

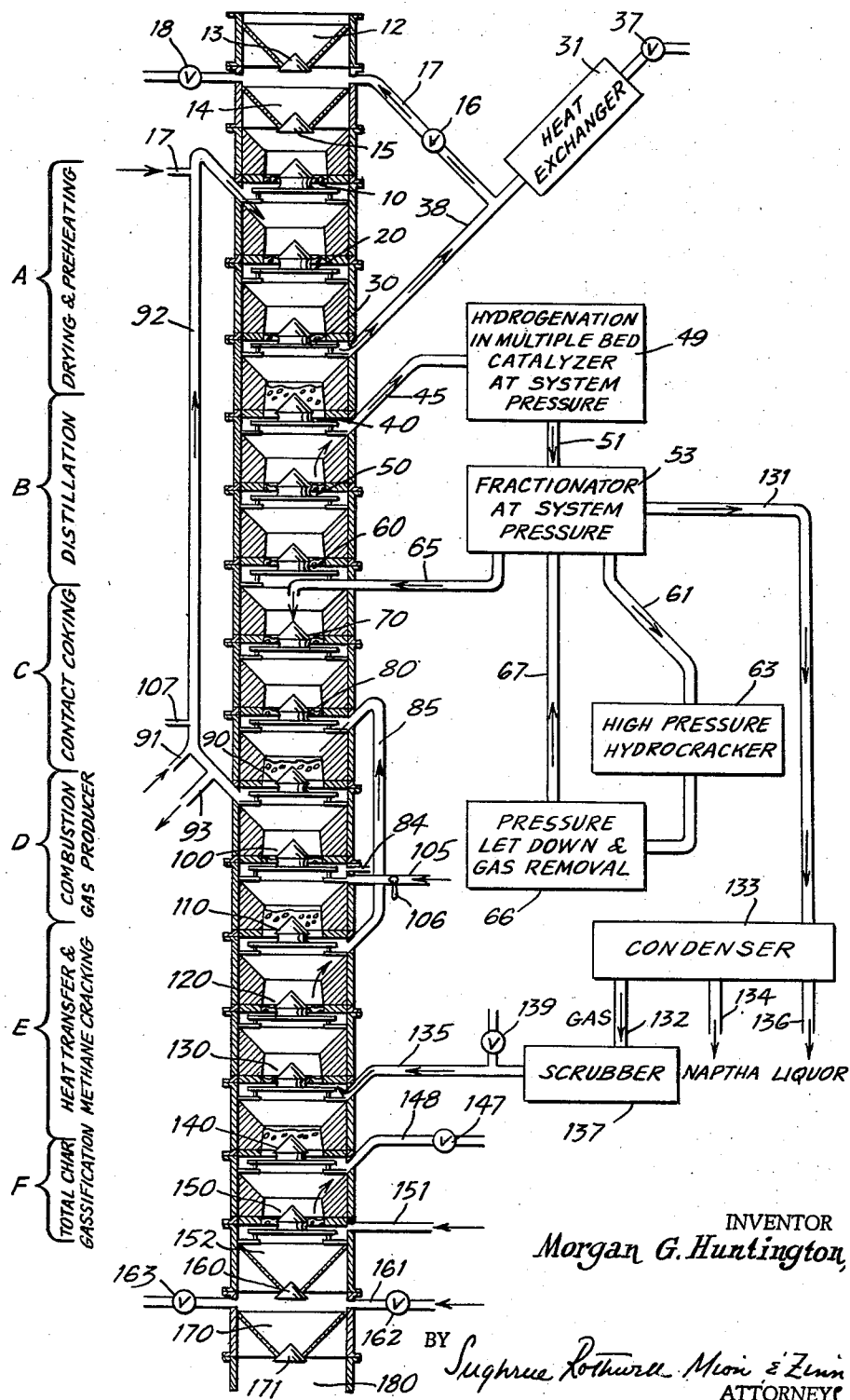
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METHOD FOR THE CONTINUOUS DISTILLATION OF COAL AND OTHER HYDROCARBONACEOUS MATERIALS AND FOR THE AUTOGENOUS HYDROGENATION OF THE CONDENSABLE VOLATILES

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This invention relates to the continuous drying, destructive distillation, gasification and carbonization of coal and other solid hydrocarbonaceous material. More particularly, this invention relates to a continuous multi-stage pressurized coal distillation and gasification system in a single vertical vessel; including the functions of coal drying, preheating, distillation with coincidental mild hydrogenation and subsequent severe hydrogenation of the condensable volatiles, and coincidental hydrogenation of recycled heavy bottoms, internal combustion of char to furnish the heat for the system, and selective total gasification of the balance of the char.

The destructive distillation of coal by heating in the absence of air is carried on for the production of coke, gas, tar and oils, and other by-products. There have been a large number of different approaches to the carbonization of coal, most of which attempt to accomplish the destructive distillation of the coal and to effect the recovery of coal tars, and at the same time to produce a minimum of uncondensable gases.

Low temperature coal tars would be practically identical to some natural crude naphthenic petroleum, if it were not for the fact that certain chemical functional groups are attached to most of the hydrocarbon molecules. These chemical "functional groups" of oxygen, sulfur and nitrogen alter the primary hydrocarbon molecules and promote the combination and complexity of molecules, and thereby so complicate the entire tar refining problem as to render it almost insoluble without initial hydrogenolysis.

It is emphasized that all prior known proposed processes which distill liquids from high volatile coals retain all of the troublesome chemical functional groups in the tar. Extensive hydrogenation is, therefore, necessary before any actual tar refining step may be undertaken.

The coal still system of this invention eliminates the chemically troublesome functional groups of oxygen, sulfur and nitrogen by the coincidental, continuous hydrogenation of the primary volatile matter as it is distilled from the coal at system pressure.

There are also known in the prior art various types of total synthesis processes, such as the Fischer-Tropsch and the Bergius processes, in which the liquefaction of a substantial fraction of the total coal is effected.

The total gasification and liquefaction processes lead to the synthesis of petroleum substitutes and the yield of products such as gasoline, diesel fuel, oil, lubricants, etc. At the present state of development, the total utilization systems are expensive to construct and to operate and while capable of producing satisfactory petroleum substitutes from coal, their present product cost is too high to be competitive with natural petroleum. This invention goes beyond the simple destructive distillation process which is common to practically all the known coal carbonization systems, but does not go as far as the total synthesis systems.

In all of the known coal gasification and carbonization systems of the internally fired type, the products of combustion inevitably mix with the primary volatile matter.

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This is undesirable particularly when the direct utilization of hydrogen is of paramount importance since an expensive separating step then becomes necessary to recover specific constituents from the mixed gases. It is an important object of this invention to provide a method for coal distillation and gasification in an internally fired retort without mixing any products of combustion with the primary volatile matter. Therefore, the uncondensable gases which result from the destructive distillation of coal, mainly hydrogen, methane and C_2 and C_3 hydrocarbons, are continuously available in practically a pure state and after removal of ammonia, hydrogen sulfide and water, can be re-cycled through the system, including a heat exchange portion thereof, while at the same time the re-cycled methane and C_2 and C_3 hydrocarbon gases are dissociated into hydrogen and colloidal carbon before entering the coking and distillation zone. With this arrangement, practically all the hydrocarbon gases are available for cracking into hydrogen and essentially no other gases are present to lower the partial pressure of hydrogen.

An important object of this invention is to provide a coal destructive distillation system operating at substantial pressures in which practically all of the distillable, uncombined hydrogen which was originally present in the coal is conserved without dilution with combustion gases and is available at system pressures. That is, since the products of combustion utilized to heat the system are not mixed with the coal being distilled, they do not mix with the primary volatile matter evolved. The uncondensable gases of the primary volatile matter principally include methane, C_2 and C_3 gases and hydrogen. These hydrocarbon gases, including methane, may then be cracked in the heat exchange portion of the system as the thermal carrier gases are re-cycled through the hot char below the combustion zone.

It is also an object of this invention to provide for hydrogenation coincidental with the destructive distillation to produce a tar which is much higher in hydrogen and is almost completely free of sulfur, while at the same time the spent char itself will be desulfurized and a substantial part of its nitrogen content recovered as ammonia. Since hydrogen is actually the thermal carrier fluid which, in the system of this invention, must raise the temperature of the preheated, dried coal from about $650^\circ F.$ to about $1300^\circ F.$, and since the thermal carrier hydrogen mixes with the primary and secondary volatiles and with nothing else, the total hydrogen leaving the retort is two to four times by weight that of the combined primary and secondary (volatiles from contact coking of the re-cycled heavy bottoms) volatile matter, this will provide at a system pressure of 15 to 30 atmospheres, the net effect of coincidental hydrogenation. Also, in this coincidental hydrogenation and destructive distillation, the generation of uncondensable gases and the disassociation of ammonia (NH_3) are retarded because of the high partial pressure of hydrogen in the distillation zone.

The coal utilization concept of this invention presents a novel method of skimming the oils from high volatile coals, or any mixture of coals in which the oxygen to hydrogen ratio (dry basis) does not exceed three to one, such that all of the uncombined hydrogen originally present in the coal is conserved at substantial pressure and in such purity and amount as to accomplish the complete, economic hydrogenolysis and hydrogenation of the condensable volatile matter. In this method the low volatile char (either gasified or pulverized) may be utilized for the generation of electric power, and atmospheric pollution normally resulting from the utilization of coal can be practically eliminated.

A number of the known prior coal gasification systems

have rigid requirements for the type of coal which may be used and the moisture content of the coal. It is an object of this invention to provide a continuous system for the distillation, gasification and carbonization of coal which may operate on various types of coal irrespective of their agglomerating and ash fusion properties and also which will not specify the maximum nor minimum moisture content of the new coal. Also, because of the particular construction of the system using gyratory shelves to feed and to support the series of beds of broken solids and controlling the amount of materials on each gyratory shelf and feed thereof as functions of individual bed pressure drop, any coal which tends to coke or agglomerate on the sides of the walls may be broken off by the gyrations of the supporting shelf and the material carried thereon. Further, any large agglomerated chunks will be broken down as they are fed off the periphery of the shelf. The structural features of the gyrating shelf system per se are disclosed in co-pending application Serial No. 17,293 (Series of 1960), filed March 24, 1960, now Patent 3,083,471, granted April 2, 1963.

In general, the capital investment in coal carbonization and processing plants is quite high and the interest on the investment plus the depreciation usually far outweighs the direct cost of operation. Obviously, for any such process to succeed, the net sales of all products must exceed by a comfortable margin the cost of the coal plus the operation and investment charges. However, at least for the present, it is evident that the entire operational cost of any coal skimming process must be borne by the revenue from the sale of the distilled liquids, since the heat unit value of the solid fuel residue and of surplus gases for steam raising is little different from that of the original coal. Therefore, the economic justification of any such process must hinge upon the enhanced yield and value of its liquid products. The only chance for commercial success of such a process will depend entirely upon the feasibility of producing a petroleum equivalent at a low cost per barrel and which can be refined into gasoline, jet fuel and diesel fuel in existing refineries. The coal still system of this invention definitely accomplishes this. To be commercially successful, the coal carbonization plant must therefore have a low cost for processing and the time required for treatment must be as short as possible. In other words, the throughput of materials through the plant must be great per unit time and the yield and utility of condensable liquids must be as high as possible. Accordingly, it is another object of this invention to provide a process for coal distillation having an exceptionally high throughput of materials per unit time and to enhance the value of the liquid product by autogenous hydrogenation.

It is also desirable that a coal distillation system be flexible in the products produced depending on the particular market and area. It is an additional object of this invention to provide a coal distillation, gasification and carbonization system in which a variety of practices may be employed depending upon the market price for fuel gas, smokeless solid fuel, or synthesis gas. That is, the process disclosed herein can, at the same time, operate as a producer of hydrogenated primary volatile matter for the direct distillation into a reformer plant feed for high octane gasoline and other petroleum products, as a gas producer (when air is used) and as a synthesis coal gasifier making carbon monoxide and hydrogen in different proportions (when oxygen and steam are employed). Also, when the market for synthesis gas does not exist and when smokeless, solid fuels are desirable, a relatively sulfur free smokeless fuel may be produced in lieu of total gasification.

Other objects and advantages of this invention will be pointed out in the following detailed description and in the claims, and will be illustrated in the accompanying drawings, which disclose, by way of example, the prin-

ciples of this invention and the best mode which has been contemplated for applying these principles.

In the drawing:

The single semi-schematic FIGURE illustrates a coal still capable of carrying out a preferred embodiment of the process of this invention. The specific mechanical components of the apparatus contained within the coal still are shown in my co-pending application Serial No. 17,293 (Series of 1960), filed March 24, 1960, now Patent 3,083,471, granted April 2, 1963.

In general, the schematic representation of the coal still includes a single, continuous, pressurized vessel having means for measuring and charging coal thereinto and discharge means for removing the char or ash therefrom. The coal still, between the charging section and the solid materials removal section, is divided into a number of zones for accomplishing various functions. The single continuous vertical vessel performs six functions in six different zones. The zones are labeled on the accompanying sheet of drawings. The zones include a concurrent flow drying and preheating zone A, a distillation zone B, a contact coking zone C, a combustion and gas producer zone D, a heat transfer and methane cracking zone E, and a total char gasification zone F which may be selectively utilized.

Each of the zones contains one or more gyratory shelf feeders for feeding and heat exchange purposes. Each gyratory shelf is of the nature disclosed in my co-pending application Serial No. 17,293 (Series of 1960), filed March 24, 1960, now Patent 3,083,471, granted April 2, 1963, and reference may be had thereto for a further description of the detail of the mechanical features of each gyratory shelf. The gyratory shelves in the concurrent flow drying and preheating zone A are shelves 10, 20, 30 and 40. Shelf 40 carries enough solid materials thereon so that it functions as a separating bed. In other words, the unsorted material on the shelf is so deep that gaseous fluids will not readily flow therethrough and will not pass from one zone to another in significant amounts at the small differential pressures which are automatically maintained. The distillation zone B may include two gyratory shelf units 50 and 60 and the contact coking zone C may also include two gyratory feeding units 70 and 80. A gyratory feeder unit 90 includes a shelf having materials thereon of such depth and density to function as a separating bed and also to prevent flow of gaseous fluids between the zones above and below the bed. A combustion and gas producer zone D includes gyratory feeder units 100 and 110. Gyratory feeder unit 110 also carries a separating bed for effectively separating the combustion and gas producer zone D from the next lower zone which is the heat transfer and methane cracking zone E. This latter zone may have, for example, three gyratory units 120, 130 and 140. Unit 140 also carries a separating bed for the purposes noted above. The total char gasification zone F may include several gyratory feeder units 150. The materials fed thereof fall into a hopper 152 and discharge from the hopper is controlled by a bell valve 160.

Although a particular number of gyratory shelves are described and shown in each zone of the apparatus, there is no intention to limit the number of gyratory shelves in any zone. For example, in the schematic drawing, because of lack of room, only one gyratory feeder shelf 150 is shown in the total gasification zone F. In order to get total gasification in some instances may require a half dozen different shelves, although these are not shown. Therefore, the number of these gyratory shelves which will be required in each zone may be varied with some latitude to accomplish the stated purpose under different conditions.

It is noted that, except for the contact coking zone C, which actually forms a lower part of the distillation zone B, all the separate functions are performed in zones which are separated within the continuous vertical vessel by beds

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containing deep layers of crushed solids or coal which substantially prevent the flow of gaseous fluids between adjacent zones. The separating beds are maintained at such a depth as to prevent any possibility of blowing out. The beds themselves are comprised of unsized, unsorted solid material through which heated gases simply cannot pass in volume at existing pressure differentials. If the pressure were to be increased sharply on the top of the bed, the effect of such pressure rise is simply to pack the bed and not enough gas would be forced downward onto the bed to blow anything off the supporting shelf. On the other hand, if a sudden pressure increase were to come from below the separating bed, before any effect would be felt in the zone above, it would be necessary to lift the entire bed. The pressure required to lift such a separating bed would be much greater than the pressures contemplated. Also, to prevent the possibility of disruption of the process by undue pressure rises, pressure relief valves are provided throughout the system at strategic locations.

The pressure differential across the separating beds could be up to 70 or 80 inches of water gauge without causing any lifting or blowing out of the separating bed. The actual maximum pressure differential across the separating beds will be very much less than this. Control of the depth of solids on the separating beds may be accomplished by any suitable known type of level sensing controller, such as a gamma ray level detector adapted to control solids being fed to the separating beds. Two positionable gamma ray level detectors can be provided for controlling the maximum and minimum depth of each separating bed.

In order to obtain adequate heat transfer from the gases to the solids, it may be necessary only that the gas pass through a bed depth of 10 to 15 average particle diameters. On each suspended non-separating bed the depth of solids could be fairly shallow, such as less than a foot thick, and the pressure drop through each suspended bed would probably be not more than 5 inches of water gauge.

At the top of the vertical cylindrical retort is a measuring bin 12 which is charged with only enough raw, crushed coal so that its entire contents may be dumped into a charging lock 14, thus leaving bell valve 13 completely clear for unobstructed closing. After the raw coal is dumped into the charging lock 14 and valve 13 is closed, the coal may be pressurized by closing a valve 18 and opening a valve 16 allowing non-explosive flue gas to flow into the charging lock through conduit 17 at system pressure. In the pressurizing of charging lock with the flue gas, the purpose is not only to use a gas more readily available and cheaper than steam but the flue gas will be entirely non-explosive since it contains principally products of combustion. This will also be true of the discharge lock and is an important point, especially when handling hot char. If, for example, the discharge lock were pressurized with steam, hydrogen would be generated and a very explosive situation would result. Therefore, both the charging and discharge locks are pressurized with relatively inert flue gas to eliminate absolutely any possibility of an explosion.

It should be understood that the present mode of operation relates to the situation in which the process has been functioning for a length of time sufficient to build up in the system a source of available pressurized gases for pressurizing the lock 14. The starting up procedure will be described hereinafter.

Upon attaining system pressure in charging lock 14, a bell valve 15 in the bottom thereof may be opened so that the crushed coal from charging lock 14 is dumped upon the gyratory shelf feeder unit 10. After the crushed coal has been discharged through bell valve 15, the charging lock 14 may be depressurized by closing bell valves 15 and 16 and opening valve 18 which discharges the contained flue gases to the atmosphere. The charging lock may be then reloaded as before.

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The rate at which the crushed coal is fed off of any of the gyratory shelf feeder units 10 . . . 150 is a function of the amplitude and rate of gyration of each gyratory shelf feeder unit 10 . . . 150. These shelf feeder units are automatically controlled in a manner set out in my aforesaid co-pending application, now Patent 3,083,471.

In the concurrent flow drying and preheating zone A, the crushed coal is retained in very shallow moving beds on the gyratory shelves 10, 20 and 30. The gyratory shelf unit 40 carries a deep separating bed to separate the drying and preheating zone A from the distillation zone B. To supply the necessary heat for drying and preheating in zone A, hot producer gas is burned by injecting air into producer gas bypasses 92 through ports 91, thus causing combustion of producer gas. The products of combustion, at around 2500° F. in flue 92, are introduced to the top of zone A between gyratory feeder units 10 and 20.

It is important that the hot products of combustion flow concurrently with the crushed coal in the drying and preheating zone A. When concurrent flow is maintained, the coal containing its original surface moisture is not thermally altered by the very hot gases. On the other hand, if the flow of coal were to be countercurrent to the stream of hot gases, the coal would continuously contact fresh portions of very hot, dry gas and immediate thermal destruction of finer coal particles would occur.

After flowing concurrently with the crushed coal in the drying and preheating zone A, the flue gases and water vapor leave this zone through flue 38 at a temperature of about 700° F. These flue gases are valved to a let down stack (not shown) through a suitable valve 37. A heat exchanger 31 may be combined with flue 38 and the heat exchanger in turn may be integrated, for instance, with a heat recovery system for a boiler.

In the drying and preheating zone A, the coal is raised to a temperature just below that at which the thermal decomposition begins, which is about 650° F. The temperature of zone A is controlled by valve 37 which regulates the amount of producer gas and secondary air flowing through the zone from flue 92 and out flue 38. Further temperature control of zone A may be effected as necessary, by injection of water through injector 17 in the top of flue 92. The exhaust flue valve 37 and the water injector 17 are thermostatically controlled. Thus, the amount and the temperature of the gases flowing concurrently with the crushed coal may be precisely controlled and the coal may be brought to the desired temperature without danger of thermal decomposition in zone A.

The dried and preheated coal is then fed off the periphery of the feeder unit 40 into the distillation zone B containing gyratory feeder units and shelves 50 and 60. In distillation zone B, a thermal carrier fluid, which consists principally of hydrogen with the secondary volatile matters from zone C, is passed countercurrently through the descending coal, contained in the moving beds on gyratory shelves 50 and 60, to drive off the primary volatile matter through flue 45. The deep separating bed on feeder unit 40 allows the intake pressure of off-take flues 38 and 45 to be independently adjustable.

A fractionator 53 to which out-take flue 45 is indirectly connected is adapted to operate at system pressure. Between the fractionator 53 and the retort in flue 45 is a multiple bed catalyzer 49 connected by line 51 to the fractionator 53. The hot mixture of thermal carrier hydrogen and primary volatile matter and other volatiles will flow through the catalyzer 49 and the fractionator 53. This catalyzer could be a gas solid contactor such as shown in my copending application Serial No. 17,293 (Series of 1960), filed March 24, 1960, now Patent 3,083,471, utilized for this purpose.

The thermal carrier fluid will be present in an amount by weight of two to four times greater than the primary volatile matter from coal distillation plus the secondary

volatile matter from contact coking which passes out through flue 45. Therefore, the partial pressure of hydrogen will be high even at modest system pressures of 15 to 30 atmospheres. Without a catalyzer, at these pressures, relatively little hydrogenolysis will take place in the time available even though active hydrogenation does begin at about 750° F. In hydrogenating such materials, it has been established that maximum liquid product yield, at least in respect to gasoline and kerosene fractions, occurs between 750° and 950° F. when a suitable catalyst is present. Therefore, it is important that, in this system, a moving bed catalyzer be positioned immediately following the primary retort to take advantage of these temperatures.

The coincidental, autogenous hydrogenation which is effected upstream from the fractionator removes practically all of the troublesome functional groups of oxygen, sulfur and nitrogen from the tar and many of the alkenes are saturated. However, the lower ranked hydrocarbons require more severe treatment in order to fully hydrogenate these into reformer stock for the production of high octane gasoline.

As is shown on process flow diagram, secondary hydrogenation of the approximately plus 400° F. minus 900° F. fraction, passed through line 61, is performed in a fixed bed, high pressure (100 to 250 atmospheres) hydrocracker 63. It is preferred that the full stream returns to the fractionator 53 from the hydrocracker 63 through line 67 after pressure letdown and removal of the H₂, CH₄, and C₂ and C₃ gases in apparatus 66. (Uncondensable methane and C₂ and C₃ gases never constitute more than a few percent of the total gas stream because of the continuous re-cycling and cracking of a large part of the gas stream.)

The char fed off the periphery of gyratory shelf unit 60 into the open boundary between distillation zone B and contact coking zone C falls on gyratory shelf unit 70 and at this point, has reached a temperature of approximately 1200 to 1300° F. Re-cycled, heavy bottoms and other heavy oils that may become available are returned from the fractionator and are introduced into the system through conduit 65 and sprayed onto the hot char in the gyratory shelf 70 in order to establish contact coking and cracking of the heavy re-cycled fractions. Contact coking is completed before the char has passed over the periphery of the next lower gyratory feeder shelf 80. Contact coking implies the spraying of liquid hydrocarbons upon incandescent solids which are at a temperature of 1200 to 1300° F. The cracked volatiles from the contact coking pass upward through zone B where they are rapidly quenched to 900° F. as they mix with the primary volatile matter evolved in distillation zone B. It is of importance that the contact coking and the cracking of secondary volatiles is accomplished under substantial partial pressure of hydrogen and, therefore, the formation of excessive quantities of uncondensable gases is avoided. Also, in the contact coking zone C, de-sulfurization of the char and the recovery of fixed nitrogen and the balance of the uncombined hydrogen is effected.

The volatile matter and the thermal carrier gases leaving the distillation zone B through take-off flue 45 are at a temperature of around 900° F. In any case, the exit temperature is maintained sufficiently high as to insure against the condensation of vapors within the coal still column. The flow of thermal carrier fluid through the descending crushed coal and char in zones B and C is thermostatically controlled by a controlling valve (not shown) in the take-off flue 45, and accurate temperature control of the coking and distillation zones may be thus accomplished. A heat exchange unit (not shown) may be inserted in the flue 45 ahead of the thermostatic control valve for the purpose of absorbing some of the heat ahead of the fractionator 53.

The thermal carrier gases which accomplish the distillation in zones B and C enter zone C through bypass con-

duit 85 at a temperature of around 2500° F. after having first been heated by the hot char in heat transfer zone E below the combustion zone D. The recycled hydrogen or hydrogen and methane is introduced into heat transfer and methane cracking zone E through an intake 135 and passes countercurrently through extremely hot char carried on gyrating units 120 and 130 and then is bypassed around the combustion and gas producer zone D through bypass conduit 85.

Heat transfer and methane cracking zone E serves the two stated purposes. The thermal carrier gas is heated by absorbing some of the heat of the hot char carried on and fed downwards by gyratory shelf units 120 and 130 and, at the same time, methane is dissociated into hydrogen and colloidal carbon. Then the hydrogen, which is substantially all of the thermal carrier gas, is bypassed around the combustion zone D, through conduit 85, so that none of the products of combustion is entrained in the thermal carrier gas. In this way, the mixing of the products of combustion with the volatile matter evolved in the distillation zone B is further avoided.

The overhead from fractionator 53 is passed through line 131 to a condenser 133. The outputs from the condenser 133 are: liquor passed through line 136; naphtha passed through line 134 to a reforming operation (not shown); and gas which is passed through line 132 to scrubber 137. The scrubber removes the balance of the ammonia, hydrogen sulfide, and CO₂, and the remaining permanent gases pass through line 135 back into the coal still to be recycled into the heat transfer and methane cracking zone E. A valved bleeder 139 may be utilized to remove the excess gas from the circuit.

The char which leaves the contact coking zone C by being fed off the deep separating bed on gyratory shelf unit 90 falls into the combustion and gas producer zone D on the gyratory shelf unit 100 therein. This char is partially oxidized by introducing heated primary air through conduit 105 and the temperature of the char is raised to around 2800° F. Carbon dioxide is not stable in the presence of incandescent coke and almost all of it is promptly converted to carbon monoxide which forms the principal combustible product leaving the combustion zone. This hot producer gas leaves zone D through bypass flue 92 whereupon secondary air is introduced through conduit 91 and completes the combustion to furnish all of the necessary sensible heat for the drying and preheating zone A. Any excess producer gas may be withdrawn through conduit 93 and used for any suitable fuel purpose. To accomplish accurate temperature control in the combustion zone D, steam may be admitted through injector 105 together with the primary air in order that the temperatures do not become excessive to the extent of damaging the heavily insulated and liquid cooled apparatus.

The char entering the heat transfer and methane cracking zone E, being fed off the periphery of gyratory shelf unit 110, has been heated to approximately 2800° F. and, therefore, heat recovery to the thermal carrier gas is effected as noted above by passing recycled hydrogen or hydrogen and methane countercurrently through the beds of very hot char retained and fed over the periphery of gyratory shelf units 120 and 130. The methane and C₂, C₃ and C₄ hydrocarbon gases will be dissociated into hydrogen and carbon as they are heated to the temperature of the incandescent char, i.e., above 1800° F. Thus the heat transfer zone also functions as a hydrogen generator as noted above.

The char may then be fed off of a deep separating bed on gyratory shelf and feeder unit 140 into a total char gasification zone F. In zone F the char may be totally gasified by the admission of oxygen and steam at 151 for the production of synthesis gas. Alternatively, the char can be totally gasified by making producer gas with air and steam injected through injector 151. However, when no use for the gas is evident and the char has some value, the char may be discharged directly from zone E through

a discharge valve 160 into a discharge lock 170 and through valve 171 into a char receiver bin 180. In this situation the injector 151 would not be used. A control valve 147 in gas offtake flue 148 may be utilized to control the production of gas and the pressures thereof.

The discharge lock 170 may be pressurized by flue gas from a takeoff of flue 38 and this pressurizing is controlled by an inlet valve 162 and outlet valve 163 as well as by solid materials entrance and exit bell valves 160 and 171. Upon attaining system pressure in the discharge lock, valve 160 may be opened to allow the passage of char or ash into the discharge lock. Valves 160 and 162 are then closed and the lock is de-pressurized by opening valve 163 to the atmosphere. When the discharge lock 170 has been de-pressurized, the bell valve 171 can be opened and the char and ash can be discharged into an ash bin or char bin 180. Care should be exercised to see to it that the material accumulating in bin 151 below gyratory feeder shelf 150 is somewhat less than enough to fill the discharge lock 170 so that the valve 160 may operate freely. In order to close the valve 160 and insure its seating free of solid materials, the gyratory shelf unit 150 may be momentarily stopped. Another collimated gamma ray source and receiver would indicate ash or char depth in the lock.

The procedure for starting up the system will now be described. It is not necessary to provide stored hydrogen or hydrocarbon gases for starting up. However, some gases which are inactive with respect to coke should be available in order to purge the system to prevent explosion when starting up either hot or cold. Therefore, pressurized cylinders of carbon dioxide or nitrogen, which are inexpensive and convenient, may be utilized for this purpose.

It is noted that there are three separate gas offtakes, ducts or flues 38, 45 and 148. Therefore, there are three separate systems of gas circulation while the solids follow one continuous straight path. One fluid circuit includes zones D and A and is controlled by outlet valves 37 of duct 38. The second fluid circuit includes zones E, C and B and the rate of flow therethrough is controlled by the rate of circulation of the thermal carrier gas through valve 47. The third fluid circuit is the total gasification zone F only. Circulation through this fluid circuit is controlled by valve 147.

All gas and air inlets are connected to large headers (not shown) which are maintained substantially at constant pressure irrespective of flow rates. System pressure in the second fluid circuit, zones E, C, and B, which is a closed circuit, is maintained by a compressor (not shown) at a few inches of water gauge greater than the combustion air pressure header in order that no air be inadvertently mixed with the thermal carrier hydrogen nor with the primary volatile matter. For starting up purposes, a non-caking material, such as coke or anthracite or any other non-caking solid fuel, is distributed throughout the system upon the various gyrating shelves and to the proper depth on each shelf to create the various suspended and separated beds as described above. To accomplish distribution of the solids on each gyrating shelf, cold air is first supplied from a common header at a pressure of approximately 5 atmospheres. The flow of the air during the pre-start up solids distribution will be proportioned to the three fluid circuits and will be in direct relation to the full load flow. With pressure controlling means, such as manometers described in aforesaid co-pending application Serial No. 17,293 (Series of 1960), filed March 24, 1960, now Patent 3,083,471, connected above and below each gyrating shelf, the rate of gyration on each shelf will respond to the pressure drop through individual beds. When there is no pressure drop across the bed and there is no material thereon, the gyrating shelf will be stationary or can be made to rotate at its lowest possible rate. When the pressure drop across any bed exceeds a predetermined maximum, the rate of

gyration of that particular bed will automatically increase quite substantially in order to reduce the suspended bed depth. The foregoing is described in the aforesaid co-pending application.

After the various beds have received sufficient material to come into equilibrium with the preset pressure drop thereacross, a gas which is non-reactive to coke at system temperatures, such as nitrogen, carbon dioxide or other gas, is introduced at air inlets 151 and 106 and re-cycled gas inlet 135 and all air is purged from the system. Fluid circuits 2 and 3 will each become closed circuits and recirculate inert gas during the start up.

In order to ignite the system, all gyratory shelves are momentarily stopped and the system pressure is reduced at atmospheric. A number of oxyacetylene torches are inserted through apertures 84, and the combustible solids suspended on shelf 100 are ignited in a number of places. Suitable peep sights may be provided adjacent the ignition ports for observing ignition. As ignition of the coal suspended on shelf 100 becomes visibly evident, air is gently admitted through inlet 106. As ignition is observed through the peep sights to be continuous around the periphery of bed 100, more and more air is admitted until combustion proceeds vigorously. The ignition torches are then withdrawn and ports 84 are closed. An ignition torch is inserted into the producer gas bypass at 107 and secondary combustion is started at this point. The ignition may be observed by peep sights conveniently placed adjacent combustion area 107. As a refractory lining (not shown) of the producer gas bypass 92 is observed to rise in temperature above 2000° F., the ignition torch is withdrawn and the ignition ports closed. The flow of air into fluid circuit #1 at inlets 106 and 91 is controlled by the outlet valve 37 with some adjustment at inlet 91 in order that the solids resting on shelf 40 may be heated to a temperature of about 600° F. The exhaust flue gases will rise to a temperature of the order of 700° F.

After igniting the coal on shelf 100 and before pressurizing the system above atmospheric, the coal resting on bed 150 is also ignited in the same manner and through suitable ports as was bed 100, and air is admitted in increasing quantities through inlet 151 as combustion is observed to proceed on bed 150. The flow of air into inlet 151 is adjusted to effect complete combustion and gasification of the carbonaceous materials. The producer gas is bled out at start up.

As combustion proceeds on bed 100, the temperature of the partially consumed char will rise to approximately 2800° F. by controlling this combustion. The circulating inert gases entering the system at said inlet 135 and leaving through outlet 45 will quickly rise in temperature. As the temperature of the fluids leaving through duct 45 rises toward 700° F., distillation of coal in zones B and C begins and the entire system is then in operation at reduced pressure.

Full operating capacity will be attained at any given system pressure when (1) the superficial fluid velocities in the empty vertical cylinder are in the range of one-quarter to one foot per second; (2) the temperature of the descending material on bed 40 has risen to 650° F.; (3) the temperature of the material of the bed 70 is 1200° F.; (4) the temperature of the solids on bed 90 is 1500° F.; (5) the temperature of the solids on bed 100 is 2800° F.; (6) the temperature of the solid material on bed 140 is about 1000° F.; (7) the ash falling off the periphery of shelf 150 contains a minimum of solid carbon; and (8) there is a minimum of carbon dioxide in the producer gas leaving by duct 148.

An illustrative but non-limiting example of the above described process operating on one particular type of coal is set out below:

Example

The example described below is for the system of this

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invention utilizing a western coal with the following, as received, approximate analysis, tabulated as follows:

	Percent
Moisture	5.6
Volatile matter	44.2
Fixed carbon	44.6
Ash	5.6

The approximate coal analysis on a dry basis is:

	Percent
Moisture	0.9
Volatile matter	46.5
Fixed carbon	46.7
Ash	5.9

The ultimate analysis of the dried coal is:

	Percent
Hydrogen	5.9
Carbon	74.3
Nitrogen	1.5
Oxygen	11.5
Sulfur	0.9
Ash	5.9

This coal will be crushed to pass through a slotted screen of aperture $\frac{1}{2}$ inch by 3 inches. Other screen sizes could be selected for various types of coal.

The gross heat value of this dried coal is 13,500 B.t.u. per pound. The coal is considered weakly caking, although a strongly caking coal could also be treated by the system of this invention.

The carbonization of coal begins just below 700° F. and most coals can be safely heated to 600° F. without evolution of important quantities of primary volatile matter or without the coal becoming sticky. Caking coals pass through an intumescent zone between 700° and 900° F. and low temperature carbonization is finished at about 900° F. Practically all coals pass through a second gas evolution stage between 1200°–1500° F. during which temperature range large quantities of hydrogen are evolved.

The as-received coal, crushed through a screen as described above, is charged into the apparatus and proceeds through the vertical retort, as described above.

In zone A, the drying and preheating zone, the coal is preheated to about 650° F. and the moisture is reduced from 5.6% to 0.9%. Some carbon dioxide is evolved in this drying and preheating section and is removed with the flue gas.

Below separating bed 40, the coal enters the distillation zone B where it comes into contact with the hot thermal carrier gas consisting principally of hydrogen. By the time the coal has passed shelf 60, most of the primary volatile matter has been distilled off and the temperature of the char rises to about 1200° F. at shelf 70.

Referring to shelf 60, the analysis of the products of carbonization at 900° F. are, on a moisture and ash-free basis, as follows:

	Percent
Char	67.4
Water, formed in the primary volatile matter	4.9
Tar	19.7
Light oil, distilling below 400° F.	1.6
Gas	6.4

The analysis of the non-condensable section of the primary volatile matter, i.e., permanent gas, is as follows:

	Percent
Carbon dioxide	14.2
Illuminants	2.0
Carbon monoxide	19.7
Hydrogen	12.7
Methane	51.4
Ethane	8.6

The calorific value of the gas is 814 B.t.u. per cubic foot.

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The approximate analysis, on a moisture and ash-free basis of the char reaching shelf 60 at a temperature of 900 to 1000° F., is as follows:

Volatile matter	percent... 19.9
Fixed carbon	do... 80.1
B.t.u./per pound moisture free ash-free basis	B.t.u./pound... 14,520

The moisture and ash-free ultimate analysis of the same char reaching 900° F. is as follows:

	Percent
Hydrogen	3.6
Carbon	86.6
Nitrogen	2.1
Oxygen	6.7
Sulfur	1.0

Shelf 70 is the beginning of contact coking in zone C and the heavy re-cycled bottoms are sprayed on the hot char retained on this shelf. The sensible heat of the hot char causes the volatile matter to vaporize and certain parts of the bottoms to carbonize and adhere to the hot char.

By the time the char has reached shelf 90, it has risen in temperature to 1500° F. and essentially all of the remaining volatile matter (90–95%) has been evolved in the second stage of carbonization.

In passing through zone D, where the char is partially burned to carbon monoxide and air is injected at inlet 106, the char may reach the temperature of 2800° F.

In passing over the periphery of gyrating shelf 110, the hot char at 2800° F. is cooled by the thermal carrier gas injected at inlet 135 and, when leaving zone E over gyrating shelf 140, the char has been cooled to about 1000° F. while transferring most of its sensible heat to the thermal carrier gas.

The only temperature control in the total gasification zone F is obtained by injecting water or steam with the air inflow change when making producer gas and this is for the purpose of keeping the temperature below that which would affect the insulated and fluid cooled apparatus.

When total gasification is effected in zone F, only ash is discharged from the system.

It can thus be seen that applicant has disclosed a novel system for the continuous distillation, gasification and carbonization of coal, which system is completely flexible and has a number of unique advantages accruing from the fact that hydrogen is used as a thermal carrier fluid and the products of combustion are not mixed with the primary volatile matter.

One of the outstanding and unique advantages of the above described distillation system is the fact that practically all of the hydrogen originally present in the coal is distilled from the coal and is conserved at system pressure and is mixed only with secondary volatiles from contact coking of the re-cycled heavy bottoms and with the primary volatile matter from coal distillation. Also, by re-cycling methane and hydrogen as thermal carrier gases passing through the beds of incandescent coke in zone E, methane (as well as C₂, C₃ and C₄ gases) is cracked into hydrogen and the resulting thermal carrier gas is almost entirely composed of hydrogen gas. Hydrogen in the volatile matter takeoff duct 45 is, therefore (due to the sensible heat requirement of the thermal carrier fluid), several times the weight of the volatile matter and its partial pressure is relatively high.

Hydrogenation of heavy oils is normally an expensive and complicated process requiring a great deal of equipment. In the subject system, effective hydrogenation is performed without the usual hydrogen purification system or a separate hydrogen manufacturing system. Autogenous hydrogenation is accomplished in the system of this invention by simply leading the combined thermal carrier hydrogen and volatile matter through beds of appropriate catalysts, such as alumina supported cobalt

molybdate. Further, by re-cycling the higher boiling range cuts, extensive hydrogenation can be accomplished without imposing the severe conditions of very high pressures. However, for more complete hydrogenation of the lower ranked tar compounds, the mixture of the thermal carrier hydrogen and the volatiles may be raised from the preferred system pressure of from 20 atmospheres to 100 or more atmospheres and passed through an appropriate fixed bed catalyzer at some closely controlled temperature between 750 and 850° F., depending upon the catalyst, space volume, etc.

It is extremely important to note that this coal carbonization and coincidental hydrogenation process of this invention requires no outside hydrogen when treating coals which have an oxygen to hydrogen ratio lower than 3 to 1 when dried.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to the disclosed preferred embodiment, it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its operation may be made by those skilled in the art without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. A process for the continuous thermal treatment of coal for the recovery of values therefrom, comprising; introducing crushed coal into a vertical retort having a series of gas isolated zones and operable at substantial pressures, distilling primary volatile matter from the coal in a distillation zone of said retort while utilizing hydrogen at high temperature and system pressure as a thermal carrier fluid for accomplishing said distillation, feeding the coal to a lower gas separated zone of said retort and partially oxidizing the char remaining from said distillation step while preventing the combustion products of said oxidation step from entering the distillation zone, feeding the oxidized hot char to a lower gas separated zone of said retort and passing methane through the partially oxidized hot char to disassociate the methane into hydrogen and carbon, and passing the hot hydrogen so produced at system pressure into the distillation zone to be utilized as the thermal carrier gas.

2. A process for continuous distillation gasification and carbonization of coal by thermal treatment that comprises; positively feeding crushed coal vertically downward through a series of separate gas isolated zones in a pressurized vertical internally heated retort, the zones being gas separated by the maintenance of solid materials of coal and char in sufficient quantities between the zones to prevent substantial passing of gases from zone to zone, drying and preheating the coal in a top zone of said vertical retort by means of gases produced within the retort, distilling primary volatile matter from the dried and preheated coal in a distillation zone below the drying and preheating zone while utilizing hydrogen as a thermal carrier fluid, partially oxidizing the volatilized char in a zone below said distillation zone while preventing the combustion products of said oxidation step from entering the volatilization zone and passing them to the drying and preheating zone to accomplish the drying and preheating, feeding the partially oxidized hot char to a lower gas separated zone and passing methane countercurrently through the partially oxidized hot char to disassociate the methane into hydrogen and carbon, and passing the hot hydrogen so produced at system pressure into the distillation zone to be utilized as a thermal carrier gas.

3. A process as defined in claim 2 further comprising introducing heavy bottoms in the lower portion of said distillation zone, and coking said heavy bottoms by contact with hot, solid char in the lower portion of said distillation zone.

4. A process for continuous thermal treatment of coal

for the recovery of values therefrom comprising; feeding coal downwardly through a series of gas separated zones in a pressurized vertically internally heated retort, maintaining the gas separation between the zones by carrying solid coal and coal product materials in sufficient quantities on gyrating shelves between said zones to prevent substantial passing of gases from zone to zone, drying and preheating coal in a top zone of said vertical retort, distilling primary volatile matter from the so dried and preheated coal in a distillation zone separated from said drying and preheating zone, and simultaneously coincidentally mildly hydrogenating by using hydrogen at high temperature and substantial pressure as the thermal carrier fluid in said distillation zone, feeding the partially volatilized char to a lower zone and partially oxidizing the same while passing the combustion products of said oxidation step concurrently through said drying and preheating zone to furnish all the heat necessary for drying and preheating and thereby also preventing the mixing of the combustion products of said oxidizing step with the products of distillation, feeding the so oxidized hot char to a lower zone and passing methane countercurrently through the partially oxidized hot char to disassociate the methane into oxygen and carbon, passing the hot hydrogen so produced at system pressure into the distillation zone to be utilized as the thermal carrier gas.

5. A process as defined in claim 4 further comprising introducing heavy bottoms in a lower portion of the distillation zone and contacting said heavy bottoms with hot char in the lower portion of the distillation zone for contact coking of said heavy bottoms, and selectively introducing an oxygen containing gas and steam for totally gasifying the char in a zone below the zone in which methane cracking and heat transfer step is performed.

6. A process for the continuous treatment of coal by thermal means for the recovery of values therefrom comprising; introducing coal to and feeding the coal vertically downward within a continuous pressurized retort having a plurality of gas separated zones and feeder shelf units vertically spaced therein, separating the zones from one another by carrying enough materials on selected ones of said feeder shelf units to prevent gases from readily flowing therethrough, drying and preheating the coal as it is fed vertically downward in the first of said zones by heat exchange with hot gases flowing concurrently therewith, distilling primary volatile matter from the preheated and dried coal in the next lower of said zones while utilizing hydrogen at substantial pressure as a thermal carrier gas passing countercurrently therethrough, feeding the coal further downward into the next zone and oxidizing the partially volatilized char in a combustion and gas producer zone by the introduction of primary air, passing the products of combustion around the distillation zone and utilizing them for drying and preheating the coal in the aforesaid concurrent flow drying and preheating zone, feeding the partially oxidized hot char from the combustion zone downwardly to a heat transfer and methane cracking zone, introducing hydrogen and methane to the hot char to flow countercurrently through the hot char in said heat transfer and methane cracking zone for transferring the heat to the hydrogen from the hot char and for cracking the methane into carbon and hydrogen in the presence of hot char, then bypassing the high temperature hydrogen around the combustion and gas producer zone into the distillation zone to be used as the thermal carrier fluid, and selectively making synthesis gas by passing oxygen and steam through the char fed downwardly from the heat transfer and methane cracking zone into a total gasification zone.

7. A process for continuous thermal treatment of coal for the recovery of values therefrom comprising; introducing coal to be treated to the top of a vertical continuous pressurized internally heated vessel having a plurality of gas separated zones and a plurality of vertically spaced feeder shelf units therein, providing for gas

separation of the zones from one another by carrying enough solid materials of coal and coal products on selected feeder shelf units to prevent gases from readily flowing from zone to zone, feeding the coal downwardly to a drying and preheating zone and therein drying and preheating the coal by passing hot gases concurrently therethrough, feeding the coal downwardly into another gas separated zone and distilling volatile matter from the preheated dried coal in said distillation zone while utilizing hydrogen at substantial pressure and high temperatures as a thermal carrier gas passing countercurrently to the coal being fed vertically downward by said feeder shelf units, introducing heavy bottoms into a contact coking area in a lower portion of said distillation zone and contacting said heavy bottoms with hot char in the distillation zone for the coking of said heavy bottoms, feeding said partially volatilized char into a gas separated combustion and gas producer zone and oxidizing the char therein by the introduction of primary air, while taking off the products of combustion and bypassing them around said distillation zone and passing them countercurrently through said coal in said drying and preheating zone to furnish the heat necessary for drying and preheating, feeding the partially oxidized hot char from the combustion zone to a gas separated heat transfer and methane cracking zone therebelow, introducing methane to said hot char fed from the combustion zone countercurrently therewith for transferring the heat from the char and for cracking the methane in the presence of the hot char into carbon and hydrogen, passing the hot hydrogen at system pressure upwardly around the combustion and gas producer zone into the distillation zone to be utilized as the thermal carrier fluid, feeding the hot char from the heat transfer methane cracking zone into a total gasification zone and introducing an oxygen containing gas and steam thereinto for total gasification and for the purpose of making synthesis gas.

8. A process for the continuous thermal treatment of coal for the recovery of values therefrom, comprising: introducing crushed coal into the top of a vertical retort housing a series of gas separated treating zones, drying and preheating crushed coal in a top zone, introducing said coal to a lower distillation zone therein and contacting said coal in said zone with a stream of thermal carrier gas comprising principally hydrogen, heating said coal by said contact to a temperature in the range of from 700° F. to 950° F. thereby distilling primary volatile matter from said coal by said heating and recovering said thermal carrier gas admixed with said primary and secondary volatile matter, further heating said coal in said distillation zone by contact with said thermal carrier gas to temperatures in the incandescent range of from 1200° F. to 1300° F. to char said coal and spraying on said coal a liquid heavy bottoms fraction derived from the distillation products of said coal to accomplish contact coking, introducing the partially charred coal into a lower zone and therein burning said charred coal by contact with a stream of air and raising the temperature of the coal in zone three to approximately 2800° F., taking off the products of combustion and utilizing the heat thereof for said drying and preheating, introducing said charred coal at about 2800° F. into a lower heat transfer and methane cracking zone in said retort, introducing gas comprising hydrogen and methane into said last recited zone, thereby heating the gas and cracking the methane to hydrogen and colloidal carbon by heat exchange with said hot charred coal, utilizing said hot hydrogen gas thereby produced as said thermal carrier gas in said distillation zone and withdrawing and recovering charred coal from said heat transfer and methane cracking zone and said thermal carrier gas and entrained primary and secondary volatile matter from said distillation zone.

9. A process for the continuous treatment of coal for the recovery of values therefrom comprising: introducing a charge of crushed coal into the top of a vertical retort

including a series of gas separated treating zones all at substantial system pressures, causing said charge of crushed coal to cascade by gravity fall through a drying and preheating zone, contacting said crushed coal in said zone with a concurrently flowing stream of hot gases to dry said coal and preheat said coal up to a temperature of approximately 650° F., passing said charge of dried and preheated coal from said drying and preheating zone to a distillation zone through said gas separation barrier maintained between all of said zones, contacting said crushed coal in said distillation zone with a countercurrently flowing stream of thermal carrier gas principally comprising hydrogen and secondary volatile matter distilled from the coal in a lower region of the retort, heating said crushed coal in said distillation zone to a temperature in the range of from 750° F. to 950° F. to distill primary volatile matter from the coal, cascading said crushed coal into a contact coking area in free vapor communication with said distillation zone and therein contacting said crushed coal with a countercurrently flowing stream of thermal carrier gas, charring said devolatilized coal by heating to incandescence at a temperature in the range of from 1200° F. to 1300° F. and spraying onto said incandescent coal while in said contact coking area liquid heavy bottoms thereby generating secondary volatile gaseous matter, passing said charred coal from said contact coking area to a combustion zone in said retort therebelow through another gas separation barrier between said combustion zones, oxidizing said charred coal in said combustion zone by contacting with a stream of primary air thereby raising the temperature of the charred coal to approximately 2800° F., passing the combustion products concurrently with said coal in said drying and preheating zone thereby furnishing the heat for the drying and preheating, cascading the charred coal from said combustion zone to a heat transfer and methane cracking zone through another gas separation barrier maintained between all said zones, introducing a stream of gases principally comprising hydrogen and methane from outside said retort into said heat transfer and methane cracking zone to flow countercurrently with said charred coal thereby heating said gases and cracking the methane content to hydrogen and colloidal carbon by contact with said charred coal in said zone, employing said hydrogen gas so produced as said thermal carrier gas by conducting said gas upwardly from said heat transfer and methane cracking zone directly to said distillation zone without passing through said combustion zone, and cascading said charred coal from said heat transfer and methane cracking zone into a gas separated total gasification zone and gasifying said charred coal in said last recited zone by contacting said charred coal with oxygen and steam to produce synthesis gas, continuously withdrawing and recovering gasified charred coal and synthesis gas from said total gasification zone, continuously withdrawing from said distillation zone mixed gases comprising said thermal carrier gas, primary gaseous volatile matter and said secondary gaseous volatile matter, introducing said mixed gases into a catalyzer, hydrogenating the non-hydrogen content of said mixed gases in said catalyzer, fractionating the products issuing from said catalyzer, recycling at least some of the liquid heavy bottoms fraction to said contact coking area in said retort for spraying onto said incandescent coal, and recycling at least a portion of the gaseous fraction principally comprising hydrogen and methane to said heat transfer and methane cracking zone in said retort for heating and cracking of the methane into hydrogen for use throughout the process as said thermal carrier gas at system pressure and high temperature.

10. A process as defined in claim 9 wherein the combustion products from said combustion zone are burned with air and recycled through said drying and preheating zone flowing concurrently with the crushed coal being fed downwardly therein to furnish the drying and preheating heat transfer gas, withdrawing said drying and preheating gas and entrained water vapor from said zone above the gas

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separation barrier between said drying and preheating zone and said distillation zone.

11. A method for the continuous distillation of coal containing chemically troublesome function groups including oxygen, sulfur and nitrogen and for the autogenous hydrogenation of the condensable volatiles therein comprising; continuously distilling the volatile matter from the coal while providing that the coal is falling freely vertically downward within an internally heated pressure retort which is pressurized at a pressure within the range of 15-30 atmospheres accomplishing the distillation by contacting the freely falling coal only with a preheated gas consisting essentially of hydrogen as a thermal carrier fluid passing countercurrently thereto, preheating the thermal carrier hydrogen in an isolated section of the same retort, and passing the mixture of thermal carrier hydrogen and distilled volatile matter from the coal to a catalyzer for autogenous hydrogenation of the volatile matter and hydrogenating said volatile matter in said catalyzer at substantially system pressure and at a temperature between 750 and 900° F., thereby eliminating said chemically troublesome functional groups including oxygen, sulfur and nitrogen by the coincidental continuous hydrogenation of the primary volatile matter as it is distilled from the coal at system pressure.

12. A method for the continuous distillation of coal containing chemically troublesome functional groups including oxygen, sulfur and nitrogen and for the autogenous hydrogenation of the condensable volatiles therein comprising; feeding coal for free falling in a pressurized vessel, distilling the volatile matter from coal by contacting the free falling coal in the pressurized vessel at a pressure of

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15 to 30 atmospheres with only a preheated thermal carrier fluid consisting essentially of hydrogen heated to a temperature sufficient to accomplish the distillation, passing the admixture of thermal carrier fluid hydrogen and the distilled volatile matter of the coal from the system at system pressure to a catalyzer for autogenous catalytic hydrotreating at a temperature within the range of 750° to 900° F., and contacting the admixture of thermal carrier fluid and distilled volatile matter from the coal at said pressure and temperature with a catalyst in said catalyzer for a short period of time to remove substantially all of said chemically troublesome functional groups including oxygen, sulfur and nitrogen by hydrogenation in an atmosphere consisting essentially of hydrogen.

13. A process as defined in claim 12 wherein the amount of thermal carrier fluid by weight will be two to four times greater than the primary volatile matter from coal distillation as passed to the catalyzer.

14. A process as defined in claim 13 further comprising, fractionating the products after the catalytic hydrotreating, and recycling at least a portion of a gaseous fraction to the coal still, and cracking at least a methane portion of the recycled gaseous fraction in an isolated section of the pressurized vessel to produce the thermal carrier fluid.

References Cited in the file of this patent

UNITED STATES PATENTS

1,960,972	Grimm et al. -----	May 29, 1934
2,657,124	Gaucher -----	Oct. 27, 1953
2,662,005	Evans -----	Dec. 8, 1953
2,934,476	Zvejnieks -----	Apr. 26, 1960