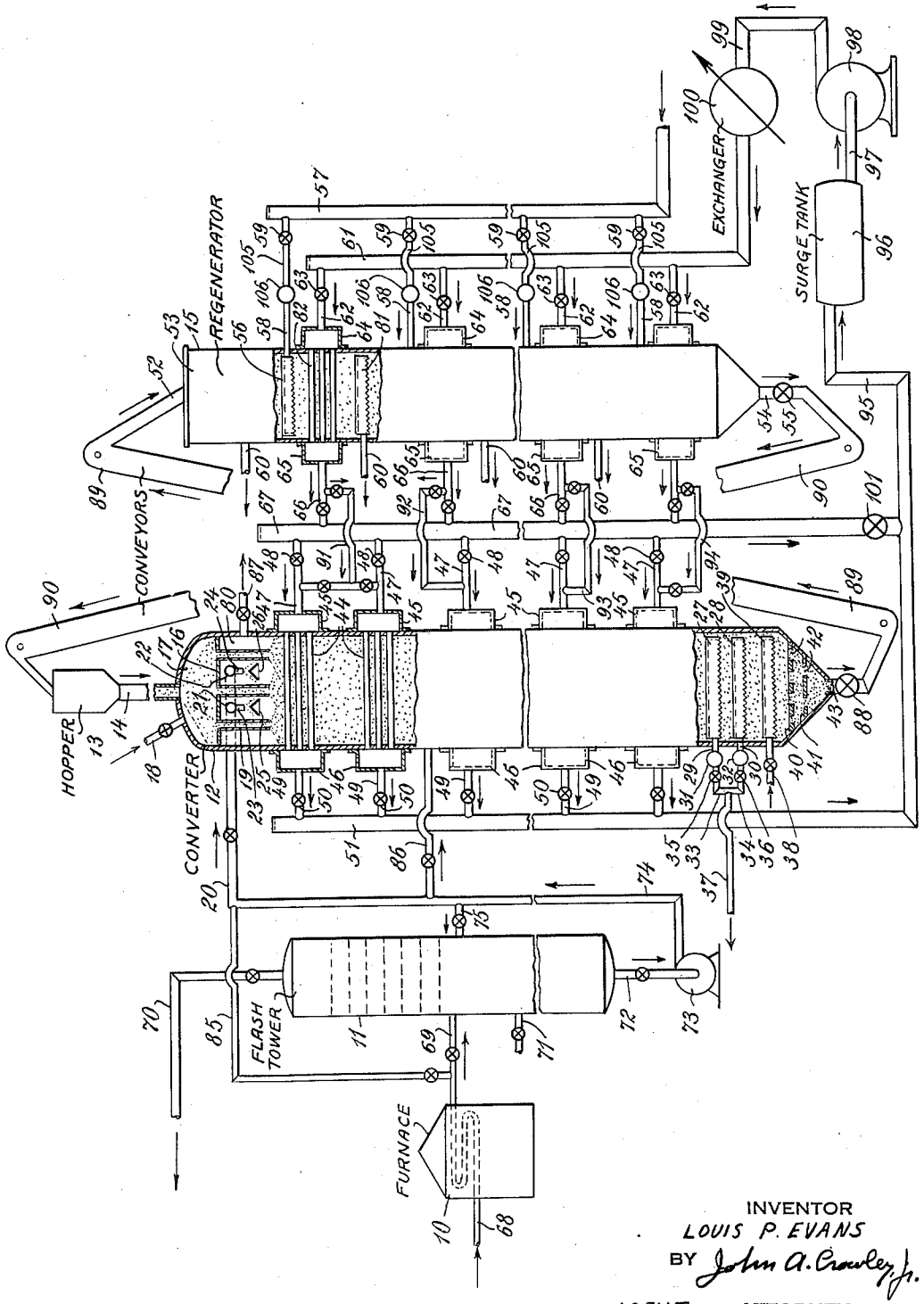
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METHOD AND APPARATUS FOR HYDROCARBON CONVERSION

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METHOD AND APPARATUS FOR HYDROCARBON CONVERSION

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This invention has to do with a method and apparatus for catalytic conversion of petroleum hydrocarbons to valuable lower boiling products a large portion of which boil in the gasoline boiling range. The invention is specifically directed to a method and apparatus for conversion of high boiling liquid hydrocarbons to lower boiling products in the presence of a moving, substantially compact mass of particle form solid contact material.

It is well known that when petroleum gas oils boiling within the range 450 to 750° F., for example, are contacted in the gaseous phase with particle form catalytic materials at temperatures above about 800° F. and usually at superatmospheric pressures, the gas oil may be converted to gasoline gas, and cycle oil. Typical of the catalytic materials employed in such processes are natural clays, bauxites, treated clays and synthetic associations of alumina, silica, or silica and alumina to which other constituents such as certain metallic oxides may be added. Such catalytic materials may vary in particle size from about 4 to 100 mesh by Standard Tyler screen analysis. For certain moving bed type processes the particle size range may be preferably maintained between about 4 to 8 mesh.

Such hydrocarbon conversion processes have recently taken the form of one wherein the contact mass material is passed cyclically through a conversion zone wherein it is contacted with hydrocarbons to effect their conversion and resulting in deposition of a carbonaceous contaminant on the contact material and through a regeneration zone wherein it is contacted with a combustion supporting gas acting to burn the contaminant from the contact material.

Heretofore such continuous catalytic hydrocarbon conversion processes have been mainly limited to conversion of hydrocarbons in the gaseous phase. Consequently, only those lighter charging stocks such as naphthas and distillate gas oils which are vaporizable below the desired conversion temperature have been employed as charging stocks to catalytic processes. Usually catalytic hydrocarbon conversions are conducted within the range of about 700 to 950° F. and preferably within the range of about 800–900° F. Many otherwise acceptable charging stocks such as heavy fuel oils and reduced crudes boil substantially above the normally desirable conversion temperatures and attempts to vaporize such high boiling charging stocks before charging to a catalytic convertor results in undesirable pyrolytic cracking and excessive coke formation. On the other hand, if such stocks be charged to a catalytic conversion zone as a liquid and the heat for vaporization thereof be supplied by charging the catalyst to said zone at temperatures above the desired conversion temperature, excessive conversion temperatures are encountered at the level of initial catalyst-oil contact causing excessive cracking of the charge at the outset. Moreover, due to the large amount of heat required for hydrocarbon vaporization and the further heat required for reaction, the catalyst temperatures will vary radically at various levels in the conversion zone and temperatures far below the desired conversion temperature may occur in the later stages of the conversion zone. Such operation gives rise to undesirably high yields of non-condensible hydrocarbons, excessive coke formation on the catalyst and low yields of gasoline making the process far from attractive from economic and practical operation standpoints.

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A major object of this invention is the provision of a practical method and apparatus for the catalytic conversion of high boiling liquid hydrocarbon charging stocks to valuable lower boiling products.

A further object of this invention is the provision in a process for catalytic conversion of high boiling liquid hydrocarbon charging stocks of a practical method and apparatus permitting control of the catalyst at a substantially uniform desirable hydrocarbon conversion temperature substantially throughout the length of the conversion zone.

These and other objects of this invention will become apparent from the following description of the invention.

The method of this invention in general involves the introduction of heated high boiling liquid hydrocarbon charge into a substantially compact column of moving particle form contact material maintained throughout the length of a confined conversion zone while supplying the heat required for conversion of said liquid charge to lower boiling gasiform product and for maintaining a substantially uniform contact material temperature along the length of said conversion zone by passage of a plurality of separately controlled streams of fluid heat exchange medium into indirect heat transfer relationship with said column of contact material at a plurality of spaced apart intervals along the length thereof. The resulting gasiform hydrocarbon products are withdrawn from said column and the spent contact material resulting from the

conversion is passed through a separate regeneration zone wherein it is subjected to a combustion supporting gas acting to burn the contaminant deposit from the contact material. A fluid heat exchange medium is passed through said regeneration zone in indirect heat transfer relationship with said contact material to remove heat liberated by the contaminant combustion, and portions of the heated heat exchange medium from the regeneration zone are then utilized for said plurality of streams of heat exchange medium in said conversion zone. It should be understood that the term "gasiform products" as used herein in describing and in claiming this invention is used broadly as covering material existing in the gaseous phase under the conditions of pressure and temperature at the convertor outlet regardless of the normal phase of such materials at ordinary atmospheric conditions.

The invention may be better understood by reference to the single drawing attached hereto which is an elevational flow plan, partially in section of a preferred apparatus arrangement adapted for conversion of high boiling liquid hydrocarbons according to the method of this invention. In the drawing 10 is a furnace adapted for preheating the liquid hydrocarbon charge, 11 is a flash tower adapted for removal of lower boiling constituents from the charge when desired, 12 is a conversion vessel supplied with contact material from hopper 13 through elongated feed leg 14 and 15 is a contact material regeneration vessel. Across the upper section of the conversion vessel 12 is a partition 16 providing a seal section 17 in the upper end of the vessel. Inert gas such as steam or flue gas may be introduced through conduit 18 so as to blanket the upper end of the conversion zone from the gravity feed leg 14, thereby preventing escape of reactants. Uniformly distributed conduits 19 depend from partition 16 for passage of contact material from the seal zone into the conversion zone therebelow and to provide a solid-free distributing space 80 above the column of contact material in the conversion zone. Liquid hydrocarbon charge is introduced to the upper end of the conversion zone through inlet conduit 20 from which it is distributed through headers 21 and 22 and dependent nozzles of which two, 23 and 24, are shown, onto V-shaped spreaders such as 25 and 26. The liquid is distributed from the spreaders onto the surface of the contact material column substantially uniformly across the entire cross-sectional area thereof. Gasiform conversion products are disengaged from the lower section of the column under the rows of collector troughs of which two, 27 and 28, are shown. It is then withdrawn from the rows of troughs at controlled rates through rows of outlet pipes such as 29 and 30. The outlet pipes in each row connect into a separate manifold 31 or 32, which in turn connect into manifolds 33 and 34 carrying flow control valves 35 and 36 respectively. The combined gasiform product finally passes through conduit 37 to a suitable distillation and treating plant which may be of conventional design and is not shown. A purge medium such as stream or flue gas may be introduced through a row of inlet pipes of which one, 38, is shown, under a row of distributing troughs such as 39 located in the lower section of vessel 12. In the lower section of vessel 12 are two partitions 40 and 41 having orifices 42 so arranged therein as to provide uniform flow of contact material from all portions of the conversion zone cross-section to the outlet conduit 43. A plurality of groups of heat transfer tubes 44, arranged in rows are provided at a plurality of spaced apart levels along the length of the conversion zone in vessel 12. The heat transfer tubes may be of any practical cross-sectional shape and may be provided with fins to increase the heat transfer capacity thereof. An inlet manifold box 45 and an outlet manifold box 46 are attached across the vessel shell at opposite ends of each group of tubes 44. Each inlet box 45 is provided with a separate inlet conduit 47 bearing a flow control valve 48 so as to permit independent control of the flow of heat exchange fluid to each spaced group of tubes. Each outlet manifold box 46 is provided with a separate outlet conduit 49 bearing a valve 50, the several outlet conduits being connected into a common withdrawal manifold 51. It will be understood that the drawing is highly diagrammatic in form and the invention is not to be limited to the exact structural form of the hereinbefore described elements of conversion vessel 12. Thus, for example, the spaced apart groups of heat transfer tubes may be arranged as spaced groups of vertically extending rather than horizontally extending tubes by suitable changes in the inlet and outlet manifold construction and arrangement.

The regeneration vessel 15 is provided at its upper end with a solid inlet conduit 52 delivering the contact material into a surge section 53 and on its lower end with a solid outlet conduit 54 bearing a flow control valve 55. A plurality of sets of gas inlet distributing troughs such as 56 and outlet collecting troughs 81 are provided at spaced intervals along the length of the vessel 15, so as to provide a plurality of superposed burning stages. Combustion supporting gas from a common manifold 57 may be directed at independently controlled rates to the row of inlet troughs 56 in each stage through manifolds 105 and 106 and separate inlet pipes 58. The manifolds 105 bear flow control valves 59. Spent regeneration gas may be withdrawn separately from each stage through outlets 60 which may connect into a stack or outlet flue (not shown). Between each burning stage is provided a group of heat transfer tubes 82 arranged in horizontal rows. Heat exchange fluid is supplied to each group of tubes 82 from a common manifold 61 through separate inlet conduits 62 bearing control valves 63 and manifold boxes 64. Heat exchange fluids may be withdrawn from each group of tubes 82 through separate manifold boxes 65 and separate conduits 66 to the common manifold 67 from which it is withdrawn as needed to the several groups of heat transfer tubes in the conversion vessel.

While the hereinabove described multi-stage type of regeneration vessel is preferred, other types of regenerators adapted to permit the regeneration of a moving mass of contact material under controlled temperature conditions may be substituted therefor within the scope of this invention. For example, a single stage regenerator provided with heat transfer tubes extending longitudinally throughout its length may be employed. Such a regenerator is described in the United States Patent 2,226,578 issued to Payne.

In operation the hydrocarbon charge which may be a long residuum, for example, is pumped through conduit 68 into the tubes in furnace 10 wherein it is heated to a suitable flash tempera-

ture such as 750–850° F. The heated charge then flows through conduit 69 into flash tower 11 wherein lower boiling constituents such as gas oils are flashed and removed through outlet 70 to be processed separately. Steam or non-condensible hydrocarbons may be introduced into the tower at 71 to assist in the flashing operation. Hot liquid hydrocarbons which may consist almost entirely of material boiling above a temperature within the range about 800–950° F., depending upon the operation, is withdrawn from the bottom of tower 11 through conduit 72. It is then pumped by pump 73 partially through conduits 74 and 75 as reflux to tower 11 and partially through conduits 74 and 20 as charge to conversion vessel 12. If the original charge does not contain undesirably large amounts of lower boiling hydrocarbons, the flash tower 11 may be eliminated, in which case the liquid charge passes from the furnace 10 via conduits 85 and 20 to the conversion vessel. In some operations it has been found convenient to introduce the liquid-hydrocarbon charge into the column at an intermediate level in the conversion zone, in which event inlet 86 is used instead of inlet 20. When inlet 86 is used, gasiform hydrocarbon products may be withdrawn from vessel 12 in part through outlet 37 and in part through outlet 87. Freshly regenerated contact material may enter the upper end of the conversion zone at a suitable conversion supporting temperature usually in the range of about 850 to 950° F. It should be noted that the contact material inlet temperature in preferable operations is below the boiling point of at least most of the liquid hydrocarbon charge and is at or near the desired conversion temperature. As a result there is no excessive hydrocarbon conversion at the point of initial contact material hydrocarbon contact in the process of this invention. Furthermore, since the contact material is below the boiling point of the liquid hydrocarbon charge there is no sudden drop in contact material temperature due to rapid vaporization of the hydrocarbon charge at or near the level of initial contact. Spent contact material bearing a carbonaceous contaminant deposit passes from the bottom of vessel 12 through conduit 43 and flow control valve 88 to a conveyor 89 by which it is transported to the top of regeneration vessel 15. The conveyor 89 may be of any conventional type adapted for transport of high temperature solid particles; for example, it may be a continuous bucket elevator. The contact material passes through the alternate burning and cooling stages in regenerator 15 while being maintained at a temperature which is in general above the desired hydrocarbon conversion temperature but below a level which would cause permanent heat damage to the contact material. The heat damaging temperature varies for different types of contact material, for example being of the order of 1200° F. for treated clay catalysts and of the order of 1400–1500° F. for certain synthetic silica-alumina gel catalysts. The freshly regenerated contact material is adjusted to a suitable convertor charge temperature by means of the lowest cooling stage in vessel 15 and then passes through outlet conduit 54 and flow control valve 55 to a conveyor 90 by which it is conducted to the convertor supply hopper 13. At least most heat required for conversion of liquid hydrocarbon charge to lower boiling gasiform hydrocarbon product is supplied by indirect heat transfer with a fluid heat exchange medium at a pluralitv of spaced levels along the conversion zone. The amount

of heat required at any given level in the conversion zone will vary from one operation to another, and the amounts of heat required at different levels may vary as the rate and type of hydrocarbon conversion varies during the course of the hydrocarbon passage through the conversion zone. It will become apparent that by the use of the apparatus of this invention the differing heat input requirements at different levels along the length of the conversion zone may be easily and accurately satisfied thereby insuring a substantially uniform contact material temperature, i. e., relatively narrow range of temperatures along the length of the conversion zone. It should also be noted that the convertor construction shown provides a series of alternating zones for conversion in the presence and conversion in the absence of heat transfer tubes. This arrangement not only permits the provision of conversion heat at different rates at different levels in the convertor but also permits more uniform contact between hydrocarbons and contact material, while requiring less total heat transfer surface. As has been shown the heat exchange fluid passes from the regeneration vessel into a common manifold 67 from which it may be withdrawn at the desired rates to the several groups of heat transfer tubes in the conversion zone. Alternatively, when a multi-stage regenerator such as is shown in the drawing is employed, heat exchange medium from any given regeneration stage may be passed through a group of tubes at an approximately corresponding level in the conversion zone by use of by-pass pipes 91, 92, 93 and 94. In either operation the heat required for conversion is obtained from burning of the contaminant deposit within the cyclic process thereby effecting a substantial saving in external heat requirement as well as a saving in external coolant requirement for the regeneration phase of the process. Heat exchange fluid from the conversion vessel passes via manifold 51 to return conduit 95 through which it passes to a surge tank 96. The heat exchange fluid then passes through conduit 97 to pump 98 by which it is circulated via conduit 99 and manifold 61 back to the regeneration vessel. In many operations the heat liberated by burning of contaminant deposit from the contact material is somewhat greater than the hydrocarbon conversion heat requirements. In such operations the excess heat is extracted from the heat exchange fluid by means of exchanger 100 before return of the heat exchange fluid to the regeneration vessel. It will be understood of course that in those operations wherein a net heat deficit occurs, the heat required to balance the operation may be provided by exchanger 100. This condition often occurs in "starting up" operations. Any portion of the heat exchange fluid from the regeneration vessel not required in the conversion vessel is returned from manifold 67 through valve 101 to conduit 95 and thence to the surge tank.

The fluid heat exchange medium employed may be a gas such as flue gas or steam water under pressure, low melting point molten metal alloys or certain low melting point mixtures of inorganic salts such as the nitrites and nitrates of potassium. Generally, the liquid type heat exchange fluid is preferred where the cooling and heating loads are heavy.

It will be understood that the exact design of the convertor and the choice of operating conditions are for the most part dependent upon the particular operational application involved. In

general, the length of the conversion zone may fall between about 5 to 50 feet and preferably between about 10 to 30 feet. The oil space velocities measured as liquid oil at 60° F. may fall between about 0.5 to 6.0 volumes of oil per volume of catalyst in the conversion zone per hour. The catalyst to oil ratio on a weight basis may fall within the approximate range 0.4 to 4 parts of catalyst per part of oil charged. It will be noted from the above that the method and apparatus of this invention permits the use of much lower catalyst to oil ratios than could be used if the heat for hydrocarbon vaporization and reaction were both supplied entirely by superheating of the incoming catalyst. Thus, not only are more desirable catalyst to oil ratios made possible in the conversion of high boiling liquid hydrocarbon charges, but the catalyst attrition loss and overall operating power requirements are materially reduced over what they would be in the absence of the apparatus arrangement disclosed herein.

Typical of the high boiling liquid hydrocarbon charges to the convertor that may be handled in the apparatus of this invention is a de-asphalted reduced crude from East Texas Crude having the following properties:

A. P. I. gravity	23.2
Vacuum assay dist., °F., corrected to atmospheric pressure:	
I. B. P	817
5%	933
10%	961
50%	1,060
Conradson carbon residue	1.6

The amount of carbonaceous contaminant deposited upon the catalyst from the conversion of the above charging stock may vary from about 5 to 12% weight of the charge, calculated as carbon, and the amount of 400° F., E. P. stabilized gasoline formed in a once-through operation may vary from 25 to 55% volume of the charge depending upon operation conditions chosen.

It should be understood that it is not intended that this invention be restricted to the exact examples of apparatus construction and operating conditions described hereinabove but is to be limited only by the following claims.

I claim:

1. Apparatus for the conversion of high boiling hydrocarbons comprising in combination, a substantially upright elongated reactor adapted for passage of particle form contact material therethrough as a substantially compact column of downwardly moving particles, liquid charge nozzles in the upper section of said reactor, inlet conduit means to supply liquid charge to said nozzles, gas collectors in the lower section of said vessel and conduit means communicating said collectors for withdrawal of gasiform products, a substantially upright elongated regeneration vessel adapted for passage of contact material therethrough as a substantially compact column of downwardly moving particles, means to conduct contact material from the lower end of said reactor to said regeneration vessel, means to introduce combustion supporting gas into said regeneration vessel and means to withdraw regeneration gas from said vessel, means to conduct regenerated contact material from said regeneration vessel to said reactor, heat transfer tubes arranged within said regenerator to permit control of the temperature of said contact material below a heat damaging level, a plurality of vertically spaced groups of heat transfer tubes arranged at vertically spaced intervals within said reactor, said groups being spaced vertically substantially further apart than the tubes within the groups so as to leave substantial vertical sections in the reactor which are free of heat transfer tubes, three separate external manifolds, conduits connecting the outlet ends of all tubes in one of said vessels to the first of said manifolds and conduits connecting the inlet ends of all tubes in said vessel to the second of said manifolds, conduits connecting the inlet ends of all heat transfer tubes in the other of said vessels to the third of said manifolds and conduits connecting the outlet ends of said tubes to said second manifold, valves at least on all the conduits connecting to said second manifold, a connecting conduit between said first and third manifolds and a fluid pump connected into said connecting conduit.

2. In a continuous cyclic apparatus for the catalytic conversion of hydrocarbons comprising a substantially vertical elongated reactor adapted for passage therethrough of catalyst as a substantially compact column of downwardly moving particles, a regenerator adapted to provide contacting of a column of catalyst particles moving downwardly therethrough with a combustion supporting gas and means to pass said catalyst cyclically through said reactor and regenerator, the improvement comprising: heat transfer tubes arranged within said regenerator to provide for heat removal from the catalyst therein by indirect heat transfer, a plurality of vertically spaced apart groups of heat transfer tubes arranged along the length of said reactor, the vertical spacing between groups of tubes being substantially greater than the spacing between tubes within the groups so as to leave substantial vertical sections in the reactor which are free of heat transfer tubes, a pump adapted for circulation of high temperature fluid heat exchange medium, manifolding communicating the discharge of said pump with the inlet ends of all heat transfer tubes in said regenerator, a riser conduit located outside of said reactor and said regenerator, conduits connecting the outlet ends of all heat transfer tubes in said regenerator and the inlet ends of all heat transfer tubes in said reactor to said riser and flow control valves on said conduits, manifolding communicating the outlet ends of all heat transfer tubes in said reactor with the suction side of said pump, liquid inlet nozzles in said reactor, inlet conduits for feeding liquid oil charge to said nozzles, and an outlet for withdrawal of gasiform product in the lower section of said reactor.

3. An apparatus according to claim 2 with the further improvement of heat exchange means located externally of said reactor and regenerator adapted for adjusting the temperature of the circulating heat exchange fluid.

4. In a system for catalytic conversion of liquid petroleum fractions wherein there is provided a vertical reactor having a catalyst inlet at its upper end, a catalyst outlet at its lower end, liquid inlet nozzles with an inlet conduit feeding the same and an outlet of gasiform product; and a vertical regenerator having a catalyst inlet at its upper end and a catalyst outlet at its lower end and means to pass regeneration gas through said regenerator; and means to circulate catalyst cyclically through said reactor and regenerator, the improvement comprising: a plurality of vertically spaced groups of heat transfer tubes at spaced intervals along the lengths of said reactor, said groups being spaced vertically substantially further apart than the tubes in any group, a plurality

of similarly vertically spaced groups of heat transfer tubes in said regenerator, a surge tank for heat exchange fluid, a pump connected to draw heat exchange fluid from said surge tank, a first riser manifold, conduit means connecting the discharge of said pump to said manifold, conduits separately connecting each group of tubes in said regenerator to said manifold, a plurality of connecting conduits, one connecting conduit connecting the outlet from each group of tubes in said regenerator to a similarly positioned group of tubes in said reactor and flow control valves on said conduits, a second riser manifold, conduits separately connecting the outlets of all of said groups of tubes in said reactor to said second riser, a return conduit connecting said second riser to said surge tank, a third riser closed on one end and communicating with said return conduit on its other end, pipes having shut-off valves thereon communicating said third riser with said plurality of connecting conduits.

5. A method for conversion of high boiling liquid hydrocarbons which comprises: introducing a particle-form solid contact material into the upper section of a conversion zone at a temperature near the desired conversion temperature and below the boiling point of at least part of the liquid hydrocarbon charge, passing said contact material downwardly as a substantially compact column through a series of alternating regions wherein it is subjected to heat supply by indirect heat transfer from a heat exchange fluid and regions wherein it is substantially free of heat supply, introducing the liquid hydrocarbon charge into said conversion zone and passing it longitudinally through a substantial portion of said column including said regions of heat supply and regions free from heat supply to effect the conversion of said charge to a gasiform product to lower boiling hydrocarbons existing in the gaseous phase by means of the heat supplied by the heat exchange fluid in said regions of heat supply, withdrawing said gasiform product from said conversion zone separately of the contact material, withdrawing used contact material from the lower section of said conversion zone separately of the gasiform product and passing it to and through a confined regeneration zone wherein it is subjected to contact with an oxygen containing gas to burn off from the contact material carbonaceous contaminants deposited thereon in said conversion zone, returning the contact material from said regeneration zone to said conversion zone, passing said heat exchange fluid cyclically in indirect heat transfer relationship with the contact material in said regeneration zone to absorb the heat released by contaminant combustion and in indirect heat transfer with said column in said conversion zone in said vertically spaced apart regions of heat supply, and controlling the temperature and rate of heat exchange medium flow in said vertically spaced regions of heat supply to effect supply of the conversion heat requirements of each of said regions whereby the contact material and hydrocarbon charge are maintained within a narrow range of temperatures near and including the desired conversion temperature throughout their passage through said conversion zone while at the same time the hydrocarbon charge contacts the contact material in the absence of indirect heat transfer during a substantial portion of its travel through the conversion zone.

6. A method for effecting catalytic cracking conversion of a high boiling liquid hydrocarbon charge comprising: introducing a freshly regenerated particle-form catalyst into the upper section of a conversion zone at a temperature near the desired conversion temperature and below the boiling point of at least most of the hydrocarbon charge, introducing the hydrocarbon charge in the liquid phase at a temperature below the desired conversion temperature into the upper section of said conversion zone, flowing the catalyst as a compact column and hydrocarbon charge together downwardly through a series of regions of indirect heat transfer where heat is supplied for converting said hydrocarbons to lower boiling gasiform products and regions wherein the conversion progresses in the absence of indirect heat transfer, maintaining the catalyst temperature within a narrow uniform range of temperatures near and including the desired conversion temperature along the length of said conversion zone by passing separately controlled amounts of heated heat exchange fluid in indirect heat transfer relationship with said catalyst in said conversion zone only in said regions of indirect heat transfer, withdrawing gasiform products from the lower section of said conversion zone, withdrawing catalyst bearing a carbonaceous deposit from the lower section of said conversion zone separately of the gasiform products and passing it as a substantially compact column through a confined regeneration zone, passing a combustion supporting gas into contact with the catalyst in said regeneration zone to burn off the deposit therefrom, passing the heat exchange fluid from said conversion zone in indirect heat transfer relationship with the catalyst in said regeneration zone to remove heat released by the deposit combustion and returning the heated heat exchange fluid to said regions of indirect heat transfer in said conversion zone as aforesaid and adjusting the temperature of said heat exchange fluid at a point outside of said conversion and regeneration zones to balance any difference in the heat absorbed by said fluid in the regeneration zone and the heat released by said fluid in said conversion zone.

7. A process for cracking high boiling liquid petroleum reactant in the presence of a particle-form catalyst comprising: forming a stream of freshly regenerated catalyst existing initially near the desired conversion temperature and below the boiling point of at least most of the liquid petroleum reactant into a compact gravitating column, supplying the liquid petroleum reactant onto said column and flowing the catalyst column and liquid reactant downwardly through a heat supply region wherein heat for effecting partial conversion of said liquid reactant to lower boiling gasiform products is supplied at a rate sufficient to maintain said catalyst near the desired conversion temperature level, then passing the catalyst as a compact column and the converted and non-converted liquid reactant downwardly through an adiabatic region from which heat supply is excluded so that the liquid reactant may undergo further conversion in the absence of heat supply from an external source, continuing the downward flow of catalyst and reactant through a series of alternating regions of heat supply and adiabatic regions until the reactant has become completely converted to a lower boiling, gasoline containing gasiform product and a small amount of carbonaceous material deposited upon the catalyst, then withdrawing the gasiform product from the catalyst

column and passing the catalyst as a substantially compact column through a confined regeneration zone, passing an oxygen containing gas through the column in said regeneration zone to burn the carbonaceous material off from the catalyst, passing a heat exchange fluid in indirect heat transfer relationship with said column in said regeneration zone at a plurality of vertically spaced apart levels to absorb heat released by the burning of the carbonaceous material and then passing the heated fluid in indirect heat transfer relationship with the catalyst and reactant in said regions of heat supply to supply the heat required for said reactant conversion, independently controlling the amount of heat exchange fluid flow in each of said regions of heat supply to maintain the catalyst temperature within a uniform, narrow range during the entire period of its contact with said reactant, and adjusting the temperature of said heat exchange fluid subsequent to its passage through said regions of heat supply to compensate for any net difference in the heat absorbed from the regeneration zone and supplied for said conversion and returning the fluid to said regeneration zone.

LOUIS P. EVANS.

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