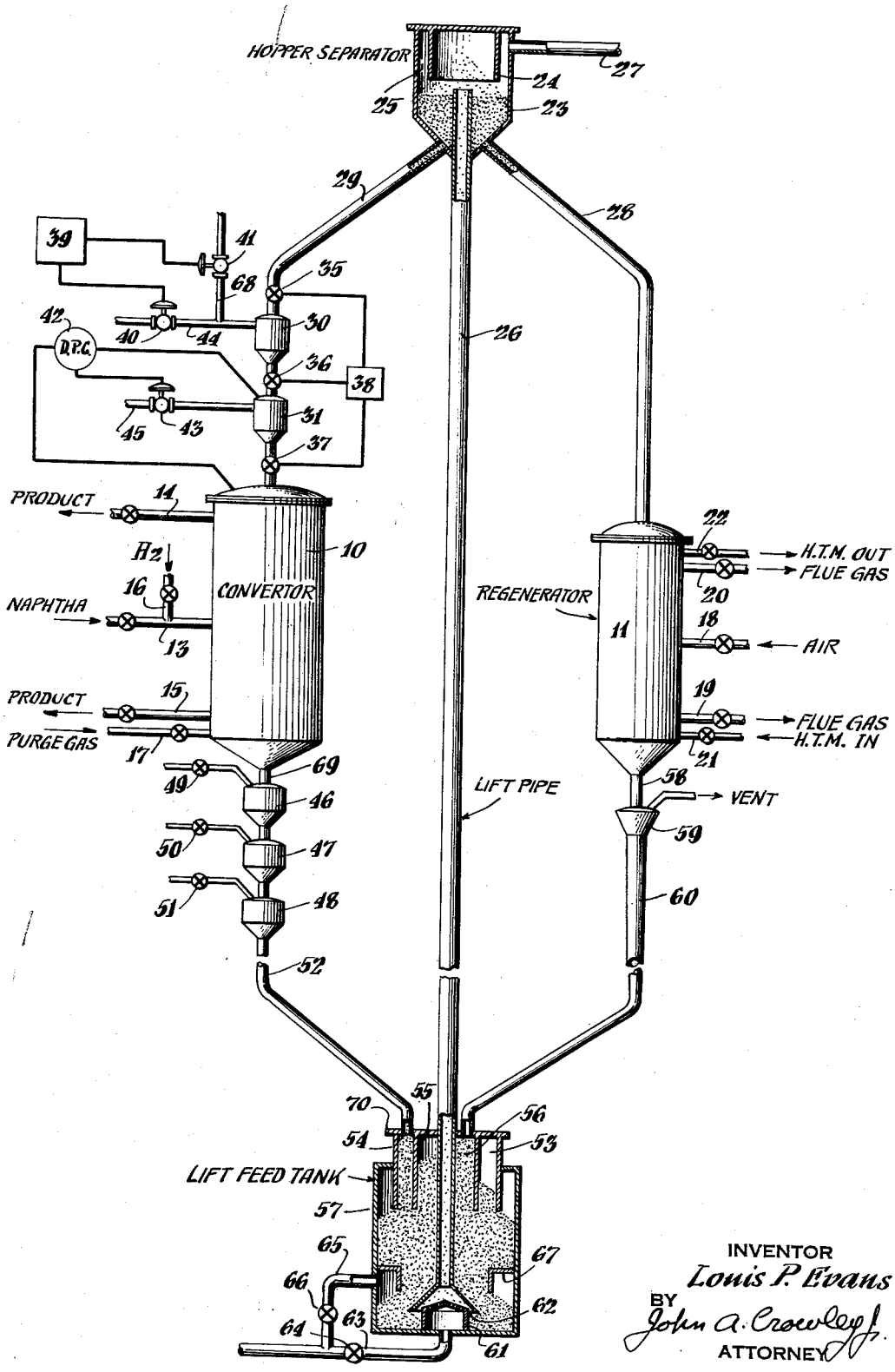
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METHOD AND APPARATUS FOR CATALYTIC CONVERSION

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METHOD AND APPARATUS FOR CATALYTIC CONVERSION

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This invention pertains to a process for conversion of hydrocarbons in the presence of moving granular contact material and particularly to processes in which the amount of carbonaceous contaminant deposited on the contact material is low relative to the amount of such deposits encountered in severe catalytic cracking and in which the conversion activity of the contact material is not seriously impaired by said deposits. Typical of the processes to which this invention may be applied are catalytic hydrogenation, light cracking operations and reforming of hydrocarbons either in the presence or in the absence of hydrogen.

This invention is directed to catalytic processes wherein the catalyst is in granular form, the term granular being employed to include pelleted, tableted, spherical pieces or pieces of regular or irregular shape. The average particle diameter should be broadly within the range about 0.006 inch to 0.25 inch and preferably within the range about 0.03 inch to 0.18 inch.

Suitable catalysts may be selected from a wide variety of materials. Among these are the oxides or sulfides of the metals of the II, IV, V, VI and VIII groups of the periodic system, especially chromium, tungsten, vanadium, molybdenum, cobalt and nickel deposited upon natural or activated clays, magnesia, activated alumina, or synthetic gels of silica, alumina or silica and alumina.

In processes of the above-mentioned types in which the deposition of carbonaceous contaminants on the catalyst is relatively low, the catalyst need not be entirely regenerated since its efficiency for hydrocarbon conversion remains at a practicable level until it has accumulated approximately 5 per cent carbonaceous contaminant by weight.

Catalytic conversion systems employing moving granular beds of catalyst are generally of two types of construction. In the first the conversion vessel and regeneration vessel are placed side by side, a conveyor employed to transport catalyst from the bottom of the converter to the top of the regenerator and a second conveyor used to transport catalyst from the bottom of the regenerator to the top of the converter. Separate surge zones are provided for converter and regenerator. In the second, converter and regenerator are placed one on top of the other and a single conveyor is supplied to transport catalyst to the uppermost vessel. Here again separate surge zones are necessary for each vessel. This invention proposes a method whereby regenerator and converter are placed side by side and a single conveyor and surge zone is provided to service both vessels. This results in an economic advantage over both of the previously described systems. This saves the cost of one of the conveyors and a surge zone from the first system and the cost of the added unit height and a surge zone from the second system.

A major object of this invention is to provide a simple, compact, inexpensive method and apparatus for the conversion of hydrocarbons in the presence of moving granular contact material.

A specific object of this invention is to provide an improved method and apparatus for conducting hydrocarbon reforming in the presence of a moving bed of granular catalytic material.

Another object is the provision in such a process of a new and improved method and apparatus for accomplishing the catalyst circulation which overcomes the disadvantages of the prior art systems discussed hereinabove.

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

According to one form of this invention converter and regenerator are placed side by side. A surge vessel, containing a mixture of regenerated and unregenerated used catalyst, is positioned above and between the converter and the regenerator. A portion of this catalyst mixture gravitates continuously from the surge vessel and passes through the regenerator wherein it contacts an oxygen containing gas which burns off the carbonaceous deposits. The regenerated catalyst then passes through a gravity feed leg and into a lift feed tank common to both the regenerator and the converter. The remainder of the catalyst mixture gravitates continuously from the surge vessel and passes through pressuring chambers and into the converter wherein it contacts a hydrocarbon feed to effect the desired conversion thereof. The catalyst then passes through a depressuring zone and into the common lift feed tank. Here the used catalyst from the converter and the regenerated catalyst from the regenerator are thoroughly mixed with a lift gas and transported by means of this gas back to the surge vessel. The surge vessel also acts as a separator for the lift gas and catalyst.

This invention will be more readily understood by reference to the attached drawing which is an elevational view, partially in section, of a preferred arrangement of this invention. This drawing is highly diagrammatic in character.

Referring to the drawing, we find converter **10** and regenerator **11** positioned side by side. The converter is provided with hydrocarbon feed conduit **13** at its center and product outlet conduits **14** and **15** at either end. Also, the converter is equipped with a hydrogen inlet conduit **16** and a purge gas inlet **17**. Vapor disengaging members (not shown) may be provided at the top and bottom of vessel **10** in association with outlets **14** and **15**. Suitable disengaging arrangements are shown in Simpson et al., U. S. Patent 2,336,041, or Fahnestock, U. S. Patent 2,362,621. The lower end of converter **10** may also be provided with baffles adapted to effect uniform withdrawal of catalyst from all sections of the horizontal cross-sectional area of the conversion zone. Such baffles are shown in Evans et al., U. S. Patent 2,412,316. Regenerator **11** is provided with inlet **18** for combustion supporting gas and outlets **19** and **20** near its opposite ends. Heat transfer tubes (not shown) with inlet **21** and outlet **22** may also be provided within the regenerator to control regeneration temperature. A combination surge vessel and catalyst separator **23** is positioned above and between converter **10** and regenerator **11**. A cylindrical baffle **24** depends downwardly from the top of chamber **23** so as to leave an annular space **25** between the baffle and the wall of cylinder **23**. A catalyst lift pipe **26** terminates just below baffle **24** and a gas outlet conduit **27** communicates with annular space **25**. Two catalyst drain conduits **28** and **29** are provided at the bottom of chamber **23**.

Conduit **28** connects into the top of regenerator **11**. Conduit **29** connects into the top of converter **10** and has spaced along its length depressuring chambers **30** and **31**. Motor operated valves **35**, **36** and **37** are placed above chamber **30**, between chambers **30** and **31**, and

below chamber 31 respectively. These valves are operated by controller 38. Chamber 30 is equipped with a conduit 44 having a motor controlled diaphragm valve 40 for the introduction of an inert gas such as steam or flue gas into chamber 30. Chamber 30 is also provided with an inert gas outlet conduit 68 having a motor controlled diaphragm valve 41. Valves 40 and 41 are operated by controller 39. Chamber 31 has a conduit 45 for inert gas flow equipped with a diaphragm valve 43 which is operated by a differential pressure controller 42. Converter 10 has a catalyst outlet 69 which connects to three depressuring chambers 46, 47 and 48 in series. These chambers are adapted to effect the release of gaseous pressure without break in the catalyst stream and without loss of catalyst. The pressures within chambers 46, 47 and 48 are controlled by means of diaphragm valves 49, 50 and 51 respectively. Suitable depressuring chamber constructions are described in United States Patent 2,448,272 issued August 31, 1948. If desired, one, two or more than three depressuring chambers may be used. Conduit 52 extends downwardly from the bottom of depressuring chamber 48 to lift feed tank 57. A catalyst outlet conduit 58 is provided at the bottom of regenerator 11. Conduit 58 terminates in a vented hopper 59 which is positioned at the upper end of a gravity leg 60. This leg should be vertical over most of its length and of sufficient height to overcome the pressure differential between hopper 59 and lift feed tank 57. It should preferably be of tapered construction its diameter decreasing at successively lower levels. Suitable tapered gravity legs are described in United States patent application, Serial Number 329,882, filed June 6, 1953. Lift feed tank 57 is situated below and between converter 10 and regenerator 11. Vertical lift feed pipe 26 having a flared lower end extends upwardly from within feed tank 57 into separator 23. At the top of feed tank 57 are provided catalyst inlet passages 53 and 56 which are formed by vertical pipe sections 54 and 55 of differing diameters. Sections 54 and 55 are arranged concentrically with respect to lift pipe 26 and extend a short distance above and below the top of feed tank 57. The pipe of larger diameter is connected to the top of the lift feed tank and a closure 70 is provided over the upper ends of both pipes. Conduit 52 extends into section 53 while gravity leg 60 extends into section 56. A gas distributor manifold 61 having a perforated upper end extends upwardly from the bottom of feed tank 57 to a point directly below the flared lower end of lift pipe 26 so as to form anular passage 62. A gas inlet conduit 63 having a flow control valve 64 thereon connects into the bottom of tank 57 below manifold 61. A ring shaped angle member 67 is attached to the inner periphery of feed tank 57 and serves as a gas distributor for a second stream of gas which is provided by conduit 65 with control valve 66 thereon.

In operation separator 23 serves both to separate lift gas and catalyst particles and to provide a surge or supply vessel for the separated particles. The separating function of 23 is performed in the upper section while surge or supply space is provided in the lower. Mixed used and regenerated catalyst flows from this surge space through conduit 29 and is admitted upon the opening of valve 35 to chamber 30. Valve 35 then closes and gaseous pressure is built up in chamber 30 by means of inert gas supplied through conduit 44 and valve 40 to a point slightly above the gaseous pressure in chamber 31. Valve 36 then opens and catalyst flows from chamber 30 to chamber 31. Valve 36 closes and chamber 30 is depressured by releasing the gas therein through conduit 68 and valve 41. The pressure in chamber 31 is maintained slightly above that in converter 10 by means of inert gas introduced through conduit 45. After valve 36 has closed valve 37 then opens and catalyst flows into converter 10. Controller 38 operates valves 35, 36 and 38 so that valves 35 and 37 open together a fixed time after valve 36 closes this fixed time being the time necessary to depressure chamber 30 through conduit 68. Valve 36 then opens a fixed time after valves 35 and 37 close this fixed time being the time necessary to pressure chamber 30 with inert gas through conduit 44. Controller 39 operates valves 40 and 41 on a time cycle in conjunction with that of controller 38. Catalyst gravitates through the conversion zone within converter 10 as a compact moving bed and is contacted therein by a naphtha feed which enters through conduit 13. A hydrogen containing gas may be admitted to the conversion zone through conduit 16. Gaseous conversion products are withdrawn from the converter through conduits 14 and 15. Used catalyst from the conversion zone is purged free of gaseous hydrocarbon products in the lower section of converter 10 by means of an inert purge gas, such as steam or flue gas, admitted through conduit 17. The purged used catalyst is removed from converter 10 through conduit 69 and passes through depressuring chambers 46, 47 and 48 wherein the gaseous pressure is successively reduced by means of diaphragm valves 49, 50 and 51. The gaseous pressure in chamber 48 is maintained slightly above that in lift feed tank 57. Used catalyst flows through conduit 52 into annular passage 53 at the top of lift feed tank 57.

A second stream of mixed used and regenerated catalyst flows from the surge section of separator 23 through 28 into the upper end of regenerator 11. Catalyst flows through the regeneration zone within regenerator 11 as a compact column and is contacted therein by a combustion supporting gas, such as air, admitted through conduit 18. Flue gas is removed by means of conduits 19 and 20. Catalyst passes through the regenerator and is removed through conduit 58. This regenerated catalyst passes into vented hopper 59 from which it flows through gravity leg 60 into annular passage 56 in lift feed tank 57. Used and regenerated catalyst from passages 53 and 56 are mixed to a certain degree as they flow with the main body of the catalyst within lift feed tank 57. Lift gas admitted through conduit 65 at a rate controlled by valve 66 forces catalyst particles up into annular passage 62 where said particles are contacted by a second stream of lift gas flowing through perforations in the top of manifold 61. Catalyst particles are suspended in the lift gas and transported upwardly through lift pipe 26 into separator 23. Particles of used and regenerated catalyst are thoroughly mixed by the lift gas during passage through pipe 26 so that a uniformly mixed catalyst flows into separator 23. Lift gas is removed from separator 23 through conduit 27 and the mixed catalyst falls downwardly onto the surge bed in the lower section of separator 23.

The lift feed tank in the process described above is operated at a pressure slightly above atmospheric pressure. However in some operations it may be desirable to develop a pressure differential across lift pipe 26 by evacuating the separator while maintaining the lift feed tank at atmospheric pressure. For example if steam is used as the lift gas a barometric condenser could be attached to conduit 27 to maintain a vacuum within separator 23. Such a system is described in U. S. patent application, Serial Number 75,642, filed February 10, 1949, now U. S. Patent No. 2,684,927. Also, while operation of the separator at atmospheric pressure is generally desirable, it is contemplated within the broader scope of this invention that the separator may be operated at a pressure above as well as below atmospheric pressure. It is further contemplated within the broader scope of this invention that final depressuring of the catalyst stream after passage through the converter may be to atmospheric pressure with a gravity feed leg provided below the lower depressuring chamber to feed catalyst to lift feed tank. It should also be understood that the hydrocarbon feed may be introduced at the top or bottom of the converter rather than the center as

described herein and that the introduction of hydrogen containing gas into the reactor is not essential to the broader forms of this invention.

It should be noted that in this invention the used and regenerated catalyst are thoroughly mixed before being contacted by either the regeneration gas or the hydrocarbon feed. This is an important part of the operation since contact of a non-uniform mixture of used and regenerated catalyst by the regeneration gas might result in the temperature of the catalyst at certain points becoming so high as to permanently injure the catalyst while contact of a non-uniform mixture by the hydrocarbon feed might result in over-conversion of a portion of the feed and under-conversion of the remaining portion. This invention has the further advantage that a separate mixing step is not required to achieve this uniform mixture since the catalyst is thoroughly mixed while being transported by the gas lift to the supply hopper.

Broadly, the converter in this invention when used for reforming should be operated at pressures within the range about 25 to 1000 pounds per square inch and preferably within the range about 15 to 400 pounds per square inch and temperatures within the range about 800° F. to 1100° F. and preferably about 900° F. to 1050° F. This invention is not limited in its broadest form to any particular range of gas velocities or catalyst stream densities in the lift pipes but it is preferable that the linear upward gas velocity be within the range about 80 to 130 feet per second and that the stream density be within the range about 1 to 30 pounds per cubic foot on the basis of a catalyst having a compact flowing density of about 45 pounds per cubic foot and a particle size of about 4 to 16 mesh Tyler. The effect of the percentage of carbonaceous contaminants on the catalyst depends on the converter and conversion conditions involved. In reforming operations the mixed used and regenerated catalyst which is fed to the converter and regenerator should have an average carbonaceous contaminant deposit not exceeding about 2 per cent by weight. Also the deposits on the used catalyst being recycled should not exceed about 6 per cent by weight and preferably should not be greater than about 4 per cent by weight. The conditions of temperature, pressure, space velocity, residence time and hydrocarbon concentration within the converter should be controlled to limit the amount of deposits on the used catalyst below the above limits. Conditions outside these ranges may be used when conversions other than reforming are practiced within the scope of this invention.

As typical of the operation according to this invention, its application to the reforming of a petroleum naphtha charging stock containing mostly paraffinic and naphthenic hydrocarbons may be considered. The granular catalyst may comprise particles of alumina with chromium oxide deposited thereon and may be of the order of 4 to 20 mesh size by Tyler standard screen analysis. Converter **10** may be maintained at a pressure of, for example, 25 pounds per square inch gauge. Pressuring chambers **30** and **31** would then operate at 26 and 25½ pounds per square inch gauge, respectively. The naphtha feed having, for example, a 10 per cent A. S. T. M. boiling point at 300 F. and an end point of 425° F. is introduced into the converter at a temperature of 950° F. Hydrogen is also supplied to the converter in the ratio of about 5 mols of hydrogen to one mol of hydrocarbon charge. Depressuring chambers **46**, **47** and **48** may be maintained at 15, 7 and 2 pounds per square inch gauge, respectively. Regenerator **11** may be operated at a pressure slightly above atmospheric pressure for example 2 pounds per square inch gauge. The temperature of the catalyst therein is best controlled below 1100° F. to avoid permanent damage to the catalyst by overheating. Lift feed tank **57** may also be maintained at a pressure slightly above atmospheric for example 2 to 4 pounds per square inch gauge.

This invention should be understood to cover all changes and modifications of the examples of the invention herein chosen for the purposes of disclosure which do not constitute departures from the spirit and scope of this invention.

I claim:

1. In a process for the conversion of hydrocarbons by a moving granular catalyst wherein at least two separate zones are maintained the first of which is a conversion zone in which hydrocarbon feed is contacted by a moving bed of granular catalyst to effect the conversion of said hydrocarbon feed and thereby deposit carbonaceous contaminant on the catalyst in an amount less than the amount of carbonaceous contaminant which reduces the efficiency of the hydrocarbon conversion below a practical low level, the second of which is a regeneration zone in which carbonaceous contaminant is removed from the catalyst by contacting said catalyst with a combustion supporting gas to effect removal of said contaminant by burning the improvement which comprises, passing at least a portion of used catalyst from the conversion zone to a location where it is suspended in a suitable carrying gas, passing at least a portion of the regenerated catalyst from the regeneration zone to said location where it is also suspended in said carrying gas, passing the resulting stream of used and regenerated catalyst suspended in said carrying gas upwardly through a confined passage to a location from which at least a portion of said catalyst may flow to said conversion zone whereby a uniformly mixed stream of used and regenerated catalyst is supplied to said bed within said conversion zone.

2. In a process for the conversion of hydrocarbons by a moving granular catalyst wherein hydrocarbon feed is passed into a conversion zone and into contact with a moving bed of granular catalyst therein at suitable temperature and pressure for effecting the conversion of the hydrocarbon feed and wherein a regeneration zone is maintained in which carbonaceous contaminant deposited on the catalyst during the conversion is burned from the catalyst by contacting said catalyst with a combustion supporting gas, the conversion reaction of the process remaining at a practical level in spite of deposits of carbonaceous contaminant up to deposits of about five per cent by weight of catalyst and the reaction depositing an amount of carbonaceous contaminant on the catalyst substantially less than five per cent by weight of the catalyst, the improvement which comprises, passing at least a portion of the used catalyst from the conversion zone to a location where it is suspended in a suitable carrying gas, passing the regenerated catalyst from the regeneration zone to said location where it is also suspended in the carrying gas, passing the resultant stream of used and regenerated catalyst suspended in said carrying gas upwardly through a confined passage to a confined separation zone located above said conversion zone whereby the used and regenerated catalyst granules are simultaneously lifted and thoroughly mixed, effecting separation of the carrying gas from the mixed catalyst in said separation zone and withdrawing the carrying gas therefrom and flowing at least a portion of the mixed catalyst downwardly to the conversion zone to replenish the catalyst bed therein.

3. In a process for the conversion of hydrocarbons in the presence of a moving compact bed of granular catalyst wherein the conversion reaction remains at a practicable level even though carbonaceous contaminants are deposited on the catalyst up to an average deposit amounting to about five per cent by weight of the catalyst, the improved mode of operation which comprises: passing a hydrocarbon feed into a confined conversion zone wherein the hydrocarbon feed contacts a substantially compact bed of moving granular catalyst at conversion temperature and pressure to effect the desired

conversion to gasiform products, withdrawing the gasiform products from the conversion zone, passing used catalyst bearing a carbonaceous contaminant deposited during the conversion to a mixing zone where it is mixed with a suspending gas, passing the used catalyst suspended in said gas upwardly through a confined lift passage to a separation zone maintained at a higher level than said conversion zone, effecting separation of the lift gas from the catalyst in said separation zone and withdrawing the lift gas therefrom, collecting the separated catalyst on a surge bed thereof, passing a portion of the catalyst from the surge bed downwardly to and through a confined regeneration zone wherein it is contacted with a combustion supporting gas to burn off said carbonaceous contaminant, passing regenerated catalyst from the regeneration zone to said mixing zone to become mixed with said used catalyst and said suspending gas, passing said regenerated catalyst suspended in said gas upwardly through said lift passage along with said used catalyst and also collecting said regenerated catalyst mixed together with said used catalyst on said surge bed and passing a second portion of said catalyst from said surge bed downwardly into said conversion zone to supply the bed of catalyst therein.

4. In a process for the conversion of hydrocarbons in the presence of a moving compact bed of granular catalyst wherein the conversion reaction remains at a practicable level even though carbonaceous contaminants are deposited on the catalyst up to an average deposit amounting to about five per cent by weight of catalyst and wherein the conversion reaction deposits an amount of carbonaceous contaminant substantially less than about five per cent by weight of the catalyst, the improved mode of operation which comprises: maintaining a supply bed of uniformly mixed regenerated and used catalyst, passing a portion of said mixed catalyst downwardly from said bed to a confined conversion zone and passing it downwardly through at least a portion of said zone as a substantially compact bed of gravitating material, passing a hydrocarbon feed into contact with said bed to contact said catalyst under conversion conditions of temperature and pressure, whereby it is converted to gasiform hydrocarbon products while a carbonaceous contaminant is deposited on the catalyst, withdrawing said gasiform product from said conversion zone, passing a second portion of said mixed catalyst from said supply bed downwardly to and through a confined regeneration zone while contacting it in said regeneration zone with a combustion supporting gas to burn off the contaminant, passing regenerated catalyst downwardly to a location where it is mixed with a lift gas to effect its suspension therein, passing used catalyst from said conversion zone downwardly to said location to mix with the lift gas and said regenerated catalyst, passing the used and regenerated catalyst in suspension in said lift gas upwardly through a confined lift passage to a separation zone located above said supply bed, effecting separation of said lift gas from said catalyst in said separation zone and collecting the separated thoroughly mixed catalyst on said supply bed to replenish the same.

5. In a cyclic process for reforming of hydrocarbon fractions to produce high octane gasoline in the presence of a moving compact bed of granular catalyst wherein the conversion reaction remains at a practicable level even though carbonaceous contaminants are deposited on the catalyst up to an average deposit amounting to about five per cent by weight of catalyst which comprises, maintaining a substantially compact bed of a suitable dehydrogenation catalyst in a confined reforming zone, maintaining a bed of mixed used and regenerated dehydrogenation catalyst in a supply zone located at a level above said reforming zone, flowing a stream of the mixed catalyst from said supply zone downwardly into said reforming zone to maintain said bed therein replenished, passing a hydrocarbon naphtha fraction into contact with said catalyst in the presence of an added hydrogen containing gas to effect reforming of said naphtha to form a product containing high octane gasoline while a carbonaceous contaminant is deposited on the catalyst, withdrawing said gasoline containing product from said reforming zone, passing a second stream of the mixed catalyst downwardly from said supply zone to and through a regeneration zone while contacting the catalyst in said regeneration zone with a combustion supporting gas to effect removal of carbonaceous contaminant from said catalyst by burning, passing regenerated catalyst from said regeneration zone and used catalyst from said reforming zone downwardly to a mixing zone and contacting the catalyst in said mixing zone with a lift gas to effect its suspension therein, passing the used and regenerated catalyst suspended in said lift gas upwardly as a confined lift stream, whereby the used and regenerated catalyst granules are simultaneously elevated and thoroughly mixed, discharging the mixed catalyst upwardly from said lift stream into an expanded separation zone, effecting separation of said catalyst from said lift gas in said separation zone and gravitating the separated mixed catalyst downwardly onto said supply bed.

6. In a cyclic process for reforming of hydrocarbon fractions to produce high octane gasoline in the presence of a moving compact bed of granular catalyst wherein the conversion reaction remains at a practicable level even though carbonaceous contaminants are deposited on the catalyst up to an average deposit amounting to about five per cent by weight of catalyst which comprises, maintaining a substantially compact bed of a suitable dehydrogenation catalyst in a confined reforming zone, passing a hydrocarbon fraction boiling within the range in which naphtha and motor gasoline boil into contact with said catalyst in the presence of an added hydrogen containing gas to effect reforming of said naphtha to form a product containing high octane gasoline while a carbonaceous contaminant is deposited on the catalyst, withdrawing said gasoline containing product from said reforming zone, maintaining a bed of dehydrogenation catalyst comprising a mixture of catalyst which has been used for the conversion in said reforming zone and catalyst which has been regenerated in the lower portion of a confined settling zone maintained at a level above said reforming zone, the used catalyst in said mixture bearing a carbonaceous contaminant deposit less than about 6 per cent by weight of the used catalyst, passing a first stream of said mixed catalyst downwardly from said settling zone to said reforming zone to supply the bed of catalyst therein, passing a second stream of the mixed catalyst downwardly from said supply zone to and through a regeneration zone while contacting the catalyst in said regeneration zone with a combustion supporting gas to effect removal of carbonaceous contaminant from said catalyst by burning, passing regenerated catalyst from said regeneration zone and used catalyst from said reforming zone downwardly onto a bed of said catalyst in a lift feed zone, passing used and regenerated catalyst together upwardly through a confined passage in suspension in a lift gas from a location within said bed in said lift feed zone to a location above said bed in said settling zone, whereby the used and regenerated catalyst are simultaneously elevated and mixed, permitting the stream from said lift passage to expand in said settling zone, whereby the catalyst settles from the lift gas, collecting the settled mixed catalyst on said bed in said settling zone and withdrawing lift gas from an upper section of said lift zone.

7. In a cyclic process for reforming hydrocarbons in the presence of a moving compact bed of granular catalyst wherein the conversion reaction remains at a practicable level even though carbonaceous contaminants are

deposited on the catalyst up to an average deposit amounting to about five per cent by weight of catalyst which comprises, maintaining a surge bed of uniformly mixed used and regenerated dehydrogenation catalyst, the used catalyst in said mixture bearing a carbonaceous contaminant deposit less than about 4 per cent by weight of the used catalyst and the average carbonaceous contaminant deposit of the catalyst mixture being less 2 per cent by weight, passing a stream of said dehydrogenation catalyst from the surge bed into a reforming zone, contacting the catalyst within the reforming zone with a hydrocarbon naphtha feed to effect conversion of the hydrocarbon feed to a gasiform product containing high octane gasoline while depositing carbonaceous contaminant on the catalyst, withdrawing said gasiform product from the reforming zone, passing a second stream of said mixed catalyst from the surge zone downwardly to and through a confined regeneration zone while contacting it in said regeneration zone with a combustion supporting gas to effect the removal of said carbonaceous contaminant by burning, passing the regenerated catalyst downwardly to a mixing zone wherein it is mixed with a lift gas to effect its suspension therein, passing used catalyst from the reforming zone downwardly to said mixing zone and mixing the used catalyst therein with the lift gas and said regenerated catalyst, passing the used and regenerated catalyst suspended in the lift gas upwardly through a confined lift passage to a separation zone located above said surge bed, separating the uniformly mixed catalyst from the lift gas in said separation zone, effecting the removal of said lift gas from said separating zone, and collecting the separated thoroughly mixed catalyst on said surge bed to replenish same.

8. A cyclic system for reforming petroleum naphtha which comprises, in combination: a conversion vessel adapted to confine a compact bed of granular catalyst, means to supply reactant to said vessel and means to withdraw reactant from said vessel, a catalyst inlet connected into the upper end of said vessel and a catalyst outlet connected into the lower end thereof, a separate regenerator vessel having a catalyst inlet at its upper end and a catalyst outlet at its lower end, said regeneration vessel being positioned alongside of said conversion vessel, a lift feed tank below said conversion and regeneration vessels and a settling chamber positioned above said conversion and regeneration vessels, a gas outlet connected into the upper section of said settling chamber, passage defining means for catalyst flow from the lower section of said settling chamber to said catalyst inlet on said conversion vessel, passage defining means for catalyst flow from the lower section of said settling chamber to said catalyst inlet on said regeneration vessel, a substantially vertical lift conduit extending upwardly from a location within said lift feed tank intermediate its upper and lower ends to a location within said settling chamber intermediate its upper and lower ends, means to supply a lift gas to said lift feed tank, passage defining means for a catalyst flow from the catalyst outlet on said conversion vessel to said lift feed tank, and passage defining means for catalyst flow from said catalyst outlet on said regeneration vessel to said lift feed tank, whereby catalyst from said conversion vessel and said regeneration vessel are mixed by the lift gas in the lift feed tank and transported upwardly through the lift pipe to the settling chamber.

9. A cyclic system for reforming petroleum naphtha which comprises in combination, an elongated conversion vessel having reactant inlet and outlet means, a separate

elongated regeneration vessel having gas inlet and outlet means, a lift feed tank located below said reactor and regenerator vessels, members defining passages for catalyst flow from the bottoms of said reactor and regeneration vessels into the upper section of said feed tank, a gas-solid separator located above said reactor and regenerator vessels, a substantially vertical lift conduit extending upwardly from a location within said feed tank intermediate its ends to a location within said separator, means to withdraw gas from the upper section of said separator, members defining passages from the lower section of said separator to the upper sections of said reactor and regenerator vessels, and means to supply a lift gas to said feed tank, whereby catalyst from said reactor and regenerator are suspended in said lift gas and passed up said lift conduit while undergoing thorough mixing therein to said separator.

10. A cyclic system for reforming petroleum naphthas which comprises in combination, an elongated conversion vessel adapted to confine a compact bed of granular catalyst, means for supplying naphtha feed to said vessel, means for removing gasiform products from said vessel, a catalyst inlet conduit connected into the upper end of said vessel, a catalyst outlet conduit connected into the lower end of said vessel, a separate elongated regeneration vessel having a catalyst inlet at its upper end and a catalyst outlet at its lower end said regeneration vessel being positioned alongside of said conversion vessel, means for introducing a combustion supporting gas into said regeneration vessel, means for removing combustion products from said regeneration vessel, means for cooling the catalyst within said regeneration vessel, a lift feed tank positioned below and between said conversion and regeneration vessels, a catalyst separator positioned above and between said conversion and regeneration vessels, a gas outlet conduit connected into the upper section of said separator, a substantially vertical lift conduit extending from a point within said lift feed tank between the upper and lower ends of said lift feed tank into said separator to a point between its upper and lower ends, a passage defining means from the lower section of said separator to said catalyst inlet on said conversion vessel and means associated with said passage defining means whereby the gaseous pressure of the catalyst stream flowing therein may be increased, passage defining means for catalyst flow from the lower section of said separator to said catalyst inlet on said regeneration vessel, passage defining means for catalyst flow from the catalyst outlet of said conversion vessel to said lift feed tank and means associated with said passage defining means whereby the gaseous pressure of the catalyst stream flowing therein may be reduced, passage defining means from said catalyst outlet on said regeneration vessel to said lift feed tank, whereby catalyst from said reactor and regenerator are suspended in said lift gas and passed up said lift conduit while undergoing thorough mixing therein to said separator.

References Cited in the file of this patent

UNITED STATES PATENTS

2,326,705	Thiele et al.	Aug. 10, 1943
2,439,730	Happel	Apr. 13, 1948
2,463,623	Huff	Mar. 8, 1949
2,490,774	Bland	Dec. 13, 1949
2,531,192	Bergstrom	Nov. 21, 1950
2,543,005	Evans	Feb. 27, 1951