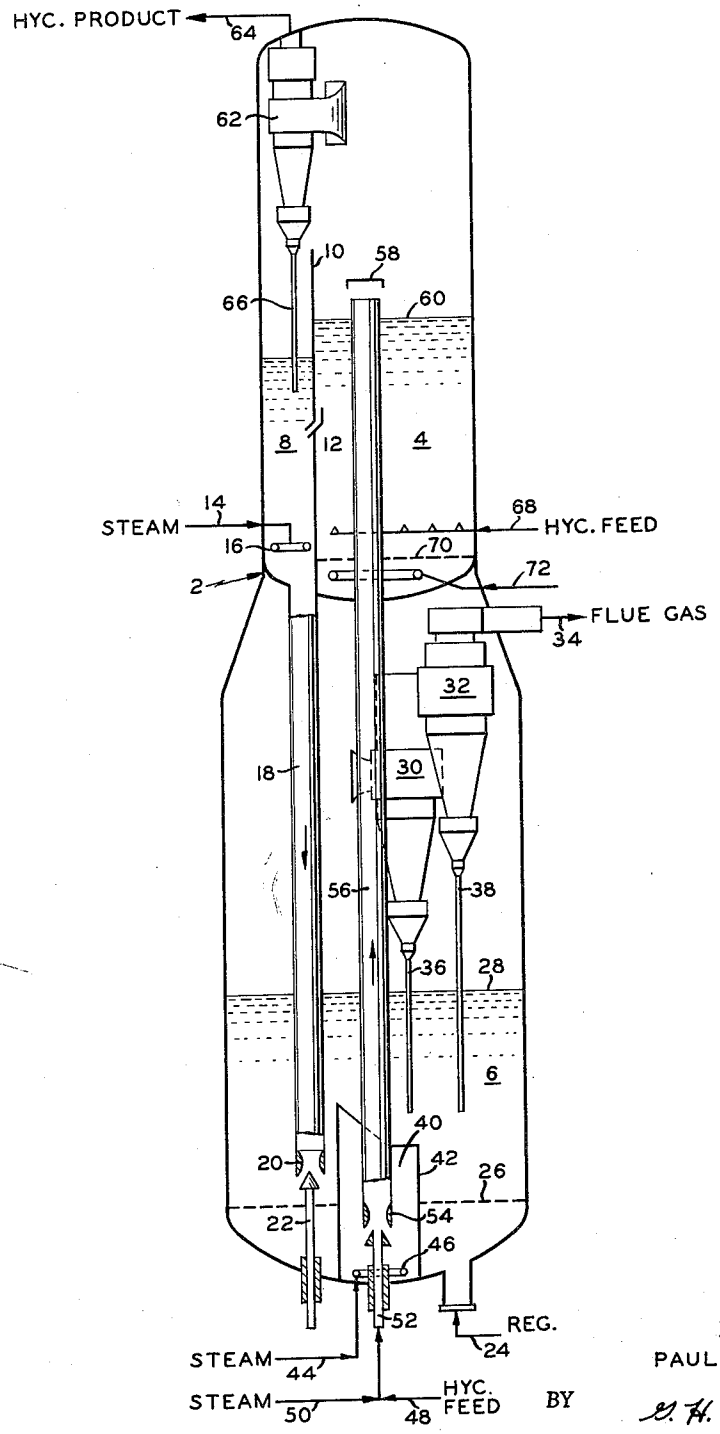
Sept. 11, 1962 P. F. SWANSON 3,053,752

APPARATUS AND METHOD FOR HYDROCARBON CONVERSION OF TWO SEPARATE FEEDS

Filed Dec. 17, 1958



INVENTOR.
PAUL F. SWANSON

BY

E. H. Palmer
ATTORNEY

Carl O. Farnsworth
AGENT

United States Patent Office 3,053,752 Patented Sept. 11, 1962

3,053,752

APPARATUS AND METHOD FOR HYDROCARBON CONVERSION OF TWO SEPARATE FEEDS

Paul F. Swanson, Short Hills, N.J., assignor to The M. W. Kellogg Company, Jersey City, N.J., a corporation of Delaware

Filed Dec. 17, 1958, Ser. No. 781,072
6 Claims. (Cl. 208—78)

This invention relates to an improved method and means for converting high-boiling hydrocarbons to lower boiling hydrocarbons. In one aspect this invention relates to the method and apparatus for effecting cracking of hydrocarbons in stages within a single vessel to produce desired products.

Since the advent of fluidized solid systems for converting chemical reactants the designers have stressed development of simple and effective methods and means for utilization of this principle, such as in the catalytic cracking of high-boiling hydrocarbons to useful gasoline products. To achieve their objectives the designers have been constantly striving to develop simplified systems of high thermal efficiency which would provide them with maximum conversion of hydrocarbon feeds to desired products. This has been accomplished to a large extent by confining within a single unitary vessel an upper contact chamber and a lower contact chamber, either one of which may be used as the hydrocarbon conversion zone or the regeneration zone with suitable interconnecting transfer conduits between each chamber. While these systems were a marked improvement over prior systems and were commercially utilized, nevertheless these too have not been completely satisfactory, particularly from the standpoint of conversion efficiency and product distribution.

As a result of an extensive investigation, many of the difficulties inherent in such designs have been overcome and consequently an improved method and means is now available for commercial use.

An object of this invention, therefore, is to provide an improved method and means for converting hydrocarbons in the presence of finely divided contact material.

Another object of this invention is to provide method and means for converting high-boiling hydrocarbons to desired lower boiling hydrocarbons.

A still further object of this invention is to provide an improved method and means for obtaining maximum conversion of high-boiling hydrocarbons to gasoline products.

Other objects and advantages of this invention will become apparent from the following description.

The present invention is directed to the method and means for contacting a hydrocarbon reactant with finely divided catalytic material under conversion conditions to suitable products in a plurality of conversion zones whereby the catalyst becomes contaminated with carbonaceous material and volatile hydrocarbons. More specifically, in accordance with the process of the present invention, freshly regenerated catalyst is passed upwardly as a relatively dilute suspension at an elevated temperature above about 1000° F., or within a range of from about 1000° F. to about 1100° F., and at a velocity within the range of from about 30 to about 60 feet per second, preferably from about 35 to about 45 feet per second in contact with a vaporous hydrocarbon reactant. Accordingly, the hydrocarbon reactant will be in contact with the catalyst for a period of time not greater than about 4 seconds and preferably less than 3 seconds, for example, about 2 seconds, in its passage through the first elongated confined conversion zone under elevated temperature cracking conditions to effect the desired conversion of the hydrocarbon reactants. This upwardly flowing mixture

of catalyst and hydrocarbons is discharged from the upper portion of the first elongated conversion zone into a second zone above the upper meniscus of a dense fluidized bed of catalytic material maintained in the lower portion of the second zone. The second zone containing a dense fluid bed of contact material therein may be employed for the conversion of a more refractory feed material such as a light cycle or a heavy cycle oil or a mixture of the two may be used therein. For example, a cycle oil may be employed to effect controlled cooling of the catalyst prior to passing the catalyst to the regeneration zone. The reaction products are separated from the major portion of the entrained catalytic material in the first elongated conversion zone by reducing the velocity of the vapors and by changing the direction of flow of the suspension. That is the suspension's vertical velocity component is changed such that the catalyst is directed outwardly and settles downwardly onto the dense catalyst bed in the second zone. During conversion of the hydrocarbon reactant the catalyst becomes contaminated with volatile and non-volatile conversion products such as carbonaceous deposits. The thus contaminated catalyst is separated from the more volatile products of reaction of the first conversion in the enlarged settling zone above the dense bed of catalyst in the second conversion zone and the catalyst falls into or onto the dense fluidized catalyst phase maintained in the second zone surrounding the upper portion of the first conversion zone. In one embodiment of this invention, a second hydrocarbon reactant, either of the same or different boiling range, generally higher boiling or more refractory than that used in the first dilute phase conversion zone, such as a cycle oil, is introduced either partially vaporized or as a liquid into the lower portion of the second zone which is vaporized upon contact with the catalyst and passes upwardly through the dense fluidized catalyst phase maintained in the second zone.

In the second zone or dense phase catalytic zone, the hydrocarbon reactant, generally cycle oil and any adsorbed hydrocarbons from the first high velocity conversion zone are subjected to cracking conditions which are lower in temperature than that employed in the first conversion zone, but for a much longer period of contact time. In the dense phase catalytic conversion zone, the hydrocarbon reactant will be in contact with the catalyst for at least about 4 seconds and preferably from about 4 to not more than about 10 seconds while employing a catalyst to oil ratio of from about 1 to about 20 to 1, and preferably about 10 to 1. Generally the temperature employed in the dense phase conversion zone or second conversion zone will be much lower than that in the first conversion zone and of the order of from about 900° F. to about 960° F., preferably about 925° F. Reaction products containing entrained catalyst of the first and second conversion zones are separated from the major portion of the catalyst in the dilute phase or settling zone in the upper portion of the second conversion zone. These products containing a minor portion of entrained catalyst are withdrawn from the upper portion of the second conversion zone and sent to a suitable cyclone separation zone wherein additional catalyst is separated from the reaction products and returned to the bed of catalyst in the stripping zone. The products of reaction, substantially free of entrained catalyst are then sent to suitable recovery equipment for separation into desired products. Catalyst contaminated with volatile or strippable reaction products, as well as non-volatile carbonaceous deposits is withdrawn from the dense phase of catalyst in the second conversion zone and passed to a suitable stripping zone adjacent to the dense bed reaction zone and in open communication with the dilute catalyst phase or settling zone above the dense bed of catalyst in the reaction zone. By

this arrangement the stripped products of reaction may be removed with the remaining reaction products without any further extended contact with catalyst. This is particularly desirable to avoid extended cracking of these products. Similarly, the catalyst separated in the cyclone separator containing adsorbed products of reaction is passed to the stripping zone for the recovery of these adsorbed products. The catalyst is stripped of hydrocarbon products in the stripping zone with a suitable stripping gas, such as steam, which is passed upwardly through a descending relatively dense bed of catalyst in the stripping zone. Generally, the catalyst will be in contact with stripping gas for at least about 30 seconds, and preferably from about 40 to about 60 seconds. The stripped catalyst is passed downwardly as a relatively dense confined stream of catalyst from the bottom of the stripping zone through a standpipe to a regeneration zone positioned beneath the second conversion zone and surrounding the lower portion of the first conversion zone. In the regeneration zone carbonaceous material contaminating the catalyst as a result of the hydrocarbon conversion reactions is removed by burning in the presence of an oxygen-containing gas under controlled conditions to regenerate and heat the catalyst to conversion temperatures. The catalyst in the regeneration zone is maintained in a relatively dense fluidized condition and the regeneration temperature is usually maintained within a range of from about 1000° F. to about 1250° F., preferably from about 1050° F. to about 1150° F. The regenerated catalyst at an elevated temperature is stripped of regeneration gases with a suitable stripping gas such as steam or other inert gas in the lower portion of the regeneration zone as it passes downwardly as an annular column of catalyst surrounding the inlet to the transfer line cracking zone and the stripped catalyst is passed at an elevated temperature to the inlet of the first conversion zone for recirculation through the system as hereinbefore described.

In the process of the present invention the reactors are positioned and interconnected with respect to the regeneration zone to facilitate circulation of catalyst at the desired temperature for each conversion stage and at a rate sufficiently high to provide the desired catalyst to oil ratio.

In one embodiment of this invention, all of the feed to be cranked, including fresh catalytic cracking feed material with or without recycle oil admixed therewith, is mixed with the hot freshly regenerated catalyst and passed upwardly through the elongated confined zone under elevated temperature conditions. As in the embodiment previously described, the cracking conditions employed in the elongated confined zone are usually effected at an elevated temperature of from about 1000° F., to about 1100° F., for a short period of time not to exceed about 4 seconds. Thereafter the cracking reaction is stopped by immediately separating the catalyst from the hydrocarbons and the separated catalyst is caused to settle into a dense fluidized bed of catalyst material surrounding the upper portion of the reaction zone. In this specific embodiment, the catalyst in the dense fluidized bed is subjected to a first stripping treatment and cooling of the catalyst to a desired temperature level is accomplished by the introduction of water thereto, that is to the lower portion of the fluid bed of catalyst. The water, upon introduction into the bed of catalyst is immediately vaporized and the steam generated therefrom passes upwardly through the bed, thereby stripping the catalyst of occluded reaction products and cooling the catalyst to the desired temperature. A portion of the thus treated catalyst is continuously withdrawn from the first stripping stage and passed to the adjacent stripping zone hereinbefore described, confined within the upper chamber of the vessel wherein the catalyst is passed downwardly in countercurrent contact with additional stripping gas prior to being passed to the regeneration zone. Accordingly, in this specific embodiment, more efficient and complete stripping of the catalyst is achieved by virtue of the increased stripping time allotted thereo.

In another embodiment, it is within the scope of this invention to employ more than one riser conduit, for example, a plurality of riser conduits, for contact of fresh feed material with hot freshly regenerated catalyst. That is, at least two or more riser conduits or dilute phase conversion zones may be satisfactorily employed with the fresh feed material substantially equally distributed for passage through each zone with catalyst or the catalyst and feed passed to each zone so selected as to provide a higher conversion temperature in one zone that the other, depending upon the particular conversion temperature conditions desired. For example, one high velocity conversion zone may be maintained at a temperature within the range of from about 1000° F. to about 1050° F., with another maintained within the range of from about 1050 to about 1100° F., or any temperature combinations thereof.

In another embodiment of this invention the fresh feed to be cracked may be separated into two or more fractions of different boiling range with contact of each fraction under the most desirable temperature conversion conditions, as well as catalyst to oil ratio for each zone. That is the ratio of catalyst to oil to be employed in the riser or transfer line cracking zone may vary from about 1 to about 20 to 1, or any intermediate ratios thereof. By this novel arrangement of process steps and apparatus for accomplishing the same, the refiner has at his disposal a highly flexible process and apparatus for the once through high temperature-short contact time conversion of a hydrocarbon feed material to desired products.

In the apparatus of this invention the regenerated finely divided contact material, which may be any suitable catalytic material, travels upwardly through a riser or conversion conduit at a superficial linear velocity of about 20 to about 100 feet per second. At such velocities, provisions for decelerating the catalyst to insure separation of catalyst from conversion products must be provided. To accomplish this separation of the catalyst from the hydrocarbon products discharged from the riser or first transfer line conversion chamber or chambers, a suitable deflecting baffle is placed above and spaced apart from the outlet of the riser to deflect the catalyst downwardly into the dense catalyst bed phase in the second conversion chamber. This deflecting baffle may be simply a horizontal plate, but is preferably a plate with a downwardly extending flange member or lip. In another embodiment the outlet may be capped and a plurality of elongated slots placed around the periphery at the discharge end of the riser conversion chamber through which the conversion products and catalyst are discharged from the first conversion chamber to the second or dense fluidized bed chamber. This latter arrangement may be referred to as a "bird-cage." In any event, the velocity component of the gases and catalyst discharged from the first conversion chamber is sufficiently changed outwardly to separate the major portion of the catalyst from the products by settling, thereby causing the majority of the catalyst from the first conversion chamber to settle into the dense fluidized catalyst bed maintained in the second chamber. In the practice of the present invention, deceleration of the catalytic material in the dilute catalyst phase above the dense catalyst phase to a superficial linear velocity of about 0.5 to about 3.0 feet per second, preferably about 1 to about 2.5 feet per second, is usually the practice. This velocity corresponds generally to the velocity desired to minimize entrainment of catalyst fines from the apparatus with the conversion products.

In addition to the above, the apparatus of this invention is confined within a unitary vessel wherein the catalyst is passed generally in substantially vertically confined paths thereby minimizing catalyst attrition, as well as erosion of the equipment. The housing of the sep-

arate and desired contact steps in the unitary vessel of this invention also has the added advantage of reducing the length of necessary transfer lines, as well as providing a process and apparatus of high thermal efficiency. These improvements are obviously of extreme importance from an economic standpoint to the refiner.

The present invention is of particular significance and importance in the art of refining hydrocarbons, since the quantity of catalyst in the conversion zones is held to a minimum and is generally less than that employed in the regeneration zone. Consequently and because of this method of operating the respective conversion zones, the conversion zones may be of substantially reduced cross-sectional area with respect to the regenerator zone. Furthermore, by virtue of the carbon production in catalytic cracking operations and the desire to maintain reasonable catalytic activity, the system of the present invention inherently requires substantially more catalyst in the regenerator than that in the conversion zones. In general, the present invention is particularly applicable to hydrocarbon conversion processes in which the regenerator contains from about 1.5 to about 6 times as much catalyst on a weight basis than the catalyst contained in the conversion zones, more usually about 2 to 3 times on the same basis.

The apparatus to be used for the purpose of this invention contains in addition to the conversion zones and regeneration zone, as hereinbefore discussed, suitable means for withdrawal and stripping of catalyst withdrawn from the dense fluidized catalyst bed in the regeneration zone prior to passing up the riser admixed with reactant. For this purpose, a stripping well open at its upper end is provided in the lower portion of the regeneration zone extending upwardly from the bottom thereof with the wall of the well adjacent to the contaminated catalyst standpipe being much higher than the remaining portion of the well wall. The extension of the well wall adjacent to the contaminated catalyst standpipe minimizes tendency of spent or contaminated catalyst from passing to the inlet of the first conversion zone before it has been properly regenerated. Furthermore, this well design takes advantage of pressure developed in the bed of catalyst above it for the cyclic flow of catalyst in the system and the use of stripping gases therein virtually eliminates the passage of regeneration gases to the inlet of the first conversion zone. Generally the well may be from about 1 to about 5 feet in height or from about 5 to 50 percent of the total height of the regenerator. Another aspect of the apparatus design of the present invention is in the location of the regenerated catalyst withdrawal conduit or well. When only one riser conduit is employed, the well and riser conduit will be preferentially coaxially positioned within the vessel. When employing two or more riser conduits, the well for each riser will be suitably positioned with respect to the standpipe to provide for uniform withdrawal of regeneration catalyst from the beds. By carefully positioning the withdrawal well there is not only a better circulation of the catalyst within the bed of the regenerator for contact with regeneration gases, but there is a more uniform withdrawal of regenerated catalyst from the catalytic bed. Hence the various conduits will be symmetrically arranged in the regenerator to provide for the best circulation of catalyst particles in the bed. By this arrangement, more uniform temperature distribution in the catalyst bed is obtained which virtually eliminates the formation of isolated small hot portions of the catalyst in the bed.

Still another important apparatus feature of this invention resides in the location of the stripping zone within the second conversion zone. This stripping zone is formed as a segmental well within and adjacent to the second conversion zone which is formed by means of a vertical transverse baffle extending from the bottom of conversion zone or reactor chamber to the upper portion thereof with sufficient space or area for the stripping gas with entrained stripped products to pass unrestricted into the upper portion of the conversion zone commonly referred to the dilute phase or settling zone. Such construction is not only simple and economical, but lends itself for the desired withdrawal of contaminated catalyst from the second conversion zone, thereby minimizing the danger of forming stagnant portions of the catalyst in the second conversion zone. Suitable slot withdrawal means are provided in this baffle for withdrawal of contaminated catalyst from a desired predetermined level of the dense fluidized catalyst bed. Furthermore, the open upper end of the stripping zone in communication with the dilute phase of the second conversion zone permits passing stripped products directly to the dilute phase for combining with the reaction products and using a common cyclone separation system for removing catalytic fines, thus providing additional apparatus economy.

The present invention is particularly applicable for catalytically cracking high-boiling hydrocarbon either of the same or different boiling range, for example, residual oils, reduced crudes, gas oils or fractions thereof. For example, when employing the improved process of the present nivention to contact fresh feed with freshly regenerated catalyst as a relatively dilute suspension in a riser or first high velocity, high temperature conversion step and a recycle stock in a second or dense fluidized catalytic conversion stage, quite often the amount of recycle stock returned to the reactor, together with slurry material returned thereto may be substantially less than, equal to, or even greater than the amount of fresh feed, depending upon the desired heat balance of the system or process. Accordingly, the cooling effect of the recycle feed may be about the same or greater than the cooling effect of the fresh feed stream so far as the catalyst is concerned. Therefore, with the regenerator operating at about 1150° F. and supplying catalyst at this temperature to the first cracking step, the mixture of fresh feed and regenerated catalyst will be at least about 1000° F. and may be as high as 1050° F., with the body of catalyst in the second cracking zone held to a temperature below about 960° F. and preferably about 925° F. These temperatures, however, may be considerably altered, depending on the rate of catalyst circulation, feed preheat and catalyst to oil ratio employed. Thus, in accordance with this invention, it is desired to crack the fresh feed at a high temperature for a short period of time with the recycle feed primarily for cooling the catalyst to a desired temperature level before returning the catalyst to the regeneration zone. The contact time between the hydrocarbon and the catalyst in the first cracking zone will generally be less than 4 seconds and of the order of from about 4 to about 1 second, preferably from about 2 to about 3 seconds, whereas the contact time in the second conversion zone will generally be greater than about 4 seconds and of the order of about 4 to about 10 seconds, preferably about 5 or 6 seconds.

The catalyst employed in the process and apparatus of the present invention is usually a siliceous material which contains about 75 to 99 percent silica with the remainder selected from any one or more of other suitable materials, such as alumina, boria, magnesium, zirconia, etc. However, it is also within the purpose of the present invention to use other catalytic cracking materials either naturally occurring or synthetically prepared.

The pressure employed within the vessel is usually low, for example, in the order of about 1 atmosphere to about 50 p.s.i.g., more usually about 5 to about 25 p.s.i.g. The weight space velocity measured as pounds of oil charged to each reaction zone per pound of catalyst present therein is usually of the order of about 0.25 to about 10, more usually about 0.5 to 5. The relative ratio of catalyst to oil on a weight basis varies from about 2 to 30, generally the catalyst to oil ratio is about 5 to 15, because it is desired to utilize the heat of combustion in the regenera-

tion zone for the endothermic cracking reactions and to maintain a desired level of catalyst activity in each of the cracking zones.

As hereinbefore discussed, the catalyst, as a result of the cracking reactions becomes contaminated with carbonaceous material which must be removed by regeneration with an oxygen-containing gas, for example, air, at a temperature of from about 1000° F. to about 1200° F., more usually from about 1050° F. to about 1150° F., and at a pressure in the order of about 1 atmosphere to about 50 p.s.i.g.

The catalyst discharged from the first high velocity dilute phase reaction zone is separated from the reaction products as hereinbefore described and passed directly to the second reaction zone containing a relatively dense phase fluidized catalyst bed without any intermediate stripping of the catalyst. The catalyst separated from the second dense phase reaction zone is passed to the stripper as hereinbefore described. The contaminated catalyst is stripped at a temperature which is approximately in the same range as the temperature employed in the second conversion zone. However, the stripping temperature may be varied as desired at any given time by employing a gasiform stripping agent at a higher or lower temperature. The gasiform stripping agent usually employed is steam and may be either steam, hydrogen, a normally gaseous hydrocarbon, as for example methane, ethane, propane, etc., or mixtures thereof.

As can be seen by the drawing, the unitary vessel containing the separate confined zones is in a substantially vertical position in order that the catalyst is circulated within the apparatus substantially vertically upwardly and downwardly. This particular arrangement not only reduces the length of transfer lines to a minimum thereby providing for high thermal efficiency, but also the particular arrangement minimizes catalyst attrition, as well as erosion of transfer lines. In addition to the above advantages, it is to be noted that the major proportion of the catalyst riser which is employed as the dilute phase first cracking zone is in indirect heat exchange with the regeneration zone.

In order to more specifically define the invention by way of example and to provide a better understanding thereof, reference is had to the accompanying drawing, which is a diagrammatic illustration in elevation of an arrangement of apparatus used in accordance with this invention.

Referring to the drawing, a unitary vessel **2** is provided with an upper reaction zone **4** containing a dense fluidized bed of finely divided catalytic material having an upper level **60** and a lower regeneration zone **6** containing a dense fluidized bed of finely divided catalytic material having an upper level or meniscus **28**. Adjacent to the reaction zone, but confined within the vessel is a stripping zone **8** separated from said reaction zone by a substantially vertical baffle **10** containing a plurality of catalyst transfer slots **12** for transferring contaminated catalyst from the reaction zone **4** into the stripping zone. The finely divided catalytic material contaminated with carbonaceous material and vaporous reaction products is stripped of volatile products in the stripping zone by contact with a stripping gas such as steam introduced to the lower portion of the stripping zone by conduit **14** to a stripping gas distributor ring **16**. The stripped finely divided catalytic material is then passed downwardly as an elongated confined stream through conduit **18** to the lower portion of the regeneration zone **6**. The stripped catalytic material is discharged from the bottom of conduit **18** through a discharge outlet **20**. In order to control the rate of discharge of contaminated catalyst into the dense fluidized bed of catalyst in the reaction zone a suitable vertically movable plug valve **22** is provided for insertion into the outlet **20** of the conduit **18**. Suitable regeneration gas such as air is introduced by conduit **24** to the lower portion of the regeneration zone and passes upwardly through a grid or perforated baffle **26** into the dense fluidized bed of catalyst to regenerate the catalytic material by burning of the carbonaceous contaminant on the catalyst. Situated above the dense fluidized catalytic material in the regeneration zone is a relatively dilute phase of catalyst mixed with flue gases. The flue gases containing entrained catalyst fines are passed through a two-stage cyclone separation system identified as cyclone separators **30** and **32** for removal of entrained catalyst fines from the flue gas prior to removing flue gases from the upper portion of the regenerator by conduit **34**. The finely divided catalytic material separated from the flue gases in the cyclone separators is then returned to the dense bed of catalytic material in the regeneration zone by diplegs **36** and **38**. Regenerated catalytic material is separated from the dense bed of catalyst in the regeneration zone and passed downwardly into a circular well **40** defined by wall **42**. The regenerated catalyst is passed downwardly in well **40** countercurrent to stripping gas introduced to the bottom of the well by conduit **44** by stripping gas distributor ring **46**. The use of stripping gas in the well **40** not only reduces the tendency of regeneration gases from passing into the well, but also prevents the hydrocarbon reactant from bypassing the riser inlet and upwardly through the well into the regeneration zone. Furthermore, the use of the stripping gas facilitates the transfer of regenerated catalyst into the inlet of riser **56** by maintaining the catalyst in a fluidized condition. The riser **56** of the present invention functions not only as a means of transferring regenerated catalyst from the lower portion of the regeneration zone to the upper conversion zone **4**, but the riser is also used as a first stage high temperature-high velocity cracking zone. That is to say a fresh hydrocarbon feed which may or may not be preheated to a temperature of about 800° F., admixed either with or without steam is introduced by conduit **48** to hollow stem plug valve **52**, which is vertically movable. In the event that steam is mixed with the hydrocarbon feed, the steam is introduced by conduit **50**. In any event, the hydrocarbon feed introduced to hollow stem plug valve **52**, which is in alignment with the inlet **54** of riser conduit **56** picks up finely divided regenerated catalyst at substantially the temperature employed in the regeneration zone and is passed as a relatively dilute suspension of catalyst in oil upwardly through the reactor conduit **56** to a point above the upper level of the dense bed of catalyst maintained in the reaction zone **4**. The products of the first stage cracking which takes place in riser conduit **56** and entrained catalyst are deflected by baffle **58** positioned above the outlet of the conduit in order to facilitate separation of the reaction products from the catalyst. The reaction products then enter the enlarged dilute catalyst phase settling zone above the upper level **60** of the dense fluidized bed of catalyst in the second conversion zone and pass to a suitable cyclone separator **62** for the separation of any entrained finely divided catalyst from the reaction products. The reaction products, substantially free of finely divided catalyst, are then removed from the upper portion of the reactor by conduit **64** and passed to suitable recovery equipment. The separated finely divided catalyst collected in cyclone separator **62** is returned by dipleg **66** to the dense phase bed **4** of catalytic material maintained in the reactor. The catalytic material separated from the riser conversion stage settles into the dense fluidized bed of catalyst in conversion zone **4** to be used for the conversion of additional hydrocarbon feed in the second conversion zone under less severe cracking conditions than employed in the first conversion zone. In conversion zone **4** an additional hydrocarbon feed which may be of the same or different boiling range than that employed in the first cracking stage and preferably a cycle oil is introduced to the lower portion of the dense fluidized bed by conduit **68** through a suitable distributor nozzle above grid **70**. Steam or any inert gaseous material may be

introduced below the grid 70 by conduit 72 through a suitable distributor to assist in fluidizing the catalyst in the lower portion of the dense bed. The hydrocarbon feed, either as a liquid or partially vaporized, is passed upwardly through the dense fluidized bed under less severe temperature cracking conditions, but is held for a greater time of contact with the catalyst than that employed in the first stage to convert the feed to desirable reaction products. Products of this second conversion stage pass into the dilute catalyst phase above the dense catalyst phase, are commingled with the reaction products of the first conversion stage and removed from the upper portion of the reactor as hereinbefore described. Contaminated catalyst is removed from the dense fluidized bed of the second conversion zone 4 by passing through a plurality of catalyst transfer slots 12 into the stripping zone for removal of hydrocarbons therefrom with a suitable stripping gas as hereinbefore described.

It can be seen that the process and apparatus of the present invention provides numerous advantages over the prior art in that it enables the operator to carry out two stages of cracking under different severity conditions as desired with a minimum of expensive apparatus and transfer lines. These improvements in apparatus design and method of operation provide a process of optimum versatility and economic advantage to the producer. That is to say, by being able to control the severity of cracking of the feed in each cracking stage, maximum conversion to desired products and optimum product distribution is obtainable.

EXAMPLE I

The following data is presented by way of example to show applicant's specific operating conditions for the process and apparatus of the present invention.

Summary of Forward Flow Cracking Results

A. TRANSFER LINE CRACKING

Reactor temp., ° F			1,000.
Pressure			12.9.
Catalyst to oil			10.6.
W./hr./w.			52.
430+conv., vol. percent			45.6.
Feed rate:			
BPSD			16,000.
Lbs/hr			210,000.
	Weight Percent	Vol. Percent	
Yields:			
Coke	3.89	-------	8,169 lb/hr.
Dry gas (propane and light)	6.43	-------	13,503 lb/hr.
C_4's	4.72	6.98	1,117 BPSD.
C_5-400	30.26	36.36	5,818 BPSD.
Total cycle oil	54.7	54.4	8,704 BPSD.

B. DENSE BED CRACKING

Reactor temp., ° F			925.
Pressure			12.9.
Catalyst to oil (T.F. to dense bed)			24.6.
W./hr./w. (basis T.F. to dense bed)			6.2.
430+conv			66.5.
Throughput ratio			1.5.
Feed rate:			
BPSD			4,735.
Lb./hr			63,200.
	Weight Percent	Vol. Percent	
Yields:			
Coke	8.44	-------	5,334 lb./hr.
Dry gas (propane and light)	6.56	-------	4,146 lb./hr.
C_4's	5.97	8.96	424 BPSD.
C_5-400	45.30	55.32	2,619 BPSD.
Light cycle oil	30.50	30.50	1,444 BPSD.
Dec. oil	3.23	3.00	142 BPSD.

C. FRESH FEED

° API gravity	25.5.
20% point ° F	660.
80-20% point ° F	260.
K-factor	11.86.

D. DENSE BED TOTAL FEED

° API gravity	23.0.
20% point ° F	650.
80-20% point ° F	300.
K-factor	11.65.

It will be understood that numerous modifications of the present invention may be made without departing from the spirit thereof and that the precise details hereinbefore set forth in the example are purely illustrative. For instance, the temperature in the first cracking stage may be varied over a wide range as hereinbefore discussed or when employing a plurality of riser first conversion zones, different temperatures may be employed. It is to be noted, however, that the temperature employed in the first cracking stage will be higher than that employed in the second cracking stage, and usually about 50° F. higher.

It is to be specifically noted that the amount of catalyst used in the second cracking stage will greatly exceed that employed in the first stage, since not only has the catalyst become partly deactivated by use in the first cracking stage, but the feed passed to the second stage will be of the type which will require longer contact time with the catalyst employed therein at the temperature employed in order to obtain the desired degree of cracking of the feed. Therefore, the catalyst to oil ratio employed in the second cracking stage should be of the order of from about 5 to about 50.

Having thus described my invention it should be understood that no undue limitations or restrictions are to be imposed by reasons thereof.

I claim:

1. A hydrocarbon conversion process which comprises maintaining a fluidized bed of finely subdivided solid catalyst particles in an upper reaction zone and a lower regeneration zone disposed in substantially vertical alignment, passing a first hydrocarbon reactant heavier than gasoline in contact with freshly regenerated catalyst withdrawn from the lower portion of the regeneration zone upwardly as a dilute suspension through at least one elongated confined zone through said regeneration zone to a level above the bed of catalyst in said reaction zone, said contact between said first hydrocarbon reactant and said freshly regenerated catalyst in said confined zones not to exceed a time greater than about four seconds, thereafter separating hydrocarbon conversion products of said first hydrocarbon reactant by separating catalyst from said hydrocarbon substantially immediately upon discharge from said elongated confined zone, passing a second hydrocarbon fraction more refractory than said first hydrocarbon fraction upwardly through said dense fluidized bed of catalyst in said reaction zone for a contact time not less than about 3 seconds and at a lower temperature than employed in said dilute suspension contact step, withdrawing hydrocarbon products of said first and second contact step from the upper portion of said reaction zone, withdrawing contaminated catalyst from said reaction zone, stripping said withdrawn contaminated catalyst in a stripping zone adjacent to said reaction zone with stripping gas for a period of time of at least about 30 seconds, passing stripped products of reaction to above the dense bed of catalyst in the reaction zone without passing therethrough, and thereafter passing the stripped catalyst substantially vertically downwardly from the bottom of the stripping zone as an elongated confined stream to substantailly the bottom of the fluidized bed of catalyst in the regeneration zone.

2. A method for converting hydrocarbon feed materials which comprises maintaining within a unitary vessel a dense fluidized bed of finely divided catalytic material in an upper reaction zone and a lower regeneration zone, passing a first hydrocarbon feed material in contact with freshly regenerated catalyst at a temperature of at least about 1000° F. upwardly through at least one substantially vertical confined conversion zone to above the upper level of the dense fluidized bed of catalyst in the reaction zone such that the contact time of the first hydrocarbon reactant material with the catalyst will be less than about 4 seconds whereby only a portion of said first hydrocarbon feed material is selectively converted to desired products, thereafter immediately separating the finely divided catalyst from the hydrocarbon of the first conversion step and passing the separated catalyst to the dense fluidized bed of catalyst in the reaction zone, passing a second hydrocarbon fraction more refractory than said first hydrocarbon fraction upwardly through said dense catalyst bed under selected conversion conditions including a contact time greater than about 3 seconds, but not above about 10 seconds, recovering products of said first and second conversion steps from the upper portion of said reaction zone, withdrawing catalyst contaminated with products of reaction from said reaction zone and passing the contaminated catalyst to an adjacent stripping zone, stripping catalyst in said stripping zone by passing the contaminated catalyst downwardly and countercurrent to stripping gas introduced to the lower portion of said stripping zone, passing stripped products of reaction to the upper portion of the reaction zone without passing through the dense bed of catalyst therein, and passing stripped catalyst from the bottom of the stripping zone substantially vertically downwardly to the lower portion of the regeneration zone.

3. In a process for the cyclic circulation of finely divided catalyst between a reaction zone and a regeneration zone wherein the process is maintained in heat balance by the deposition of carbonaceous deposits upon the circulating catalyst and the carbonaceous deposits are removed from the catalyst by burning in a regeneration zone thereby heating the catalyst to a desired elevated temperature, the improved method of operation whereby the conversion to desired products is increased without upsetting the heat balance of the cyclic process which comprises passing hot freshly regenerated catalyst withdrawn from the regeneration zone in admixture with a vaporous hydrocarbon reactant as a dilute suspension through a first substantially vertical confined conversion zone at a temperature of about 1050° F. first in indirect heat exchange relationship with the catalyst undergoing regeneration and then in indirect heat exchange relationship with a cooler dense fluidized bed of catalyst material at a temperature below about 960° F., separating products of said first conversion zone from entrained catalyst, recovering separated products, passing catalyst separated from said first conversion zone into the cooler dense fluid bed of catalyst, introducing a second liquid hydrocarbon stream more refractory than said vaporous hydrocarbon reactant into said dense fluid catalyst bed whereby said bed is further substantially cooled, withdrawing cooled catalyst from said dense fluid bed, stripping said withdrawn catalyst in a stripping zone and passing stripped catalyst to the lower portion of said regeneration zone as a substantially vertical downwardly flowing confined column of catalyst.

4. A unitary apparatus comprising in combination an upper reaction chamber and a lower regeneration chamber, said upper reaction chamber having a substantially vertical transverse baffle member extending upwardly from the bottom of the reaction chamber to the upper portion thereof thereby forming a separate stripping chamber adjacent to said reaction chamber, a first open end standpipe extending substantially vertically downwardly from the bottom of the stripping chamber to above a perforated grid horizontally positioned in the lower portion of the regeneration chamber, vertically movable plug valve aligned with the bottom open end of said standpipe, at least one cylindrical stripping well chamber of smaller diameter than said regeneration chamber extending substantially vertically upwardly from the bottom of said regeneration chamber, being open at its upper end and higher on the side adjacent to said standpipe than the remaining portion of said well, each of said chambers containing a relatively dense fluid bed of finely divided contact material therein, a riser conduit extending from the lower portion of said cylindrical well substantially vertically upwardly to above the bed of contact material in said reaction chamber, the upper end of said riser conduit adapted to change the direction of flow of said contact material passing upwardly therein, a plug valve means for introducing a first chemical reactant to the bottom of said riser conduit, conduit means for passing a second chemical reactant to the lower portion of said bed of contact material in said reaction chamber, means for introducing a gaseous material beneath a perforated grid positioned in the lower portion of said regeneration chamber for flow of gaseous material upwardly into the bed of contact material in said regeneration chamber, means for introducing stripping gas to the lower portion of said stripping chambers, means for removing gaseous product from the upper portion of said regeneration chamber and means for removing vaporous product from the upper portion of said reaction chamber.

5. A unitary apparatus comprising in combination an upper reactor chamber and a lower regeneration chamber, said reactor chamber being of smaller diameter than said regeneration chamber, each of said chambers containing a relatively dense fluidized bed of contact material therein, a separate stripping chamber confined within said reactor chamber and being in open vaprous communication in the upper portion therewith, a standpipe extending from the bottom of the stripping chamber to the lower portion of said regeneration chamber, a cylindrical stripping chamber higher on the side adjacent to said standpipe and open at its upper end extending upwardly from the bottom of said regeneration chamber into the fluid bed of contact material therein, an open end riser conduit extending from the lower portion of the cylindrical stripping chamber substantially vertically upwardly to above the bed of contact material in said reactor chamber, the upper end of said riser conduit being provided with a plurality of elongated slots around the top periphery thereof for the passage of finely divided contact material therethrough, a vertically movable hollow stem plug valve aligned with the bottom open end of said riser conduit for the introduction of a first hydrocarbon reactant thereto, a vertically movable plug valve aligned with the bottom of said standpipe, conduit means for introducing a second hydrocarbon reactant into the lower portion of the fluid bed of contact material in said reactor chamber, means for introducing stripping gas into the lower portion of each of said stripping chambers, means for introducing regeneration gas into the lower portion of said regeneration chamber, means for removing a gaseous product from the upper portion of said regeneration chamber and means for removing a vaporous product from the upper portion of said reactor chamber.

6. An apparatus comprising in combination an upper reactor chamber and a lower regeneration chamber, each of said chambers containing a relatively dense fluidized bed of finely divided catalyst material therein, said regeneration chamber containing at least about twice the quantity of catalyst as employed in said reactor chamber, said reactor chamber provided with a separate stripping chamber by a vertical wall member separating said stripping chamber from said reactor chamber terminating above the upper level of the dense bed of catalyst in said reactor chamber and said wall member being provided with means for passing catalyst from below the upper level of said dense fluidized bed in said reactor chamber

to a more dense fluidized bed of catalyst in said stripping chamber, said regeneration chamber provided with a stripping chamber open at its upper end extending upwardly from the bottom of the regeneration chamber into the dense bed of catalyst therein, means for introducing stripping gas into the lower portion of each of said stripping chambers, an open end standpipe connected with the bottom of the stripping chamber in the reactor chamber extending substantially vertically downwardly to the lower portion of the dense fluid bed of catalyst in the regeneration chamber and terminating below the upper level of the stripping chamber in said regeneration chamber, a vertically movable plug valve aligned with the bottom open end of said standpipe, a riser conduit extending from the lower portion of the stripping chamber in said regeneration chamber substantially vertically upwardly through said dense bed of catalyst in said reactor chamber to above the upper bed level thereof, but below the terminus of the wall member, said riser conduit adapted at its upper end thereof to alter the direction of flow of finely divided catalyst passing upwardly therethrough and distributing the catalyst on the top of the bed of

catalyst in said reactor chamber, said riser conduit provided with a vertically movable hollow stem plug valve for the introduction of a vaporous material to the bottom of said riser conduit, conduit means for separately introducing liquified material to the lower portion of said dense fluid bed of catalyst in said reactor chamber, means for removing a vaprous material from the upper portion of said reactor chamber, means for introducing a gaseous material to the bottom of the bed of catalyst in said regeneration chamber and means for removing a gaseous material from the upper portion of said regeneration chamber.

References Cited in the file of this patent

UNITED STATES PATENTS

2,459,824	Leffer	Jan. 25, 1949
2,700,639	Weikart	Jan. 25, 1955
2,727,810	Leffer	Dec. 20, 1955
2,883,332	Wickham	Apr. 21, 1959
2,900,324	Patton et al.	Aug. 18, 1959
2,953,520	Boisture	Sept. 20, 1960