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(54) MULTIPLE-STAGE HYDROCARBON CONVERSION WITH GRAVITY-FLOWING CATALYST PARTICLES

(71) We, UOP INC, a corporation organized under the laws of the State of Delaware United States of America, of Ten UOP Plaza, Algonquin & Mt. Prospect Roads, Des Plaines, Illinois, 60016, United States of America, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following Statement:-

The present invention is directed toward an improved technique for effecting the catalytic conversion of a hydrocarbonaceous reactant stream in a multiple-stage reaction system wherein (i) the reactant stream flows serially through the plurality of reaction zones, and (ii) the catalyst particles move through each reaction zone via gravity-flow. The described process technique is particularly intended for utilization in vapor-phase systems wherein the conversion reactions are principally endothermic, especially those where the flow of the hydrocarbonaceous reactant stream, with respect to the downward direction of catalyst particle movement, is cocurrent with respect to the arrangement of reaction zones and essentially radial within each zone.

Various types of multiple-stage reaction systems have found widespread utilization throughout the petroleum and petrochemical industries for effecting multitudinous reactions, especially hydrocarbon conversion reactions. Such reactions are either exothermic, or endothermic, and encompass both hydrogen-producing and hydrogen-consuming processes. Multiple-stage reaction systems generally take one of two forms: (1) side-by-side configuration with

intermediate heating between the reaction zones, and wherein the reactant stream or mixture flows serially from one zone to another zone; and, (2) a stacked design wherein a single reaction chamber, or more, contains the multiple catalytic contact stages. Such reactor systems, as applied to petroleum refining, have been employed to effect numerous hydrocarbon conversion reactions including those which are prevalent in catalytic reforming, alkylation, ethylbenzene dehydrogenation to produce styrene, and other dehydrogenation processes. Our invention is specifically intended for utilization in those processes where the conversion reactions are effected in vapor-phase, catalyst particles move via gravity-flow, where the reaction system exists in side-by-side relation, where two or more catalytic contact zones are "stacked", or where one or more additional reaction zones are disposed in a side-by-side relationship with the stack.

Since catalyst particles which are movable through a reaction system by way of gravity-flow are necessarily moving in a downwardly direction, the present technique contemplates the withdrawal of catalyst particles from a bottom portion of one reaction zone and the introduction of fresh, or regenerated catalyst particles into the top portion of a second reaction zone. The present technique is also intended to be applied to those reaction systems wherein the catalyst is disposed as an annular bed and the flow of the reactant stream, serially from one zone to another reaction zone, is perpendicular, or radial to the movement of catalyst particles. In the interest of brevity, the following discussion will be directed toward those

systems wherein a downwardly moving bed of catalyst particles is employed in the conversion of a hydrocarbonaceous reactant stream, with the catalyst particles being disposed in the form of an annular bed, through which the reactant stream flows laterally and radially.

A radial-flow reaction system generally consists of tubular-form sections, having varying nominal cross-sectional areas, vertically and coaxially disposed to form the reaction vessel. Briefly, the system comprises a reaction chamber containing a coaxially disposed catalyst-retaining screen, having a nominal, internal cross-sectional area less than said chamber, and a perforated centerpipe having a nominal, internal cross-sectional area which is less than the catalyst-retaining screen. The reactant stream is introduced, in vapor-phase, into the annular-form space created between the inside wall of the chamber and the outside surface of a catalyst-retaining screen. The latter forms an annular-form, catalyst-holding zone with the outside surface of the perforated centerpipe; vaporous reactant flows laterally and radially through the screen and catalyst zone into the centerpipe and out of the reaction chamber. Although the tubular-form configuration of the various reactant components may take any suitable shape -- e.g., triangular, square, oblong, diamond, etc. -- many design, fabrication and technical considerations dictate the advantages of using components which are substantially circular in cross-section.

A multiple-stage stacked reactor system, to which the present invention is particularly adaptable, is that shown in U.S. Patent No. 3,706,536. Transfer of the gravity-flowing catalyst particles, from one reaction zone to another, as well as introduction of fresh catalyst particles and withdrawal of used catalyst particles, is effected through the utilization of a plurality of catalyst-transfer conduits. Experience in the use of such systems, as well as those where the reaction zones are disposed in a side-by-side relationship indicates that the high vapor flow through the annular-form catalyst-holding sections results in catalyst particles being unable to move in the vicinity of the perforated centerpipe, thereby creating stagnant catalyst areas where the catalyst particles are prevented from assuming the gravity-flow pattern.

According to the present invention there is provided a method of effecting the conversion of a hydrocarbonaceous charge stock in a multiple-stage catalytic conversion system, wherein (1) heated hydrocarbonaceous charge stock and hydrogen flow serially through a plurality of catalytic reaction zones maintained at hydrocarbon conversion conditions; (2) the reaction product

effluent from each zone (except the last) is heated prior to the introduction thereof into the next succeeding reaction zone; (3) the reaction product effluent from the last reaction zone is separated to provide (i) a normally liquid product stream and (ii) a hydrogen-rich vaporous phase; (4) catalyst particles move through each reaction zone via gravity-flow; (5) catalyst particles are at least periodically withdrawn from the last reaction zone; and (6) fresh or regenerated catalyst particles are at least periodically introduced into the first reaction zone; which method includes the step of restricting the flow of the effluent from at least one of the reaction zones.

Preferably, the flow of product effluent from at least one intermediate reaction zone is restricted, prior to the introduction thereof into the next succeeding reaction zone, and the flow of product effluent from the last reaction zone is restricted, prior to effecting the separation thereof.

In a more preferred embodiment, the flow of a portion of the hydrogen-rich vaporous phase separated from the last reaction zone effluent is also restricted and that material is recycled to the first reaction zone.

Various types of hydrocarbon conversion processes utilize multiple-stage reactor systems, either in a side-by-side configuration, as a vertically-disposed stack, or a combination of a stacked system in side-by-side relation with one or more separate reaction zones.

Such systems may be employed in a wide variety of hydrocarbon conversion reactions. While the inventive concept is adaptable to many conversion reactions and processes, through the reactor system of which the catalyst particles move via gravity-flow, it will be further described in conjunction with the well known endothermic catalytic reforming process.

Historically, catalytic reforming was effected in a non-regenerative, fixed-bed system comprising a plurality of reaction zones disposed in side-by-side relation. When the catalytic composite had become deactivated to the extent that continuous operation was no longer economically feasible, the entire unit was shut-down and the catalyst regenerated in situ. Of a more recent vintage was the so-called "swing bed" system in which an extra reactor was substituted for one which was due to be placed off-stream for regeneration purposes. Still more recently, multiple-stage reactor systems have been provided in which the catalyst particles flow, via gravity, through each reaction zone. In a "stacked" system, the catalyst particles also flow downwardly from one catalyst-containing zone to another, and ultimately transfer to a

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suitable regeneration system also preferably functioning with a downwardly-moving bed of catalyst particles. In effect, the catalyst particles are passed from one section to another in a manner such that the flow of catalyst particles is continuous, or occurs at frequent intervals or at extended intervals, with the movement being controlled by the quantity of catalyst withdrawn from the last of the series of individual reaction zones.

U.S. Patent No. 3,470,090 illustrates a multiple-stage, side-by-side reaction system with intermediate heating of the reactant stream which flows serially through the individual reaction zones. Catalyst particles withdrawn from any one of the reaction zones are transported to suitable regeneration facilities. This type of system can be modified to the extent that the catalyst particles withdrawn from a given reaction zone are transported to the next succeeding reaction zone, while the catalyst withdrawn from the last reaction zone may be transported to a suitable regeneration facility. The necessary modifications can be made in the manner disclosed in U.S. Patent No. 3,839,197, involving an inter-reactor catalyst transport method. Catalyst transfer from the last reaction zone in the plurality to the top of the catalyst regeneration zone is made possible through the use of the technique illustrated in U.S. Patent No. 3,839,196.

A stacked reaction zone configuration is shown in U.S. Patent No. 3,647,680 as a two-stage system having an integrated regeneration facility which receives that catalyst withdrawn from the bottom reaction zone. Similar stacked configurations are illustrated in U.S. Patent No. 3,692,496, and U.S. Patent No. 3,725,249.

U.S. Patent No. 3,725,248 illustrates a multiple-stage system in side-by-side configuration with gravity-flowing catalyst particles being transported from the bottom of one reaction zone to the top of the next succeeding reaction zone, those catalyst particles being removed from the last reaction zone being transferred to suitable regeneration facilities.

General details of a three-reaction zone, stacked system are presented in U.S. Patent No. 3,706,536 and illustrates one type of multiple-stage system to which the present inventive concept is applicable. As generally practiced in a catalyst reforming unit, each succeeding reaction zone contains a greater volume of catalyst in that the annular-form catalyst-holding zone is greater in cross-sectional area.

These illustrations are believed to be fairly representative of the art which has been developed in multiple-stage conversion systems wherein catalyst particles move through each reaction zone via gravity-flow.

Noteworthy is the fact that none recognizes the existence of stagnant catalyst areas which result when catalyst particles are lodged against the perforated centerpipe by the lateral/radial vapor flow across the annular form catalyst bed. Likewise, it is readily ascertained that there is no recognition of restricting the reaction zone effluent to alleviate these difficulties and remedy the problem.

The process encompassed by the inventive concept is used in hydrocarbon conversion systems which are characterized as multiple-stage and in which catalyst particles move via gravity-flow through each reaction zone. The present invention is principally intended for utilization in reactor systems where the principal reactions are endothermic and are effected in vapor-phase. Although the following discussion is specifically directed toward catalytic reforming of naphtha boiling range fractions, there is no intent to so limit the present invention. Catalytic reforming, as well as many other processes, has experienced several phases of development currently terminating in the system in which the catalyst beds assume the form of a descending column in one or more reaction vessels. Typically, the catalysts are utilized in spherical form having a nominal diameter ranging from 0.8 to 4 mm. in order to offer free-flow characteristics which will neither bridge, nor block the descending column, or columns of catalyst within the overall reactor system.

In one such multiple-stage system, the reaction chambers are vertically stacked, and a plurality (generally from about 6 to about 16) of relatively small diameter conduits are employed to transfer catalyst particles from one reaction zone to the next lower reaction zone (via gravity-flow) and ultimately to withdraw catalyst particles from the last reaction zone. The catalyst particles are then transported to the top of a catalyst regeneration facility, also functioning with a descending column of catalyst particles; regenerated catalyst particles are then transported to the top of the upper reaction zone of the stack. In order to facilitate and enhance gravity-flow within each reaction vessel, as well as from one zone to another, it is particularly important that the catalyst particles have a relatively small nominal diameter, and one which is preferably less than 4 mm. In a conversion system having the individual reaction zones in side-by-side relationship, catalyst transport vessels (of the type shown in U.S. Patent No. 3,839,197) are employed in transferring the catalyst particles from the bottom of one zone to the top of the succeeding zone, and from the last reaction zone to the top of the regeneration facility.

Catalytic reforming of naphtha boiling

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range hydrocarbons, a vapor-phase operation, is effected at conversion conditions which include catalyst bed temperatures in the range of 371 to 549°C. Other conditions generally include a pressure from 4.4 to 69 atmospheres, a liquid hourly space velocity (defined as volumes of fresh charge stock per hour, per volume of total catalyst particles) of from 0.2 to 10 and a hydrogen to hydrocarbon mole ratio generally in the range of 1:1 to 10:1. Continuous regenerative reforming systems offer numerous advantages when compared to the prior art fixed-bed systems. Among these is the capability of efficient operation at comparatively lower pressures in the range of 4.4 to 14.6 atmospheres and higher consistent inlet catalyst bed temperatures in the range of 510 to 543°C.

Catalytic reforming reactions include dehydrogenation of naphthenes to aromatics, the dehydrocyclization of paraffins to aromatics, the hydrocracking of long-chain paraffins into lower-boiling normally-liquid material and the isomerization of paraffins. The reactions, the net result of which is endothermicity, are effected through the utilization of one or more Group VIII noble metals (e.g. platinum, iridium, rhodium, palladium) combined with a halogen (e.g. chlorine and/or fluorine) and a porous carrier material such as alumina. Recent investigations have indicated that more advantageous results are attainable through the conjoint use of a catalytic modifier; these are generally selected from the group of cobalt, nickel, gallium, germanium, tin, rhenium, vanadium and mixtures thereof. Regardless of the particular selected catalytic composite, the ability to attain the advantage over the common fixed-bed systems is greatly dependent upon achieving acceptable catalyst flow downwardly through the system.

Catalytic reforming processes generally utilize multiple stages, each of which contains a different quantity of catalyst, generally expressed as volume percent. The reactant stream, hydrogen and the hydrocarbon feed, flow serially through the reaction zones in order of increasing catalyst volume with interstage heating. In a three-reaction zone system, typical catalyst loadings are: first, 10% to 30%; second, from 20% to 40%; and, third, from 40% to 60%. With respect to a four-reaction zone system, suitable catalyst loading would be: first, 5% to 15%; second, 15% to 25%; third, 25% to 35%; and, fourth, 35% to 50%. Unequal catalyst distribution, increasing in the serial direction of reactant stream flow, facilitates and enhances the distribution of the reactants as well as the overall heat of reaction.

The lodging of catalyst to the perforated centerpipe stems primarily from the high

vapor velocity laterally across the annular-form catalyst-holding zone, this adverse effect increasing in degree as the cross-sectional area and length of the catalyst bed decreases. In multiple-stage catalytic reforming systems, therefore, the effect is most pronounced in the first and second reaction zones, having the smaller annular cross-sectional areas, somewhat less in the third reaction zone and of a relatively minor consequence in the fourth reaction zone due to its length and larger cross-sectional catalyst area. Restricting the flow of the product effluent from the last reaction zone in the serial plurality, will reduce the amount of lodged catalyst. Preferably, the flow of the product effluent from all the reaction zones is restricted prior to the introduction thereof into the next succeeding reaction zone, or with respect to the last reaction zone, prior to the separation thereof into a normally liquid product and a hydrogen-rich vaporous phase. In a four-zone system, with respect to the intermediate reaction zones, being numbers 2 and 3 in a four-zone system, it is preferred to restrict the flow of effluent therefrom in addition to that emanating from the fourth reaction zone, with or without restriction of the first zone effluent.

The flow restrictions of the various reaction zone effluents may be effected in any suitable manner. Preferably, they should each produce a pressure drop, or result in an additional pressure drop for the overall reactor system, of from 1 to 10 psi (0.07 to 0.7 atmospheres). Restriction of effluent flow may be accomplished through the use of venturi tubes, orifice plates, etc.; the orifice plate is preferred for the vapor-phase operation.

Principally, the lodging of catalyst to the perforated centerpipe is a function of two dependent variables: (1) the vapor mass flow rate; and, (2) the density of the vapors flowing laterally through the annular-form catalyst bed. To reduce, or eliminate the lodged catalyst, for a given design flow of charge stock, the rate of hydrogen-rich gas recycle to the system must be reduced. This, however, reduces the total mass flow to a given reaction zone, which, in turn, reduces the reactor system pressure drop. Of course, the effective pressure in the initial reaction zone, in which catalyst pinning is most prevalent and troublesome, is reduced; a corresponding reduction in vapor density ensues. The utilization of restriction orifices (or other suitable devices) between reaction zones increases the pressure drop in the reactor circuit; this increases the pressure in the first reaction zone and thus the density of the vapors. Higher vapor density alleviates the catalyst lodging problems which results in stagnant catalyst areas. The use of

restriction orifices also affords greater recycle gas flow which reduces carbonaceous material deposition and the regeneration load imposed upon the regeneration facility.

Furthermore, the final reaction zone functions at a lower pressure which gives rise to a liquid yield advantage. Preferably, the restriction orifices are placed upstream of the reaction zone inter-heaters to decrease the heater operating pressure and increase the velocity of the reactor effluent in the heater tubes. In accordance with a more preferred mode of effecting the present invention, the recycle hydrogen flow is also restricted. While the restriction of the recycled hydrogen flow does not contribute to the alleviation of stagnant catalyst areas to as great an extent as the restrictions of reaction zone effluent, it does serve to insure better flow distribution of the reactant stream to the combined feed-heat exchanger, particularly when the heat exchanger consists of at least two heat exchangers in parallel.

In further describing the present invention, and its method of operation, reference will be made to the accompanying drawing. It is understood that the drawing is presented solely for the purposes of illustration, and the same is not intended to be construed as limiting upon the scope of our invention as defined by the appended claims. Therefore, miscellaneous appurtenances, not required for a complete understanding of the inventive concept, have been eliminated or reduced in number. Such items are well within the purview of one possessing the requisite skill in the appropriate art. The illustrated embodiment is presented as a simplified schematic flow diagram showing four reaction zones, stacked catalytic reforming system 1 having an upper first reaction zone I, two intermediate zones II and III, and a lowermost fourth reaction zone IV.

The drawing illustrates the particularly preferred embodiment in which the product effluent from each of the reaction zones is restricted, in addition to the restriction of the flow of hydrogen-rich recycle gas. With respect to the four reaction zones I, II, III and IV, this is accomplished through the use of restriction orifices 10, 14, 18 and 22, respectively. The flow of the hydrogen-rich recycle gas is restricted through the utilization of restriction orifice 3.

Stacked, gravity-flowing catalytic reaction system 8 is shown as having four individual reaction zones which are sized as to length and annular catalyst cross-sectional area such that the distribution of the total catalyst volume is 10.0% (zone I), 15.0% (zone II), 25.0% (zone III) and 50.0% (zone IV). In a normal, substantially problem-free operation, fresh or regenerated

catalyst particles are introduced through conduit 29 and inlet port 30 into the uppermost zone I and flow via gravity therefrom into reaction zone II, from zone II into zone III, from zone III into zone IV, and are ultimately withdrawn from the reactor system through a plurality of outlet ports 31 and conduits 32. Catalyst particles so removed may be transported to a continuous regeneration zone (not illustrated), or may be stored until a sufficient quantity is available for a batch-wise regeneration. The rate of catalyst flow through stacked reactor system 8, or the period of time required for catalyst particles to be introduced into the system, traverse the four reaction zones and be withdrawn for regeneration, is determined by the rate at which the latter is effected. By monitoring various operating parameters while the system is in continuous operation, the catalyst withdrawal rate, or regeneration load can be controlled.

The naphtha boiling range charge stock is introduced into the process by way of line 1, admixed with a hydrogen-rich vaporous phase from line 2, containing a restriction orifice 3 having a rating of about 0.41 atm., and introduced into heat-exchanger 4. The temperature of the mixture is increased by way of indirect heat-exchange with hot product effluent entering by way of line 21. The thus-heated mixture continues through conduit 5 into charge heater 6, and therefrom through line 7 into uppermost reaction zone I at a temperature required to provide the desired temperature at the inlet to the first catalyst bed disposed therein.

Reaction product effluent from catalyst zone I passes through line 9, containing restriction orifice 10 rated at about 0.34 atm., into inter-heater 11, and therefrom through line 12 into first intermediate reaction zone II. Product effluent from catalyst zone II is withdrawn by way of line 13, containing a restriction orifice 14 rated at about 0.41 atm., and is introduced thereby into inter-heater 15; the heated vaporous material is introduced into second intermediate reaction zone III by way of conduit 16. Conduit 17, containing a restriction orifice 18, also rated at 0.41 atm., carries the effluent from catalytic zone III into interheater 19, the heated mixture being introduced into lowermost reaction zone IV by way of line 20.

The reaction product effluent from lowermost catalytic zone IV is withdrawn by way of line 21, containing restriction orifice 22 having a rating of about 7.0 psi. The product effluent continues through conduit 21 and is utilized as the heat-exchange medium in heat-exchanger 4. Thus cooled, the product effluent passes through line 23 into condenser 24 wherein cooling and condensation takes place at a temperature in the range of

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about 16°C. to about 60°C., and the mixture passes through line 25 into separation zone 26. Hydrogen-rich vaporous material is withdrawn through conduit 2, containing restriction orifice 3, for recycle at least in part to uppermost reaction zone I; excess hydrogen is withdrawn from the process through line 28, the rate being determined by suitable pressure control. The normally liquid product effluent is withdrawn by way of line 27 and introduced thereby into suitable fractionation facilities (not illustrated).

Although indicated as a single separation vessel 26 and condenser 24, the separation of the product effluent in line 25 may be effected using an initial low pressure separator followed by a high pressure separator. Vaporous material from the low pressure separator is compressed and introduced into a high pressure cooler in admixture with the liquid material recovered from the low pressure separator. The mixture is then introduced into the high pressure separator from which the hydrogen-rich recycle vaporous phase and a normally liquid product effluent are recovered.

WHAT WE CLAIM IS:-

1. A method of effecting the conversion of a hydrocarbonaceous charge stock in a multiple-stage catalytic conversion system, wherein (1) heated hydrocarbonaceous charge stock and hydrogen flow serially through a plurality of catalytic reaction zones maintained at hydrocarbon conversion conditions, (2) the reaction product effluent from each zone (except the last) is heated prior to the introduction thereof into the next succeeding reaction zone, (3) the reaction product effluent from the last reaction zone is separated to provide (i) a normally liquid product stream and (ii) a hydrogen-rich vaporous phase, (4) catalyst particles move through each reaction zone via gravity-flow, (5) catalyst particles are at least periodically withdrawn from the last reaction zone, and (6) fresh or regenerated catalyst particles are at least periodically introduced into the first reaction zone; which method includes the step of restricting the flow of the effluent from at least one of the reaction zones.

2. The method of claim 1 wherein the flow of product effluent from the last reaction zone is restricted, prior to effecting the separation thereof.

3. The method of Claim 1 wherein the flow of product effluent from at least one intermediate reaction zone is restricted, prior to the introduction thereof into the next succeeding reaction zone, and the flow of product effluent from the last reaction zone is restricted, prior to effecting the separation thereof.

4. The method of any of Claims 1 to 3

wherein the flow of at least a portion of the hydrogen-rich vaporous phase separated from the last reaction zone effluent is restricted and that material is then recycled to the first reaction zone.

5. The method of any of Claims 1 to 4 wherein the plurality of reaction zones are disposed in side-by-side relationship and catalyst particles are transferred from the bottom of one reaction zone to the top of the next succeeding reaction zone.

6. The method of any of Claims 1 to 4 wherein the plurality of reaction zones are stacked and share a common vertical axis, and catalyst particles move via gravity-flow from one reaction zone to the next lower reaction zone in said stack.

7. The method of any of Claims 1 to 6 wherein the conversion system contains at least three catalytic reaction zones.

8. The method of Claim 7 wherein the product effluent flow from each of the reaction zones is restricted.

9. The method of any of Claims 1 to 6 wherein the conversion system contains four catalytic reaction zones.

10. The method of Claim 9 wherein the flow of the effluent from each of only the last three reaction zones is restricted.

11. The method of Claim 9 wherein the product effluent flow from each of the four reaction zones is restricted.

12. The method of Claim 2 wherein the flow of the effluent from the last reaction zone is restricted to produce an additional reactor system pressure drop of from 1 to 10 psi.

13. The method of Claim 10 wherein each restriction of the flow of effluent from one of the last three reaction zones is selected to produce an additional reactor system pressure drop in the range from 1 to 10 psi.

14. The method of Claim 4 wherein the flow of the recycled portion of said hydrogen-rich vaporous phase is restricted to produce an additional pressure drop of from 1 to 10 psi.

15. The method of any of Claims 1 to 14 wherein the catalytic conversion system is a multiple-stage hydrocarbon catalytic reforming process.

16. The method of claim 3 or of any of claims 4 to 11 or 13 to 15 as appendent to claim 3 wherein the restriction in the flow of product effluent from the intermediate (or first) reaction zone or zones is effected prior to the heating of that effluent for entry into the next succeeding reaction zone.

17. The method of any of Claims 1 to 16 wherein in each reaction zone the reaction mixture flows radially across an annular-form catalyst bed perpendicular to the direction of motion of the catalyst particles.

18. A method of effecting the conver-

about 16°C. to about 60°C., and the mixture passes through line 25 into separation zone 26. Hydrogen-rich vaporous material is withdrawn through conduit 2, containing restriction orifice 3, for recycle at least in part to uppermost reaction zone I; excess hydrogen is withdrawn from the process through line 28, the rate being determined by suitable pressure control. The normally liquid product effluent is withdrawn by way of line 27 and introduced thereby into suitable fractionation facilities (not illustrated).

Although indicated as a single separation vessel 26 and condenser 24, the separation of the product effluent in line 25 may be effected using an initial low pressure separator followed by a high pressure separator. Vaporous material from the low pressure separator is compressed and introduced into a high pressure cooler in admixture with the liquid material recovered from the low pressure separator. The mixture is then introduced into the high pressure separator from which the hydrogen-rich recycle vaporous phase and a normally liquid product effluent are recovered.

WHAT WE CLAIM IS:-

1. A method of effecting the conversion of a hydrocarbonaceous charge stock in a multiple-stage catalytic conversion system, wherein (1) heated hydrocarbonaceous charge stock and hydrogen flow serially through a plurality of catalytic reaction zones maintained at hydrocarbon conversion conditions, (2) the reaction product effluent from each zone (except the last) is heated prior to the introduction thereof into the next succeeding reaction zone, (3) the reaction product effluent from the last reaction zone is separated to provide (i) a normally liquid product stream and (ii) a hydrogen-rich vaporous phase, (4) catalyst particles move through each reaction zone via gravity-flow, (5) catalyst particles are at least periodically withdrawn from the last reaction zone, and (6) fresh or regenerated catalyst particles are at least periodically introduced into the first reaction zone; which method includes the step of restricting the flow of the effluent from at least one of the reaction zones.

2. The method of claim 1 wherein the flow of product effluent from the last reaction zone is restricted, prior to effecting the separation thereof.

3. The method of Claim 1 wherein the flow of product effluent from at least one intermediate reaction zone is restricted, prior to the introduction thereof into the next succeeding reaction zone, and the flow of product effluent from the last reaction zone is restricted, prior to effecting the separation thereof.

4. The method of any of Claims 1 to 3

wherein the flow of at least a portion of the hydrogen-rich vaporous phase separated from the last reaction zone effluent is restricted and that material is then recycled to the first reaction zone.

5. The method of any of Claims 1 to 4 wherein the plurality of reaction zones are disposed in side-by-side relationship and catalyst particles are transferred from the bottom of one reaction zone to the top of the next succeeding reaction zone.

6. The method of any of Claims 1 to 4 wherein the plurality of reaction zones are stacked and share a common vertical axis, and catalyst particles move via gravity-flow from one reaction zone to the next lower reaction zone in said stack.

7. The method of any of Claims 1 to 6 wherein the conversion system contains at least three catalytic reaction zones.

8. The method of Claim 7 wherein the product effluent flow from each of the reaction zones is restricted.

9. The method of any of Claims 1 to 6 wherein the conversion system contains four catalytic reaction zones.

10. The method of Claim 9 wherein the flow of the effluent from each of only the last three reaction zones is restricted.

11. The method of Claim 9 wherein the product effluent flow from each of the four reaction zones is restricted.

12. The method of Claim 2 wherein the flow of the effluent from the last reaction zone is restricted to produce an additional reactor system pressure drop of from 1 to 10 psi.

13. The method of Claim 10 wherein each restriction of the flow of effluent from one of the last three reaction zones is selected to produce an additional reactor system pressure drop in the range from 1 to 10 psi.

14. The method of Claim 4 wherein the flow of the recycled portion of said hydrogen-rich vaporous phase is restricted to produce an additional pressure drop of from 1 to 10 psi.

15. The method of any of Claims 1 to 14 wherein the catalytic conversion system is a multiple-stage hydrocarbon catalytic reforming process.

16. The method of claim 3 or of any of claims 4 to 11 or 13 to 15 as appendent to claim 3 wherein the restriction in the flow of product effluent from the intermediate (or first) reaction zone or zones is effected prior to the heating of that effluent for entry into the next succeeding reaction zone.

17. The method of any of Claims 1 to 16 wherein in each reaction zone the reaction mixture flows radially across an annular-form catalyst bed perpendicular to the direction of motion of the catalyst particles.

18. A method of effecting the conver-



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sion of a hydrocarbonaceous charge stock carried out substantially as hereinbefore described with reference to the accompanying drawing.

- 5 19. A hydrocarbon conversion product when obtained by a method as claimed in any of claims 1 to 18.

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