrocarbon constituents in the coke are rapidly driven off. These gaseous hydrocarbons mix with the gases rising from the subjacent retort section and the residence time and high temperatures (1700-2200° F.) to which the gaseous mixture is subjected effects cracking and synthesis of some of the hydrocarbons present to form new hydrocarbons in a stable or a metastable condition.

In the lower part of the high temperature gasification zone, the descending mass of coke and pellets is contacted by superheated steam at a relatively high temperature and a water gas reaction takes place between the steam and the coke, forming hydrogen and carbon monoxide which flow upwardly in the retort chamber and mix with the gaseous hydrocarbons driven off in the superjacent part of the high temperature gasification zone. The steam supply from the pipe 31^a is advantageously regulated as close as possible to the theoretical steam requirements for the water gas reaction to thus minimize loss of heat in the outgoing gases.

The heat requirements for the endothermic water gas and pyrolysis reactions and for heating the mass of heat transfer material are supplied substantially entirely by the combustion of the residual carbon remaining on or intermingled with the pellets leaving the water gas reaction zone. The oxygen required for this combustion reaction is supplied by the controlled admission of air through the pipe 30, inlet chamber 26 and screen 24. The air is heated to a high temperature during its passage through the mass of pellets in the lowermost part of the retort chamber, so that when the air encounters the descending carbon coated pellets a rapid combustion of the carbon takes place. The air

supply is also advantageously maintained slightly below the theoretical oxygen requirements for complete combustion to minimize the formation of carbon dioxide. The amount of carbon dioxide in the ascending heating gases is further reduced by the reducing action thereon, $\text{CO}_2 + \text{C} = 2\text{CO}$, effected by contact with the descending residual carbon in the superjacent water gas reaction and high temperature gasification zones.

When the gaseous hydrocarbons driven off in the upper or low temperature gasification zone are withdrawn through the auxiliary outlet 32, these end products can be maintained separate from the end products discharging through the outlets 35 and/or 36 and separately treated. Likewise when both sets of outlets 35 and 36 are in use, the end products withdrawn there-through can be separately treated.

The gaseous end products leaving through the outlets 35 and/or 36 are rapidly quenched to a low temperature by the operation of the gas quenching devices 48 in the outlet pipes 42^a. This immediate and rapid quenching of the gaseous end products leaving the high temperature zone to a low temperature causes any hydrocarbon end products in a metastable condition when formed to be stabilized for subsequent separation and treatment. The non-condensable gaseous end products are separated in a well known manner and are available for use as a fuel gas for combustion requirements in the plant and for commercial distribution. The condensable products contain a relatively high percentage of constituents suitable for further treatment to produce aliphatic and aromatic hydrocarbons and other valuable products. A substantial range of regulation of the operating conditions in the retort chamber, and particularly the time and temperatures for the various reactions described, is obtained by controlling the feed stock, air and steam supplies, and varying the rate of movement of the fluent mass of feed stock and heat transfer material downwardly through the retort chamber. The character of the end products can be further controlled by regulating the control valves for the gas outlets 35, 36 and 32 to apportion the gaseous end products between the outlets and vary the treatment in the retort chamber received by the gaseous end products before reaching the respective outlets.

The pellets leave the combustion zone with substantially all of their residual carbon coating completely consumed and move downwardly with the ash residue to the outlet openings 25 and 28. The pellet temperature is reduced to the desired outlet temperature by contact with the steam and air flowing upwardly to the water gas reaction and combustion zones. A pellet temperature of 500-1000 F. is normally desired at the outlet 28 to provide sufficient residual heat in the pellets for the low temperature gasification of the entering coal when the pellets are returned to the upper end of the retort chamber. The ash residue and any other fines present in the material discharged are preferably separated in a suitable manner, such as by a steam blast from a steam pipe 30 entering a stepped bottom section 31 of the pipe 49 at a point above the rotary feeder 52 and sweeping through the moving mass of material in that location. The steam and separated fines are discharged to a suitable receiver (not shown) through a screened outlet pipe 32 in the opposite side of the pipe 49.

The location of the series of gas outlets 35 and 36 at the mid-section of the retort chamber is especially advantageous from an operating standpoint as it permits the immediate withdrawal and quenching of the valuable metastable hydrocarbon formed in the high temperature section of the retort chamber. A further advantage of this location is the substantially lower gas quantities and resultant low gas velocity conditions in the low temperature gasification zone, providing a low pressure drop in this section. This low pressure drop not only reduces the power requirements of the apparatus, but also minimizes lifting and carryover of the fines in the upper section of the retort chamber. With a feed stock of solid hydrocarbon or carbohydrate material, loss of fines therein due to carryover with the gases would correspondingly reduce the efficiency of the process, but with the described gas outlet arrangement such losses are avoided. Another advantage is the resultant confining of the low temperature gasification to the heating effect of the heat transfer material in that section, avoiding the use of products of combustion from the lower sections of the retort chamber. The low temperature hydrocarbons driven off in this section are consequently undiluted with such products of combustion.

I claim:

1. A process of heat treating coal as a feed stock which comprises passing a mixture of the feed stock and a heated solid heat transfer material in a porous fluent mass downwardly through a retort chamber, maintaining heat transfer contact between the feed stock and said heat transfer material for a period sufficient to effect a low temperature gasification of the feed stock in a zone at the upper part of said mass, then passing the mixed mass of remaining feed stock and heat transfer material through a subadjacent high temperature zone for further heat treatment, supplying combustion air to the lower part of said chamber for burning the feed stock residual carbon in said mass in a subadjacent zone below said high temperature zone to supply the heat requirements of the process, returning the heat transfer material to the low temperature gasification zone with a heat content sufficient to effect said low temperature gasification, and withdrawing gaseous end products directly from the high temperature heating zone of said chamber.

2. A process of continuously heat treating a carbon containing feed stock which comprises introducing the feed stock into the upper part of a vertically elongated retort chamber in commingled relation with heated pieces of heat transfer material to form a continuous porous fluent mass in said chamber, moving said porous fluent mass of feed stock and heat transfer material substantially continuously downwardly through said chamber, effecting a low temperature gasification of the feed stock while in a zone at the upper part of said mass by a heating effect mainly due to heat transfer from said heat transfer material, subjecting a lower portion of the descending feed stock to a high temperature gasification effect, supplying combustion air to the lower part of said chamber for burning the descending feed stock residue in said mass while in a subadjacent section of said chamber below said high temperature gasification zone to supply the heat required in said gasification effect, recovering the reaction products from said low and high temperature gasification zones, and returning

heat transfer material to the upper part of the chamber at a temperature sufficient to effect said low temperature gasification.

3. A process of continuously heat treating coal as feed stock which comprises introducing the feed stock into the upper part of a vertically elongated retort chamber in commingled relation with heated pieces of non-combustible heat transfer material to form a continuous porous fluent mass in said chamber, moving said porous fluent mass of feed stock and heat transfer material downwardly through successive subjacent low and high temperature gasification zones and a combustion zone, effecting a low temperature gasification of the feed stock in said low temperature gasification zone by a heating effect substantially solely due to heat transfer from said heat transfer material, then subjecting the descending feed stock to a high temperature gasification effect at a position intermediate the height of said mass, supplying combustion air to the lower part of said chamber for burning the descending feed stock residue in said mass in said combustion zone to generate the heat required in said gasification zones, withdrawing the gases generated in the low and high temperature gasification zones from said chamber at the upper part of said high temperature gasification zone, and returning heat transfer material to the upper part of the chamber at a temperature sufficient to effect said low temperature gasification.

4. A process of heat treating a coal feed stock which comprises introducing the feed stock into the upper part of a vertically elongated retort chamber in commingled relation with heated pieces of heat transfer material to form a continuous porous fluent mass descending in said chamber, effecting a low temperature gasification of the feed stock in the upper part of said mass by a heating effect sufficient to convert the feed stock into a low temperature coke or char, subjecting the descending feed stock in a subadjacent portion of said mass to a high temperature gasification effect sufficient to drive off the remaining hydrocarbon constituents, passing steam in contact with the descending feed stock in a section of said mass below said high temperature gasification zone for the generation of water gas, supplying combustion air to the lower part of said chamber for burning the descending feed stock residue in said mass to generate the heat required in said gasification and water gas generating zones, withdrawing the gases generated in the high temperature gasification and water gas reaction zones from said chamber at said high temperature gasification zone, and continuously returning the heat transfer material from the last of said reaction zones to the first at a temperature sufficient to effect said low temperature gasification.

5. A process of heat treating coal as feed stock which comprises introducing the feed stock into the upper part of a vertically elongated retort chamber in commingled relation with heated pieces of heat transfer material to form a continuous porous fluent mass descending in said chamber, effecting a low temperature gasification of the feed stock in the upper part of said chamber by heat transfer to the feed stock from the heat transfer material, subjecting the descending feed stock in a subadjacent portion of said chamber to a high temperature heating effect sufficient to drive off remaining volatile constituents and effect the formation of hydrocarbons in

a metastable condition, passing steam in contact with the descending feed stock residue in a subjacent section of said chamber for the generation of water gas, burning the descending feed stock residue in said mass with preheated oxygen in a subjacent section of said chamber below said water gas reaction zone to generate the heat required in said gasification and water gas reaction zones, withdrawing the gases generated in the high temperature gasification and water gas reaction zones from the chamber at the upper part of said high temperature gasification zone, rapidly quenching the gaseous end products withdrawn to stabilize any hydrocarbons in a metastable condition, and continuously returning the heat transfer material from the last of said reaction zones to the first at a temperature sufficient to effect said low temperature gasification.

6. A process of continuously heat treating a carbon containing feed stock which comprises introducing the feed stock into the upper part of a vertically elongated retort chamber in commingled relation with heated pieces of non-combustible heat transfer material to form a continuous porous fluent mass descending in said chamber, effecting a low temperature gasification of the feed stock while in the upper part of said chamber by a heating effect mainly due to heat transfer from said heat transfer material sufficient to convert the feed stock into a low temperature coke or char, subjecting the descending feed stock while in a subjacent and intermediate portion of said chamber to a high temperature gasification effect sufficient to drive off the remaining volatile constituents, supplying superheated steam in intimate contact with the descending feed stock residue while in a section of said chamber below said high temperature zone for the generation of water gas, supplying combustion air to the lower part of said chamber for burning the remaining feed stock residue in said mass to generate the heat required in said gasification and water gas generating zones, withdrawing the gases generated in the high temperature gasification and water gas reaction zones from the chamber at a point in said high temperature gasification zone, absorbing heat from the descending heat transfer material while in the portion of the retort chamber below the combustion zone to superheat steam, and returning the heat transfer material to the upper part of the chamber with a heat content sufficient to effect said low temperature gasification.

7. A process of continuously heat treating a carbon containing feed stock which comprises introducing the feed stock into the upper part of a vertically elongated retort chamber in commingled relation with heated pieces of heat transfer material to form a continuous porous fluent mass descending in said chamber, effecting a low temperature gasification of the feed stock while in the upper part of said chamber by a heating effect substantially solely due to heat transfer from said heat transfer material and sufficient to convert the feed stock into a low temperature coke or char, subjecting the descending feed stock

while in a subjacent portion of said chamber to a high temperature gasification effect sufficient to drive off the remaining volatile constituents, supplying superheated steam in intimate contact with the descending feed stock while in a subjacent section of said chamber for the generation of water gas, burning the remaining feed stock residue in said mass with preheated combustion air to generate the heat required in said gasification and water gas generating zones, withdrawing the gases generated in the high temperature gasification and water gas reaction zones from the upper part of said high temperature gasification zone, absorbing heat from the descending heat transfer material while in the portion of the retort chamber below the combustion zone to preheat combustion air and superheat steam, and returning the heat transfer material to the upper part of the chamber with a heat content sufficient to effect said low temperature gasification.

8. A process of gasifying a coal feed stock which comprises passing a mixture of crushed solid feed stock and a heated solid non-combustible heat transfer material in a volumetric ratio providing a porous fluent mass downwardly through a retort chamber, maintaining heat transfer contact between the feed stock and the heat transfer material sufficient to effect gasification of the feed stock to a low temperature coke, then passing the mass through a subjacent high temperature gasification zone maintained at a temperature about 1500 F. to gasify the remaining volatile constituents, passing steam into contact with the feed stock residual carbon to effect a water gas reaction, supplying combustion air to the lower part of said chamber for burning the remaining feed stock residual carbon in the lower part of said chamber, returning heat transfer material to the low temperature gasification zone with a heat content sufficient to effect said low temperature gasification, withdrawing the gaseous end products from said chamber at a high temperature level therein, and rapidly quenching the gaseous end products as withdrawn to stabilize any hydrocarbons in a metastable condition therein.

ERVIN G. BAILEY.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,450,327	Meischke-Smith	Apr. 3, 1923
1,568,018	Forrest et al.	Dec. 29, 1925
1,699,989	Pyzel	Jan. 22, 1929
1,714,453	Schwarz	May 21, 1929
2,323,501	Tuttle	July 6, 1943
2,348,699	Tuttle	May 9, 1944
2,351,214	Kaufmann et al.	June 13, 1944
2,398,954	Odell	Apr. 23, 1946

OTHER REFERENCES

Griswold: "Fuels and Their Combustion," 1946, McGraw-Hill Book Co., New York, page 226.