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CONVERSION OF HEAVY HYDROCARBONACEOUS MATERIALS IN THE PRESENCE OF SUBDIVIDED COKE

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FIG. 1

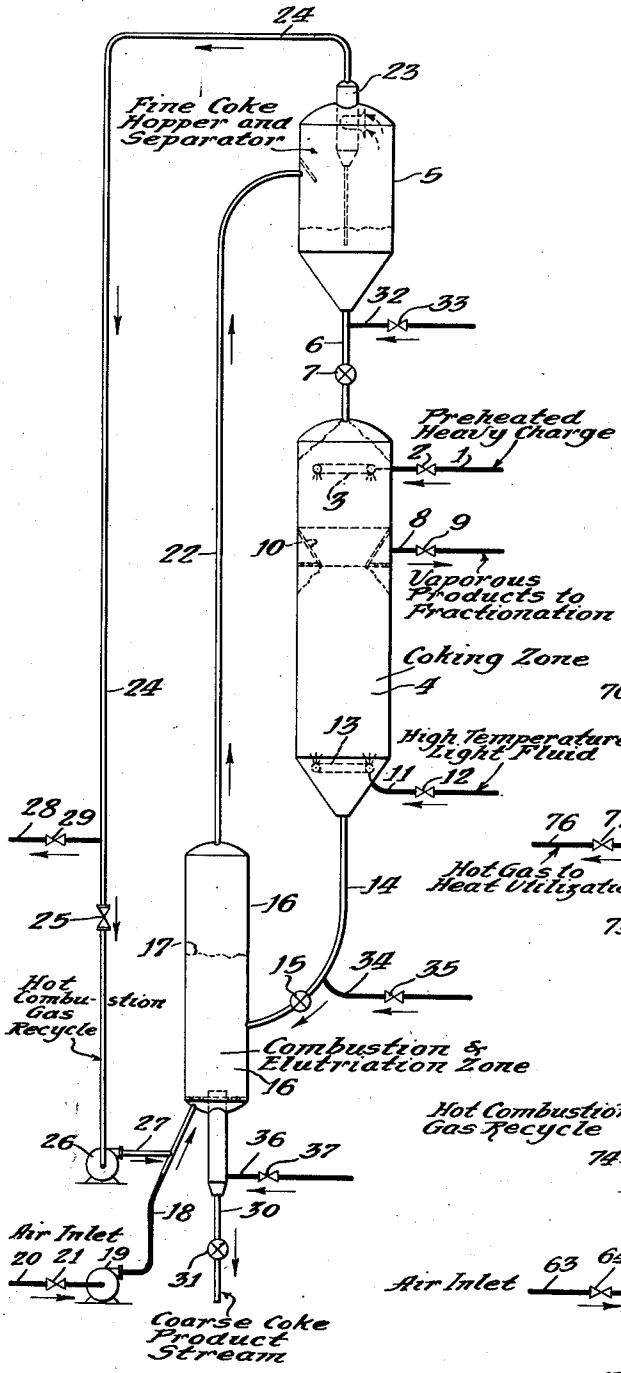
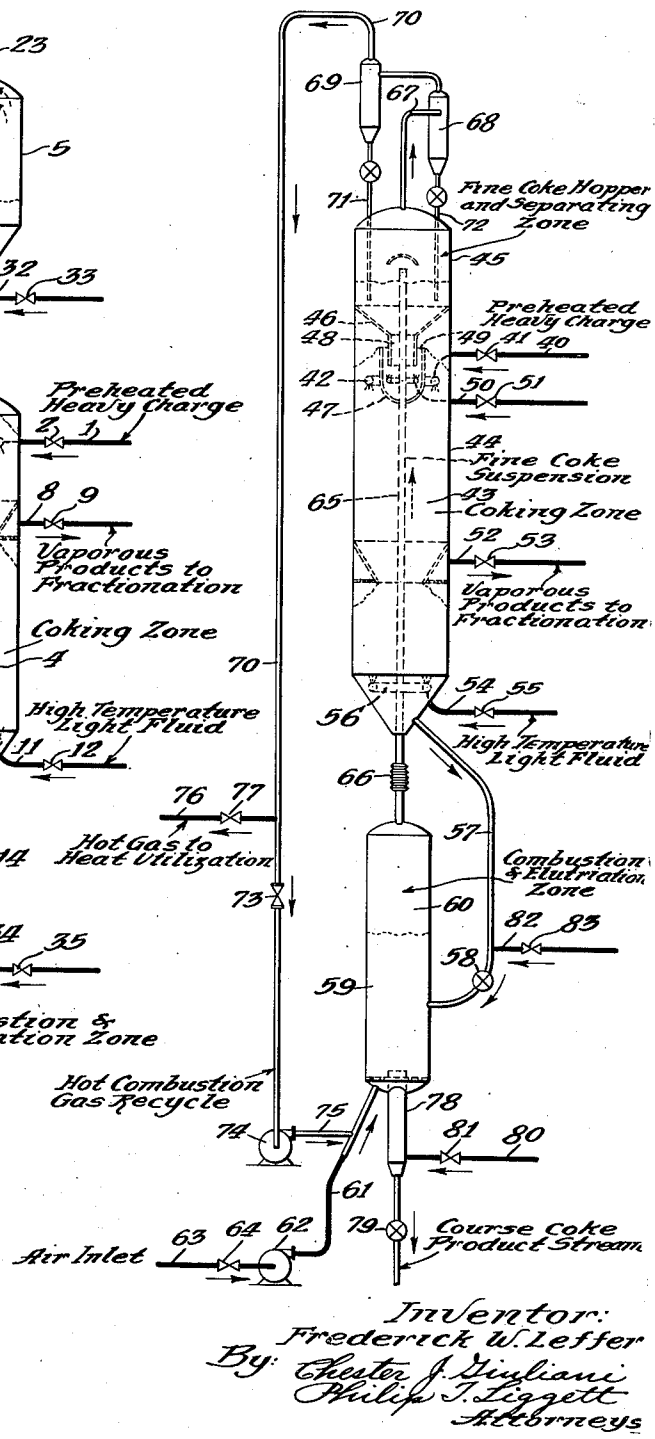


FIG. 2



Inventor:
Frederick W. Leffer
By: Chester J. Giuliani
Philip T. Liggett
Attorneys

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CONVERSION OF HEAVY HYDROCARBONACEOUS MATERIALS IN THE PRESENCE OF SUBDIVIDED COKE

Frederick W. Leffer, Riverside, Ill., assignor to Universal Oil Products Company, Chicago, Ill., a corporation of Delaware

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This invention relates to an improved method and means for effecting the conversion of heavy hydrocarbonaceous materials and particularly the coking of relatively heavy hydrocarbon oil streams in the presence of subdivided coke, to produce more desirable lighter hydrocarbon fractions and net usable coke. More specifically, the present invention is directed to the cracking and coking of heavy residual petroleum oils and tars in a moving or fluidized bed type of operation, with heat being supplied to the coking zone by a continuous recycle stream of heated coke particles, and it provides an improved method and means for effecting the separation of the resulting coke particles so that only the finer coked particles are returned to the coking zone to supply heat thereto and to provide nuclei for the formation of additional coke.

Many of the recently disclosed continuous types of coking operations of the moving or fluidized bed type, have been designed in a manner which provides for transfer of both hot combustion gases and coke particles to the coking zone to aid in the distillation and coking of the charge stream. The hot combustion gases within the coking zone give rise to the contamination of the desired condensable conversion products by undesired oxygenated impurities, as well as considerable quantities of uncondensable gases. Also, many of the processes make use of mechanical crushing or other mechanical sizing and separating means to provide for the return of finely divided particles to the coking zone, with the disadvantages accompanying the continuous operation of the mechanical apparatus, as well as high installation costs.

It is a principal object of the present invention to provide a simple and efficient method and means for effecting the separation of the coke produced and the return of only the finer of the particles to the coking zone as nuclei and as a heat supplying medium.

It is also an object of the present invention to provide for the continuous separation of the coke particles passing to a combustion and devolatilizing zone from the coking zone, simultaneously with a heating of these particles by the burning of a portion thereof in an improved manner which assures a continuously replenished accumulation of heated finer coke particles in a collecting zone or reservoir wherefrom a stream of the hot fine coke particles may be returned to the coking zone at a rate controllable independently of the rate of introduction of reactant fluids to this zone.

It is a further object of the present invention

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to provide a method and means for effecting the transfer of the fine coke particles and combustion gases, resulting from the coke separation and heating in the combustion and burning zone, from this zone to a fine coke collecting zone in a manner permitting maximum preservation and utilization of the heat contained in these combustion gases and fine particles simultaneously with the feeding of the separated hot fine particles substantially by gravity flow to an elevated portion of the coking zone.

It is still another object of this invention to provide an improved method and means for simultaneously minimizing the coke combustion and controlling the separation in the combustion zone by supplying to the latter an oxygen-containing gas stream containing regulated amounts of a hot relatively inert gas produced and separated within the system.

Principally, the improved method for effecting the conversion of a heavy hydrocarbonaceous charge stream into more valuable lower boiling products and coke according to this invention comprises, introducing a stream of heated fine coke particles into a confined coking zone and therein contacting them with the heavy hydrocarbonaceous charge stream at a temperature at which this charge stream is converted into lower boiling vaporous products and coke with the transformation of at least some of fine coke particles into coarser particles, continuously withdrawing resulting vaporous conversion products from the coking zone and passing them to a fractionating zone, discharging a stream of mixed fine and coarser coke particles from the coking zone into a fluidized bed of coke particles maintained in the lower portion of a separate confined combustion zone, introducing a gas stream containing free oxygen into the lower portion of the fluidized bed and therein burning a portion of the coke and heating the residual portion of the coke particles while simultaneously passing the oxidizing gas stream and resulting combustion gases upwardly through the fluidized bed at a rate at which fine coke particles are elutriated from the coarser particles and are entrained in the gas mixture disengaging from the fluidized bed into the upper portion of the combustion zone, passing the resulting hot fine coke suspension into a separate confined collecting zone of higher elevation than the coking zone, separating the suspension in the collecting zone at a temperature substantially above the average temperature maintained in the coking zone into combustion gases which are continuously with-

drawn from the upper portion of the collecting zone and into fine coke particles which are collected in the lower portion thereof, passing a stream of the separated fine coke particles from the lower portion of the collecting zone substantially by gravitational flow as the aforesaid heated fine coke particles into the coking zone, and withdrawing a stream of relatively coarse particles from the lower portion of the fluidized bed and the combustion zone as net coke production of the process.

In a preferable operation, the heavy hydrocarbonaceous feed stream is preheated to a high temperature, precluding cracking or coking within the transfer line to the coking zone, say to the order of 825° F. for a reduced crude charge and generally within the range of from about 750° to about 850° F., and is commingled with the hot finely divided coke particles in the top portion of a descending bed of coke particles maintained within the cracking and coking zone. At the desired high temperature conditions, the heavy hydrocarbonaceous charge stream is substantially non-viscous and is cracked and coked with a minimum of agglomeration of particles. Additional coke may be formed by the deposition of a thin film-like layer over the coke nuclei introduced to the zone, while in addition new nuclei or particles may be formed during the ensuing conversion and the descent of the dense bed of particles through the conversion and coking zone. Where the heavy charge stream is introduced to the upper portion of a descending relatively compact moving bed of coke particles extending through substantially the entire height of the coking zone, the resulting vaporous fractions are preferably withdrawn from an intermediate or lower portion of the descending bed of particles. However, when operating with a fluidized dense phase bed of coke particles in the conversion zone, the heavy charge stream is introduced preferably at an elevated point of such bed below the upper level of the latter and the vaporous conversion products are discharged from the fluidized bed into the upper portion of the conversion zone to be thereafter directed from the latter to fractionation.

In accordance with a preferred operation, the fine coke particles are introduced to the upper portion of the coking zone to maintain the descending bed of particles, and are supplied thereto at a high temperature within the range of from about 1000° to about 1100° F., while the average bed temperature in the conversion zone is maintained at about 925°–965° F., and all or at least a considerable portion of the necessary heat for effecting the cracking and coking of the charge stream is introduced in this manner by the supply of heated fine coke particles. However, a desirable operation also utilizes a light high temperature gaseous or vaporous stream within the lower portion of the coking and conversion zone to supplement the supply of reaction heat and to aid in the deasphalting and drying of the resulting coke formation and in the substantially complete removal of valuable low boiling hydrocarbon fractions absorbed or entrained with the descending bed of particles so that a substantially asphalt-free hard coke reaches the bottom portion of the coking zone in a freely flowing particulated state. A gasiform material which will not combine with the desired vaporous product stream in a detrimental manner, and more particularly a gasiform material practically devoid of free oxygen, or a vapor stream which may be readily condensed and separated from the desired product fractions, is preferably used as the high temperature fluid stream within the lower portion of the conversion zone and may be introduced thereto at a suitable temperature of from about 950° to about 1100° F. Superheated steam may be used to advantage for this purpose, or alternatively, a light refractory hydrocarbon fraction, such as a distillate or light reflux condensate recovered from the fractionating zone receiving the vapors from the coking and cracking step provides a desirable light charge material for this purpose.

Inasmuch as the continuous coking operation of the present type effects coke deposition, at least in part, as an additional layer to coke particles present in the coking zone, and there is net coke production in addition to the formation of desired lower boiling fractions which are particularly suitable for the subsequent conversion to gasoline and fuel oil by catalytic cracking processing, the substantially ideal operation provides for the withdrawal of coarser particles from the unit and the return of the finer particles to the coking and conversion zone as the heat carrying material and as nuclei for the formation and deposition of the additional coke. An exacting separation of the fine from coarse particles would, in general, require the utilization of automatic mechanical sizing or screening of particles or other equivalent step or steps in a continuous cyclic system. The present invention utilizes advantageously a combined method of burning and heating and elutriation of particles within a separate confined combustion zone, such that the finer of the coke particles that are elutriated from the bed in the combustion zone are suspended and entrained with the resulting combustion gases for elevation to a point above the coking zone, whereby they may be subsequently introduced to the upper portion of the latter zone continuously and at a rate controllable independently of the rate of supply of the heavy hydrocarbonaceous charge to the coking zone, and also independently of the supply of gasiform high temperature fluid to the lower portion of the latter, to permit therein the aforedescribed preferable operation of the coking and cracking step.

In order to effect the desired elutriation within the combusion zone, gas must be passed through the descending bed of particles therein in a sufficient quantity and at a sufficient velocity to separate and entrain the desired finer particles in a fluidized transfer to the elevated fine coke collecting zone. Thus, in accordance with a more specific embodiment of the present invention, hot combustion gas used for carrying fine coke particles to the elevated collecting zone is separated from the particles therein and is then recycled in controlled amounts and substantially without intentional cooling to the lower end of the combustion zone to become admixed with the air or other oxygen-containing stream supplied from an extraneous source so as to provide the desired quantity of a hot gaseous oxidizing, fluidizing and entraining medium without unduly increasing the oxygen content of the burning an elutriating stream. A stream of regulated low oxygen content is, of course, necessary to in turn control and regulate the amount of oxidation or burning effected within the fluidized bed of the combustion zone, so that only so much of the carbon is burned therein as is necessary to heat the remaining particles to a desired temperature for subsequent introduction into the cok-

ing and cracking zone. Thereby, the hot recycle combustion gases also provide for an economical utilization of heat produced within the unit.

Excess hot combustion gases may be passed from the fine coke collecting zone through a heat exchanger to produce or heat steam; or alternatively excess hot combustion gases may be used to advantage for the preheating of a charge stream. The present operation also effects the combustion of a portion of the coke as well as the elutriation, in a zone entirely separate from the coking zone, whereby the mixing of combustion gases and other contaminating gases with the desired vaporous hydrocarbon product fractions is precluded and the formation of oxygenated products in the coking zone is substantially avoided.

In a still more specific and desired embodiment of the present invention, there is provided an improved method for cracking and coking a heavy hydrocarbon charge stream, which comprises, supplying a stream of heated finely divided coke particles to the upper portion of a descending bed of coke particles maintained within a cracking and coking zone, the finely divided coke particles being introduced into the coking zone at a temperature above the average bed temperature therein, introducing the heavy hydrocarbon charge stream at a temperature below the average bed temperature into the upper portion of the bed and effecting therein the conversion of the charge stream into desired lower boiling vaporous products and coke with the transformation of at least a portion of the fine coke particles into coarser particles, withdrawing resulting vaporous conversion products from the descending coke bed at an intermediate point and passing them to a fractionating zone, discharging a stream of coke particles from the bottom portion of the descending bed and passing them substantially by gravity into a fluidized bed of coke particles within the lower portion of a separate confined combustion zone maintained directly below the coking zone, introducing a gas stream containing free oxygen to the lower portion of the fluidized bed within the combustion zone, burning a portion of the coke therein and heating the remaining coke particles while simultaneously passing the gaseous stream and resulting combustion gases upwardly through the fluidized bed at a rate at which the finer coke particles are elutriated from the coarser particles and are entrained in the gas mixture disengaging from the fluidized bed into the upper portion of the combustion zone passing the resulting hot fine coke suspension upwardly from the combustion zone in a substantially vertical confined path in indirect heat exchange relationship with the descending bed of particles maintained within the coking zone, discharging the suspension from the confined path into a collecting zone superimposed directly above the coking zone and therein separating the suspension at a temperature above the average bed temperature in the coking zone into combustion gases which are continuously discharged from the upper portion of the collecting zone and into fine coke particles which are collected in the lower portion thereof, passing a stream of the separated hot fine coke particles from the lower portion of the collecting zone substantially by gravity as the aforesaid stream of heated finely divided coke particles to the upper portion of the coking zone, and withdrawing a stream of relatively coarse particles from the lower portion of the fluidized bed and the combustion zone as the net coke production of the process.

Preferably, a substantially vertical straight transfer conduit is provided from the upper end of the combustion zone directly through the center portion of the coking zone to an elevated point in the collecting zone, which in turn is superimposed over the coking zone, so that the entrained fine coked particles passing upwardly with the combustion gases may pass in a substantially straight line flow through the coking zone and in heat exchange relationship therewith, whereby loss of heat from the unit is reduced to a minimum. A portion of the heat from the hot combustion gases and fine particles may be transmitted through the wall of the vertical transfer conduit to the surrounding descending bed of coke within the coking and cracking zone; however, the combustion and elutriation operation is effected in the combustion zone in a manner permitting finely divided coke particles to reach the upper portion of the coking zone, after passage through the vertical transfer conduit and the collecting zone, at a temperature which is higher than the average bed temperature in the coking zone and sufficiently high to effect, or at least materially aid in, the desired cracking and coking of the heavy hydrocarbon charge stream.

Also, in connection with a preferred embodiment of the coking operation, a light high temperature gasiform stream, such as superheated steam or heated hydrocarbon distillate, is introduced into the lower portion of the coking zone to pass upwardly countercurrently through at least the lower portion of the descending bed therein and provide such portion of the heat requirement of the cracking and coking reactions as is not furnished by the heated fine coke particles supplied to the elevated portion of the coking zone, and moreover to effect the heating and dry distillation of the coke particles prior to the discharge of the latter into the combustion zone, as well as to effect the stripping of desired low boiling hydrocarbon fractions from the coke material. The latter embodiment is particularly desirable in order to preclude the agglomeration of particles where the heavy hydrocarbon charge has a tendency to form a heavy tarry or asphalt-like deposition on the coke particles in the descending bed.

The operation of the present improved cracking and coking process as well as additional advantages, will be more apparent upon reference to the accompanying drawing and the following description thereof.

Figure 1 of the drawing, is an elevational diagrammatic view of the contacting zones and transfer lines permitting the improved elutriation operation in combination with the combustion of a portion of the coke particles to heat the recycled coke.

Figure 2 of the drawing is a diagrammatic elevational view of a preferred construction and arrangement of the contacting zones, with a substantially straight conduit from the upper portion of the combustion zone passing internally through the coking zone, precluding the loss of heat from the system during the transfer of the finely divided coke particles to an elevated collecting zone or hopper, from which the high temperature finely divided material is subsequently passed to the coking zone.

Referring now to Figure 1 of the drawing, there is indicated line 1, having control valve 2, connecting with a suitable distributing header or ring 3, which in turn is adapted to distribute a heavy hydrocarbonaceous charge stream to the

upper portion of the contact chamber 4 serving as cracking and coking zone. This heavy charge stream may be a heavy residual petroleum such as reduced crude, topped crude, Bunker "C" fuel, or the like, which does not ordinarily provide a good charging stock to a catalytic cracking unit or it may be a heavy tar or an asphalt liquefiable by moderate heating. A continuously descending mass of particles is maintained either as a fluidized bed or as a compact moving bed in the coking zone or contact chamber 4, the particles being supplied at a high temperature from an upper elevated hopper or collecting chamber 5 by a line 6, having a valve or feeding mechanism 7, suitable to supply a continuous stream of heated coke particles to the descending bed in the coking zone. In accordance with the present cracking and coking operation, the particles are supplied at a high temperature, of the order of 950° to 1100° F., suitable to effect the desired cracking and coking of the heavy charge stream being introduced by way of the distributor 3. The particles are heated prior to their introduction into the collector or hopper 5, as will hereinafter be more fully described, and since the particles in the preferred method of operation furnish at least a major portion of the heat being supplied to the coking zone, they are at a temperature substantially above that of the average temperature in the bed of descending particles of the coking zone. Resulting vaporous products from the cracking and distillation of the heavy charge stream are continuously removed from the coking zone 4 by way of an intermediately positioned outlet line 8 and control valve 9. Suitable baffling 10 permits the collecting of the resulting vapors from the descending bed for removal through line 8.

In the present embodiment, the lower portion of the coking zone 4 is utilized as a dry distilling zone for conversion of asphalt-like components on the coke particles into hard coke and volatile products, as well as a stripping zone for the removal of low boiling vaporous hydrocarbon fractions adsorbed in the descending bed of particles. The high temperature fluid medium, suitable for stripping and drying the coke is introduced to the lower portion of the coking chamber 4 by way of line 11 and control valve 12, with a suitable header or distributing ring 13 utilized to uniformly distribute the gasiform medium throughout the descending bed of particles. The high temperature medium being introduced by way of line 11 has still another desirable function in that it maintains coke material in the lower portion of the descending bed in a freely flowing or loose, particulated state, preventing the agglomeration of particles while effecting the drying and stripping operations.

As hereinbefore noted, this fluid medium may be a light hydrocarbon distillate which will commingle with the vaporous products resulting from the cracking and coking step within the upper portion of the coking zone 4, or alternatively, the fluid medium may be superheated steam which may be later condensed and removed from the hydrocarbon product fractions without unduly elaborate separation steps. The stream is preferably charged to the lower portion of the coking zone at a high temperature above the average bed temperature in order to be more effective in the dry distilling and stripping functions.

The resulting and newly formed coke material, reaching the lower end of the coking chamber 4 in a substantially asphalt-free state, is passed by way of conduit 14 and regulator or feeder 15 to an elutriating chamber 16, which serves also as combustion chamber and wherein there is maintained a fluidized and elutriated bed of coke particles, the upper extremity of the fluidized dense phase bed being indicated by the dotted line 17. An oxidizing and elutriating gas stream is introduced to the lower portion of the chamber 16 by way of line 18, pump 19, and line 20 having control valve 21. In accordance with the present invention, the gaseous stream introduced into the lower portion of the elutriating or combustion chamber 16 is in sufficient quantity and at a suitable velocity to effect the elutriation of the finer from coarser particles within the fluidized bed therein, while simultaneously effecting the burning of a portion of the coke to effect the heating of the residual coke particles within the bed. Thus, the finer particles are transported as a suspension in hot combustion gases to the collector 5, at the aforementioned high temperature, to supply heat to the coking zone, and the elutriation effected within the combustion and elutriation chamber 16, is such as to carry a sufficient quantity of fine particles by way of conduit 22 to the elevated hopper and collector 5 to maintain the continuously descending bed of particles within the coking chamber 4. The hot fine coke particles carried from the fluidized bed 17 in suspension by the resulting combustion gases and through the conduit 22 into the collecting chamber 5, are separated from the gases by means of the enlarged area zone and the mechanical or centrifugal separator 23. The freed combustion gases are discharged from the separator 23 by way of outlet line 24, while recovered entrained particles are passed to the lower portion of the collector 5 by gravitational settling and by a return leg of the centrifugal separator 23. Also in accordance with the present invention, hot combustion gases from the collecting chamber 5 are recycled by way of the conduit 24, control valve 25, pump 26 and line 27 to the lower portion of the combustion and elutriation chamber 16. The combustion gases provide a suitable high temperature diluent medium for mixing with the air stream in line 18, whereby a sufficient volume of gaseous medium containing free oxygen is made available to effect the desired elutriation of the finer from coarse coke particles in that zone as well as the desired burning and heating therein. The recirculated hot combustion gas and air charged to the combustion zone are blended in such regulated proportions that the resultant mixture has the desired oxygen content for effecting the burning of coke within the combustion zone to supply the desired amount of heat to the finer particles being recycled to the conversion zone Excess hot flue gas is withdrawn from line 24 by way of line 28 and valve 29, being utilized to generate or superheat steam, or for other heating purposes prior to being discharged to the atmosphere by way of a suitable stack.

A particle withdrawal standpipe 30 and regulating valve 31 provide means for withdrawing excess coke, primarily the coarser particles, from the combustion and elutriation zone 16, such coke being a net product of the conversion operation. Although not indicated in the present drawing, excess heat may be recovered from the withdrawn stream of coarser particles, for example, by contacting this stream with an aqueous medium in a quenching zone to generate steam. Steam from such a quenching zone may be superheated by indirect heat exchange with a stream of the excess hot combustion gases and

may thereafter be utilized to advantage as the light gaseous medium being introduced to the lower portion of the coking zone in chamber 4, as well as for stripping steam at various points in the present unit. As noted in the drawing, aerating and stripping steam is preferably introduced into each of the principal particle transfer lines or conduits. Line 32 and control valve 33 supplies steam or other stripping medium to the particle conduit 6; line 34 and valve 35 connect with and control the introduction of stripping steam into line 14; and line 36 with valve 37 provides means to introduce steam into the coarse coke withdrawal line 30.

Figure 2 of the drawing provides a somewhat more compact and preferable arrangement of the various contacting zones and means for transferring particles with a minimum loss of heat from the system. The preheated heavy charge stream is introduced by way of line 40, control valve 41 and distributing head 42 into the descending bed of particles maintained within the contact or coking zone 43 of a single elongated vertically disposed chamber 44. The heavy charge stream is supplied at a temperature and rate of flow at which line 40, valve 41 and distributing head 42 remain clean and free from coke deposits. High temperature finely divided coke particles are continuously introduced to the upper portion of the coking zone 43 from a coke hopper or collecting zone 45 maintained in the upper portion of chamber 44. The collecting zone is separated from the coking zone by suitable partitioning 46 and a U shaped baffling 47, which in combination with the lower depending portion of the baffle 46 provides a U tube or U trap arrangement for the transfer of finely divided particles from the upper collecting zone 45 into the coking zone 43 and for precluding access of vaporous material from the latter to the former. The high temperature fine coke particles are continuously passed by gravity through annular zones 48 and 49 of the U trap arrangement, with a suitable fluid medium being introduced by way of line 50 and valve 51 to the lower portion of the particle transfer zone to act as a sealing fluid and at the same time to regulate the continuous flow of particles essentially by gravity from the collecting zone 45 through the U trap arrangement to the descending fluidized bed of particles in the coking zone 43.

As described in connection with Figure 1 of the drawing, the coke particles are continuously introduced to the upper portion of the descending bed in the coking zone at a high temperature suitable to effect the conversion and coking of the heavy hydrocarbon charge stream to desired lower boiling fractions and into coke depositing at least partly on the particles being continuously introduced into that zone. The resulting vaporous products or hydrocarbon fractions are withdrawn from an intermediate portion of the descending bed of particles in the coking zone 43 by way of an outlet line 52 and control valve 53, and may be passed to a suitable fractionating equipment for the separation or recovery of the desired products. Also, in accordance with a desirable operation, the descending bed of coke particles in the lower portion of the chamber 44 is subjected to contact with a high temperature light fluid medium, such as steam or a light hydrocarbon fraction, so that there may be dry distillation, hardening and stripping of the coke prior to its withdrawal from the coking zone. The light fluid medium is introduced to the lower portion of the descending bed of coke particles of chamber 44 by way of line 54, valve 55, and distributing head 56, and at a high temperature at least about equal to and preferably substantially above that of the average bed temperature within the chamber 44. This light fluid medium is advantageously supplied at a temperature and rate of flow adequate to furnish the balance of the heat required in the coking zone 43 as far as not furnished by the heated fine coke particles entering this zone through the U trap arrangement. The resulting asphalt-free coke particles reaching the lower portion of the bed in chamber 44 are continuously passed by way of conduit 57 and valve or regulating mechanism 58 to a separate confined chamber 59.

A fluidized and elutriated bed of coke particles is maintained within the lower portion of the elutriating and combustion chamber 59, as indicated by the bed 60, with an oxygen-containing stream being introduced to the lower end of the chamber 59 by way of line 61, pump 62 and line 63 having control valve 64. Burning of a portion of the carbonaceous matter is effected to in turn provide a heating of the entire bed of particles such that a recycle stream of the finer particles will supply to the conversion or coking zone 43 all or at least a major portion of the heat required in this zone. In accordance with the present invention, the burning operation is carried out in combination with an elutriation operation, whereby only the finer of the coked particles are returned to the collecting zone 45 for subsequent return to the coking zone. Thus, the oxygen-containing or air stream is introduced to the lower portion of the chamber 59 at a sufficient velocity and in sufficient quantity to effect the removal of fine coke particles from the bed of the combustion zone 60 and carry them in suspension in the resultant hot combustion gas mixture through the internal conduit 65 to the upper portion of the collecting zone 45.

It is a particularly desirable feature of the present apparatus arrangement to have the internal transfer conduit 65 extend substantially vertically and concentrically upwardly through the compact or coking zone 43 and collecting zone 45 to an elevated portion within the latter. Thus, the fine coke particles are carried in suspension in the resulting hot flue gases to the elevated hopper and collecting zone with little or no loss of heat from the system and with a minimum of friction and erosive action in the transfer conduit 65. The combustion chamber 59 is located directly below the coking chamber 44, and conduit 65 is provided with a suitable expansion joint 66 positioned between the two chambers to accommodate differential expansions, due to the high temperature operating conditions and linear expansions resulting therefrom. The gaseous charge stream to the combustion chamber 59 and resulting flue gases effect the transporting of the fine coke particles to the chamber 45, and as hereinbefore noted, is regulated and controlled to assure the transporting of sufficient fine material to maintain the continuously descending bed of particles in the coking and conversion zone 43.

Flue gas from the upper portion of the collecting zone 45 is passed by way of conduit 67, and separators 68 and 69 to a transfer line 70, while recovered entrained particles are returned to the lower portion of the collecting zone 45 by suitable return legs 71 and 72. Also, in accordance with the present invention, at least a portion of the separated hot flue gas is recycled with-

out intentional cooling by way of the conduit 70 and control valve 73, pump 74 and line 75 to the charge line 61 and the lower portion of the combustion chamber 59. Thus, a hot gaseous medium is provided for blending with the oxygen-containing gas stream supplied from an external source and for aiding in furnishing the desired quantity of elutriating gas utilized within the fluidized bed 60 of the combustion and elutriation chamber 59. Excess hot flue gas from line 70 may be withdrawn by way of line 76 and valve 77 and transferred to suitable heat exchanger equipment for conversion of heat from the hot combustion gases. The coarser coke particles which represent net coke production from the unit, are continuously withdrawn from the lower portion of the combustion zone 59 by way of standpipe or outlet conduit 78 and regulating means 79. This coke may be passed to cooling and processing zones for further treating as may be desired. Provision is also made in this embodiment of the unit, for the introduction of steam or other stripping fluid into each of the coke withdrawal conduits by way of line 80 and control valve 81 communicating with standpipe 78, and by way of conduit 82 and valve 83 communicating with the withdrawal conduit 57.

The elevational arrangement of the contacting zones, in accordance with the accompanying drawing, is advantageous in that the coke particles have a descending gravity flow through all zones but the burning zone and there is required but a single fluidized lift of the finer coke particles to maintain a continuous cyclic flow of coke particles through the entire system. Also, the elutriation in combination with the burning operation eliminates the need of any additional equipment for sizing operations to effect the classification of particles. The control of the elutriating and oxydizing gas stream by the blending of suitable proportions of air and recycled hot combustion gases and the action of the blended gas stream in a simple straight-through type of combustion chamber, substantially free of internal structures or obstructions, materially contribute to the high efficiency and economy of the operation of the present invention.

The cracking and coking operation, within the conversion or coking zone, may be carried out under any suitable pressure conditions, including atmospheric pressure; however, it is preferably effected at a relatively moderate super-atmospheric pressure, within the range of from 8 to 150 pounds per square inch, with temperatures correlated to the particular operating pressure to provide the desired lower boiling conversion products. The pressure in the elutriating and combustion zone and in the elevated fine particle collecting zone is substantially balanced with the pressure in the conversion zone so that the substantially gravitational flow of coke particles from the collecting zone into and downwardly through the conversion zone and from the latter into the elutriating and combustion zone is assured.

I claim as my invention:

1. An improved method for converting a heavy hydrocarbonaceous charge stream in the presence of subdivided coke, which comprises introducing a stream of heated fine coke particles into a confined coking zone and contacting them therein with said heavy charge stream at a temperature at which said heavy charge is converted into lower boiling vaporous products and coke with the transformation of at least a portion of said fine coke into coarser particles, continuously withdrawing resulting vaporous conversion products from said coking zone and passing them to a fractionating zone, discharging a stream of mixed fine and coarser coke particles from said coking zone into a fluidized bed of coke particles maintained in the lower portion of a separate confined combustion zone, introducing a gas stream containing free oxygen into the lower portion of said fluidized bed and therein burning a portion of the coke and heating the residual coke particles while simultaneously passing said oxygen-containing gas and resulting combustion gases upwardly through said fluidized bed at a rate at which fine coke particles are elutriated from the coarser particles and are entrained in the gas mixture disengaging from said fluidized bed into the upper portion of said combustion zone, passing the resulting hot fine coke suspension from said combustion zone into a separate confined collecting zone of higher elevation than said coking zone, separating said suspension in said collecting zone at a temperature substantially above the average temperature maintained in the coking zone into combustion gases which are continuously discharged from the upper portion of said collecting zone and into fine coke particles which are collected in the lower portion thereof, passing a stream of the separated fine coke particles from the lower portion of said collecting zone substantially by gravitational flow as said heated fine coke particles into said coking zone, and withdrawing a stream of relatively coarse coke particles from the lower portion of said fluidized bed and said combustion zone as net coke production.

2. An improved method for converting a heavy hydrocarbonaceous charge stream in the presence of subdivided coke, which comprises introducing a stream of heated fine coke particles into an elevated portion of a confined coking zone, passing said particles downwardly through said zone and contacting them therein with said heavy charge stream at a temperature at which said heavy charge is converted into lower boiling vaporous products and coke with the transformation of at least a portion of said fine coke into coarser particles, continuously withdrawing resulting vaporous conversion products from said coking zone and passing them into a fractionating zone, discharging a stream of mixed fine and coarser coke particles from the bottom portion of said coking zone substantially by gravitational flow into a fluidized bed of coke particles maintained in the lower portion of a separate confined combustion zone of lower elevation than said coking zone, introducing a gas stream containing free oxygen into the lower portion of said fluidized bed and therein burning a portion of the coke and heating the residual coke particles while simultaneously passing said oxygen-containing gas and resulting combustion gases upwardly through said fluidized bed at a rate at which fine coke particles are elutriated from the coarser particles and are entrained in the gas mixture disengaging from said fluidized bed into the upper portion of said combustion zone, passing the resulting hot fine coke suspension from said combustion zone into a separate confined collecting zone of higher elevation than said coking zone, separating said suspension in said collecting zone at a temperature substantially above the average temperature

maintained in the coking zone into combustion gases which are continuously discharged from the upper portion of said collecting zone and into fine coke particles which are collected in the lower portion thereof, passing a stream of the separated fine coke particles from the lower portion of said collecting zone substantially by gravitational flow as said heated fine coke particles into said coking zone, and withdrawing a stream of relatively coarse coke particles from the lower portion of said fluidized bed and said combustion zone as net coke production.

3. An improved method for cracking and coking a heavy hydrocarbon charge stream in the presence of heated subdivided solid material which comprises, supplying a stream of heated fine coke particles to the upper portion of a confined cracking and coking zone and maintaining a descending bed of fine coke particles therein, introducing said heavy charge stream at a temperature lower than the average bed temperature to an elevated portion of said bed and effecting therein the conversion of said heavy charge stream into lower boiling vaporous products and coke with the transformation of a portion of the fine coke into coarser particles, withdrawing resulting vaporous conversion products from said coke bed and passing them to a fractionating zone, discharging a stream of coke particles from the bottom portion of said descending bed into a fluidized bed of coke particles maintained in the lower portion of a separate confined combustion zone, introducing a gas stream containing free oxygen into the lower portion of said fluidized bed and therein burning a portion of the coke and heating the residual coke particles while simultaneously passing said oxygen-containing gas and resulting combustion gases upwardly through said fluidized bed at a rate at which fine coke particles are elutriated from the coarser particles and are entrained in the ascending gas mixture disengaging from said fluidized bed into the upper portion of said combustion zone, passing the resulting hot fine coke suspension substantially without intentional cooling into a confined collecting zone superimposed above said cracking and coking zone, separating said suspension in said collecting zone at a temperature substantially above the average bed temperature maintained in said coking zone into combustion gases which are continuously discharged from said collecting zone and into fine coke particles which are collected in the lower portion thereof, passing a stream of the separated fine coke particles from the lower portion of said collecting zone substantially by gravitational flow as said heated fine coke particles into said coking zone, and withdrawing a stream of relatively coarse coke particles from the lower portion of said fluidized bed and said combustion zone as net coke production.

4. The method of claim 3 further characterized in that said oxygen-containing gas stream being introduced into said combustion and elutriation zone comprises air in admixture with a controlled portion of hot combustion gases recycled from said collecting zone.

5. An improved method for cracking and coking a heavy hydrocarbon charge stream in the presence of subdivided solid material, which comprises, supplying a stream of heated fine coke particles to the upper portion of a descending bed of coke particles maintained within a cracking and coking zone, said coke particles being introduced into said zone at a temperature above the average coke bed temperature therein, introducing said heavy hydrocarbon charge stream into an elevated portion of said bed at a temperature below said average bed temperature and effecting therein the conversion of the charge stream into lower boiling vaporous fractions and coke with the transformation of at least a portion of the fine coke into coarser particles, withdrawing resulting vaporous conversion products from the descending coke bed and passing them to a fractionating zone, discharging a stream of mixed fine and coarser coke particles from the bottom portion of the descending bed and passing them substantially by gravity into a fluidized bed of coke particles maintained within the lower portion of a separate confined combustion zone underneath said coking zone, introducing a gas stream containing free oxygen into the lower portion of said fluidized bed and therein burning a portion of the coke and heating the remaining coke particles while simultaneously passing said oxygen-containing gas stream and resulting combustion gases upwardly through said fluidized bed at a rate at which fine coke particles are elutriated from the coarser particles and are entrained in the gas mixture disengaging from said fluidized bed into the upper portion of said combustion zone, passing the resulting hot fine coke suspension from said combustion zone upwardly in a confined path through said coking zone and in indirect heat exchange relationship with said descending bed and thereupon discharging it at a temperature substantially above the average temperature of said descending bed into a collecting zone superimposed on said coking zone, separating said suspension substantially without intentional cooling in said collecting zone into combustion gases which are continuously withdrawn from the upper portion of said collecting zone and into fine coke particles which are collected in the lower portion thereof, passing a stream of the separated fine coke particles from said collecting zone substantially by gravity flow as said heated fine coke particles to the upper portion of said descending bed in said coking zone, and withdrawing a stream of relatively coarse particles from the lower portion of said fluidized bed and said combustion zone as net coke production of the process.

6. The method of claim 5 further characterized in that said oxygen-containing gas stream introduced to the lower portion of the fluidized bed maintained within said combustion zone consists essentially of a mixture of a regulated portion of the hot combustion gases discharged from said collecting zone and air in a proportion assuring controlled heating of the coke in the combustion zone and entrainment of hot fine coke in the resulting combustion gas mixture at a rate sufficient to maintain said descending bed in said coking zone.

7. The method of claim 5 further characterized in that a light vaporous stream substantially devoid of free oxygen at a higher temperature than the average bed temperature in the coking zone is introduced into the lower portion thereof and passed upwardly through at least a substantial portion of the descending bed of coke particles therein, whereby to aid in the conversion of said heavy hydrocarbon charge stream to desired lower boiling products and a hard dry coke.

8. The method of claim 7 further characterized in that said light vaporous stream comprises superheated steam produced by passing an aqueous fluid stream in heat exchange relationship with hot coarse coke particles withdrawn from

said combustion zone and with excess hot combustion gases discharged from said collecting zone.

9. The process of claim 7 further characterized in that said light vaporous stream comprises a heated relatively light hydrocarbon fraction obtained from the fractionating zone receiving the vaporous conversion products from said coking zone.

10. Apparatus suitable for effecting the conversion of heavy hydrocarbonaceous material in the presence of subdivided coke, which comprises in combination a vertically elongated confined contact chamber disposed inbetween and vertically aligned with an upper confined collecting chamber and a lower confined elutriating chamber, said contact chamber having fluid inlet and outlet ports, a particle transfer conduit containing flow regulating means and connecting the bottom portion of said contact chamber with the lower portion of said elutriating chamber, particle passageway means connecting the bottom portion of said collecting chamber with an elevated portion of said contact chamber, a substantially vertical particle suspension transfer conduit extending upwardly from the top portion of said elutriating chamber substantially along the axis of alignment of said chambers through said contact chamber and centrally through said particle passageway means into an elevated portion of said collecting chamber, a fluid inlet and a particle outlet at the lower portion of said elutriating chamber, and a fluid outlet at the upper portion of said collecting chamber.

11. The apparatus of claim 10 further characterized by a fluid recirculation conduit connecting the fluid outlet at the upper portion of said collecting chamber with said fluid inlet at the lower portion of said elutriating chamber and containing means for forcing fluid discharged from said collecting chamber into the lower portion of said elutriating chamber.

12. The apparatus of claim 10 further characterized in that said particle passageway means is arranged to discharge into the top of the contact chamber and comprises a U trap arranged annularly around said particle suspension transfer conduit, and fluid inlet and distributing means are positioned at the lower end of said U trap for the introduction of a fluid stream thereto and the regulation of particle flow from said collecting chamber to said contact chamber.

FREDERICK W. LEFFER.

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