Nov. 20, 1945. J. G. ALTHER 2,389,399

METHOD AND APPARATUS FOR CONTACTING FINELY DIVIDED SOLID PARTICLES WITH FLUIDS

Filed May 27, 1943 3 Sheets-Sheet 1

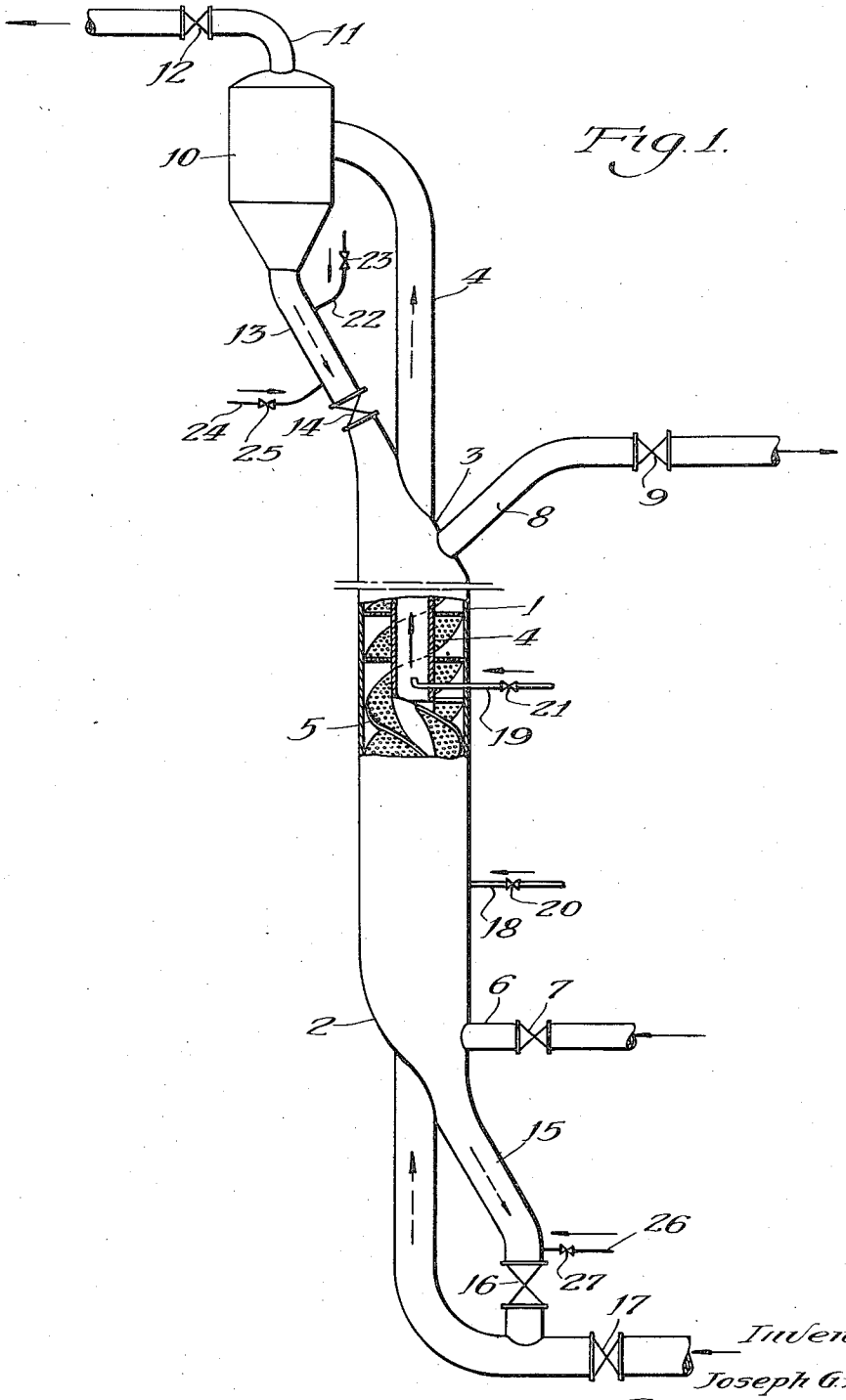


Fig. 1.

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Fig. 2.

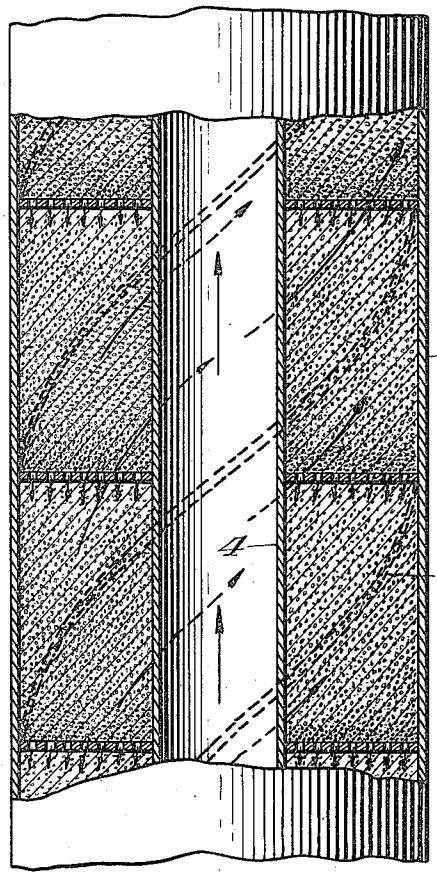


Fig. 5.

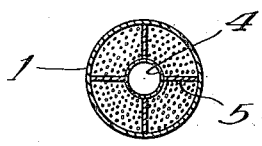
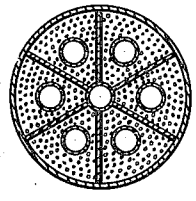


Fig. 6.



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Fig. 3.

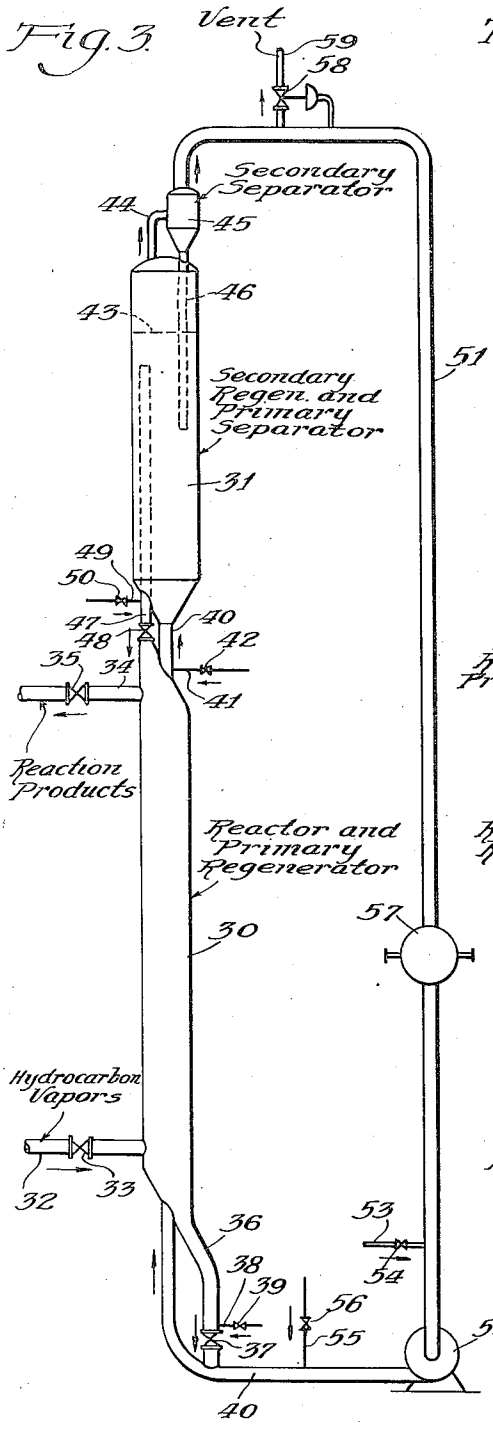
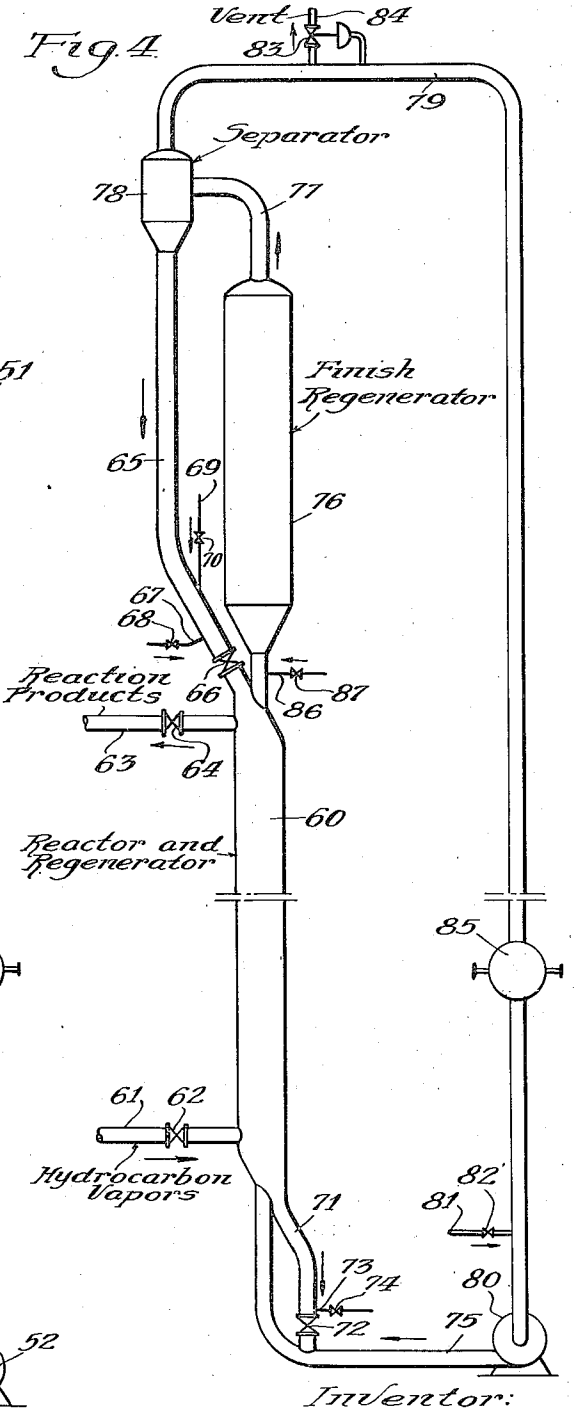


Fig. 4.



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Patented Nov. 20, 1945 2,389,399

UNITED STATES PATENT OFFICE

2,389,399

METHOD AND APPARATUS FOR CONTACTING FINELY DIVIDED SOLID PARTICLES WITH FLUIDS

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Application May 27, 1943, Serial No. 488,681

14 Claims. (Cl. 196—52)

This invention relates to an improved method and apparatus for contacting finely divided solid particles with fluids and more particularly to a method and apparatus which may be advantageously applied to the catalytic treatment of hydrocarbon oils and gases.

The method and apparatus herein disclosed are especially well adapted to processes for the conversion of hydrocarbon oils such as catalytic cracking, dehydrogenation, aromatization, reforming, and the like, although the method may be readily applied to any process in which it is desired to contact solid particles with streams of fluid.

As yet no entirely satisfactory method has been devised for the continuous countercurrent contacting of finely divided solid particles with fluids, most of the heretofore proposed methods resulting in more or less channeling of the fluids passing through the moving bed of solid particles thereby effecting a relatively inefficient process. Other difficulties present in conventional methods are high pressure drop, non-uniform contacting and excessive recycling of particles and fluids within the contacting zone.

The present invention offers a method by which the aforesaid difficulties can be eliminated in a simple and effective manner by passing the solid particles downwardly at a steady uniform rate with substantially uniform particle dispersal throughout the contacting zone while at the same time maintaining a flow of the fluid to be contacted in a generally upward direction but substantially transverse to the motion of the dropping solid particles.

One of the objects of this invention is the provision of a method for the countercurrent contacting of solid particles and fluids with substantially no back circulation of either solid particles or fluid.

It is another object of this invention to provide uniform contacting of solid particles and fluids with a low pressure drop through the contacting zone.

A still further object of this invention is to provide apparatus in which contacting of finely divided solid particles with fluids may be accomplished uniformly with low pressure drop of the fluids passing therethrough.

It is another object of this invention to provide apparatus for use in processes employing both endothermic and exothermic reactions; for instance, in the catalytic cracking process for hydrocarbon oils, the catalyst first passes through a cracking step which is endothermic, therein accumulating a deposit of carbonaceous material which is removed by combustion, which is exothermic, in a succeeding stage of the process. The apparatus as provided in the present invention offers means for utilizing the exothermic heat of combustion as a source of heat for the endothermic portion of the process.

Another object of this invention is the provision for a substantially uniform rate of fall of solid particles throughout the contacting zone. This is accomplished by breaking up the fall of particles into a series of relatively short drops by spaced distribution means thereby substantially overcoming the accelerating effect of gravity which in cases where free falling solid particles are employed results in non-uniform contacting because of the increasing speed of the falling particles as they reach the lower extremity of their travel.

Broadly, this invention concerns a method of contacting a fluid with finely divided solid particles which comprises passing the finely divided solid particles in a downward direction with a substantially uniform cross-sectional particle distribution through a zone through which said fluid is directed helically in an upward direction.

In a more specific embodiment, the present invention comprises a continuous process for the conversion of hydrocarbon oils which comprises, passing finely divided solid cracking catalyst particles in a downward direction and with substantially uniform cross-sectional particle distribution through a zone maintained at a cracking temperature, simultaneously passing hydrocarbon vapors helically through said zone in an upward direction in contact with said catalyst particles whereby said hydrocarbon vapors are converted and a carbonaceous material is deposited upon said catalyst particles, withdrawing said catalyst particles having said carbonaceous deposit and passing them commingled with oxygen-containing gas in an upward direction and in heat exchange relation with but out of contact with said hydrocarbon vapors and said downward passing catalyst particles whereby said carbonaceous deposit is removed from said upward catalyst particles by combustion, separating the thus reactivated catalyst particles from the products of combustion and returning said reactivated catalyst particles to said zone to again pass downwardly therethrough.

In order to more clearly illustrate the features and advantages of the present invention, reference is made to the accompanying diagrammatic

drawings and following description thereof in connection with a catalytic cracking process.

Figure 1 of the drawings is an elevational view partly in section of one form of apparatus in which the process of the present invention may be conducted.

Figure 2 is an enlarged detail of a portion of the apparatus illustrated in Figure 1.

Figure 3 is an elevational view of a modified form of apparatus in which the present invention may be conducted.

Figure 4 is another alternate form of apparatus for use in accomplishing the process herein disclosed.

Figures 5 and 6 illustrate two of the many possible arrangements of helical flights and heat exchange conduits which may be utilized.

Referring now to Figures 1 and 2, the main body of the contactor comprises an elongated substantially cylindrical shell 1, closed at its lower end by a conical head 2 and at its upper end by the conically shaped head 3. Centrally disposed within shell 1 is a vertical conduit 4 extending through both heads thereof. About conduit 4 are disposed a number of (in this instance four) perforated helically shaped members 5 which extend from adjacently the lower end of shell 1 to adjacent its upper end. These perforated members are similar in form to the flight of a screw conveyer and hereinafter and in the appended claims will be designated by that term.

The lower closure head 2 is provided with an inlet conduit 6 through which hydrocarbon vapors controlled by valve 7 may be introduced to the contactor. The reaction products are withdrawn through conduit 8 controlled by valve 9 from the upper portion of the contactor. Conduit 4 extends through head 3 and terminates in a cyclone separator 10, the effluent gases from which pass through conduit 11 controlled by valve 12. Solid particles separated out in separator 10 pass through conduit 13 controlled by valve 14 to enter the upper portion of the contactor.

The finely divided solid particles introduced to the contactor through conduit 13 pass downwardly through the perforations in the helical flights and are removed from the lower end by means of conduit 15 controlled by valve 16.

When operating the contactor in a catalytic cracking process, finely divided cracking catalyst particles either in formed shapes or as granules or powdered are introduced through conduit 13 controlled by valve 14. The size and density of the finely divided solid particles should be such that with the fluid velocities employed in the contacting zone, relatively little carrying effect will be exerted by the fluid on the solid particles. The relative directions of travel of the solid particles and the fluid stream will, of course, have an effect upon the particle size and density which may be successively employed. For example, with true countercurrent flow larger and/or denser particles would be necessary than in the process herein disclosed in which substantially transverse flow of fluid with respect to the direction of motion of the falling particles is obtained. This latter feature makes possible a more efficient process because in general smaller particle size will yield better contacting. These particles will drop through the contactor from flight to flight passing through the perforations therein and thereby being uniformly distributed throughout the cross-sectional area of the contactor exclusive of the vertically disposed conduits. Heated hydrocarbon vapors will be introduced through line 6 controlled by valve 7 and pass spirally up the contactor, thereby contacting the falling catalyst particles and the reaction products will be withdrawn through line 8 controlled by valve 9. The contaminated or spent catalyst particles will be withdrawn through conduit 15 controlled by valve 16 and will be commingled with oxygen-containing regenerating gas passing through conduit 4 controlled by valve 17. The regenerating gas will act as a carrying medium for the catalyst particles conducting them upwardly through conduit 4. At the same time, the oxygen will cause combustion of the carbonaceous deposit on the catalyst, thereby supplying heat to the contactor. Additional oxygen may be introduced to conduit 4 through lines 18 and 19 controlled by valves 20 and 21 respectively. This additional oxygen will supplement the original oxygen in the regenerating gas and spread out the burning in conduit 4 to more uniformly distribute the heat to the contactor. The length of conduit 4 within the contactor and the amounts of oxygen supplied at the various points should be regulated to obtain substantially complete burning of the carbonaceous deposit within the contactor.

The reactivated catalyst will be separated from the combustion products in separator 10 and be returned to the contactor through conduit 13 controlled by valve 14. The spent regenerating gas will leave separator 10 by means of conduit 11 controlled by valve 12. Makeup catalyst may be introduced through line 22 controlled by valve 23 and suitable inert stripping medium may be introduced to conduit 13 through line 24 controlled by valve 25. The spent catalyst in conduit 15 may be stripped by suitable inert medium supplied through line 26 controlled by valve 27.

In some cases where insufficient heat is supplied by the reactivation of the contaminated catalyst, to conduct the endothermic cracking reaction it may be desirable to house the entire contactor in a furnace.

In Figure 3 is illustrated a modified form of the apparatus in which the present process may be conducted and comprises a contactor 30 similar in form to that illustrated in Figure 1 and a secondary regenerator and primary separator 31. Hydrocarbon vapors are introduced through conduit 32 controlled by valve 33 and after contacting the catalyst, the reaction products will be removed through line 34 controlled by valve 35. The spent catalyst will leave the contactor through conduit 36 controlled by valve 37 after stripping with suitable medium introduced through line 38 controlled by valve 39. The spent catalyst will commingle with oxygen-containing regenerating gas in conduit 40 and pass upwardly through the contactor and into regenerator 31. In its upward passage through the contactor, the carbonaceous deposit on the catalyst will be at least partially removed by combustion and the remaining deposit will be burned off in regenerator 31. Additional oxygen may be introduced to conduit 40 to finish the burning by means of line 41 controlled by valve 42. The upward velocity of the regenerating gas in vessel 31 is insufficient to maintain the catalyst particles moving in an upward direction, and settling therefore will take place thereby forming two phases of catalyst and gas, one relatively dense and the other light, the line of demarcation therebetween being indicated by the broken line 43. The effluent gas from regenerator 31 will pass through conduit 44 into separator 45 and suspended catalyst particles will be removed and returned

through conduit 46 to the dense phase in vessel 31. Reactivating catalyst will be withdrawn from regenerator 31 by means of conduit 47 controlled by valve 48 passing into the upper end of contactor 30. Suitable stripping gases may be introduced to conduit 47 by means of line 49 controlled by valve 50. The spent regenerating gases leaving separator 45 are recycled through conduit 51 and by means of blower 52 are returned through conduit 40 to act as carrying medium for the spent catalyst particles. Controlled quantities of oxygen-containing gases may be introduced through line 53 regulated by valve 54. Makeup catalyst may be introduced to the system through line 55 controlled by valve 56. Heat may be removed from the regenerating gases by means of a suitable waste heat boiler or heat exchanger 57. The pressure on the system is maintained by means of pressure regulating valve 58, in conduit 59.

As in the apparatus shown in Figure 1, contactor 30 may be enclosed in a suitable heater or may be covered with suitable insulation not shown in order to conserve the desired heat for the processing reaction.

Figure 4 illustrates another modified form of the apparatus shown in Figure 1 which can be advantageously used in cases where more burning time is required to regenerate the spent catalyst. In this apparatus, the contactor is designated by numeral 60 which may be supplied with hydrocarbon vapors by means of conduit 61 controlled by valve 62, and the reaction products may be withdrawn through conduit 63 controlled by valve 64. Reactivated catalyst will be introduced to the contactor by means of conduit 65 controlled by valve 66. This catalyst may be stripped by suitable inert gases introduced through line 67 controlled by valve 68. Makeup catalyst may be introduced to the system through line 69 controlled by valve 70. The catalyst particles will pass downwardly through contactor 60 effecting the desired conversion and the contaminated particles will be withdrawn through conduit 71 controlled by valve 72. A suitable inert stripping medium may be introduced to conduit 71, by means of line 73 controlled by valve 74. The spent catalyst particles after passing through valve 72 will be commingled with an oxygen-containing regenerating gas in conduit 75 by means of which they will be transported upwardly through the contactor and into regenerator 76. Additional air may be introduced to complete the regeneration of the catalyst by means of line 86 controlled by valve 87. In regenerator 76, the catalyst particles suspended in the regenerating gases will tend to settle because of the decreased velocity of the gases and will therefore have more time for completing reactivation. The effluent gases from regenerator 76 containing suspended reactivated catalyst particles will be removed by means of conduit 77 and directed to separator 78. The catalyst particles will be removed therein and returned to the contactor by means of conduit 65. The spent regenerating gases will be withdrawn from separator 78 by means of conduit 79 and will be recycled by blower 80 to conduit 75. Oxygen-containing gases may be introduced to the regenerating gas stream through conduit 81 controlled by valve 82, and excessive pressure in the system is relieved by pressure regulating valve 83 in conduit 84. Heat may be removed from the recycling regenerating gases in a suitable heat exchanger or waste heat boiler 85 and utilized in any desired portion of the plant.

Figure 5 shows a cross-sectional view through one of the contactors having 4 helical flights and one centrally disposed heat exchange conduit. It is well within the scope of the invention, however, to employ any convenient number of helical flights or heat exchange conduits; for example, a contractor having 6 perforate helical flights and 7 heat exchange conduits as illustrated in Figure 6 may be employed.

Suitable conversion conditions and catalysts for the various processes coming within the scope of the present invention are well known in the art and need not be dealt with in detail in this specification.

I claim as my invention:

1. A continuous process for the conversion of hydrocarbon oils which comprises passing finely divided solid cracking catalyst particles in a downward direction and with substantially uniform cross-sectional particle distribution through a zone maintained at a cracking temperature, simultaneously passing hydrocarbon vapors helically through said zone in an upward direction in contact with said catalyst particles whereby said hydrocarbon vapors are converted and a carbonaceous material is deposited upon said catalyst particles, withdrawing said catalyst particles having said carbonaceous deposit and passing them commingled with oxygen-containing gas in an upward direction in heat exchange relation with but out of contact with said hydrocarbon vapors and said downward passing catalyst particles whereby said carbonaceous deposit is removed from said upward passing catalyst particles by combustion, separating the thus reactivated catalyst particles from the products of combustion and returning said reactivated catalyst particles to said zone to again pass downwardly therethrough.

2. A continuous process for the conversion of hydrocarbon oils which comprises passing finely divided solid cracking catalyst particles in a downward direction and with substantially uniform cross-sectional particle distribution through a zone maintained at a cracking temperature, simultaneously passing hydrocarbon vapors helically through said zone in an upward direction in contact with said catalyst particles whereby said hydrocarbon vapors are converted and a carbonaceous material is deposited upon said catalyst particles, withdrawing said catalyst particles having said carbonaceous deposit and passing them commingled with oxygen-containing gas in an upward direction in heat exchange relation with but out of contact with said hydrocarbon vapors and said downward passing catalyst particles whereby said carbonaceous deposit is removed from said upward passing catalyst particles by combustion, separating the thus reactivated catalyst particles from the products of combustion, returning said reactivated catalyst particles to said zone to again pass downwardly therethrough, and increasing the oxygen content of said combustion products and returning them as said oxygen-containing gas.

3. The process as defined in claim 1 further characterized in that the combustion of said carbonaceous deposit on said catalyst particles supplies at least a portion of the endothermic heat of the cracking reaction.

4. The process as defined in claim 2 further characterized in that the combustion of said carbonaceous deposit on said catalyst particles sup-

plies at least a portion of the endothermic heat of the cracking reaction.

5. The process as defined in claim 1 further characterized in that oxygen is added at intermediate points to said oxygen-containing gas during its sepaarte passage in heat exchange relation with but out of contact with said hydrocarbon vapors and said downward passing catalyst particles.

6. The process as defined in claim 2 further characterized in that oxygen is added at intermediate points to said oxygen-containing gas during its separate passage in heat exchange relation with but out of contact with said hydrocarbon vapors and said downward passing catalyst particles.

7. An apparatus for contacting finely divided solid particles with a fluid which comprises in combination a vertically elongated closed vessel, at least one perforate helical flight having perforations of sufficient size to pass said finely divided solid particles and extending within said vessel from adjacent its lower end to adjacent its upper end, at least one vertically disposed conduit extending through said vessel from one end to the other, means for introducing finely divided solid particles to the upper end of said vessel, means for withdrawing said solid particles from the lower end of said vessel and directing them into and through the aforesaid at least one vertically disposed conduit, means for introducing fluid to the lower end of said vessel and means for withdrawing fluid from the upper end of said vessel.

8. An apparatus for contacting finely divided solid particles with a fluid which comprises in combination a vertically elongated closed vessel, a plurality of perforate helical flights having perforations of sufficient size to pass said finely divided solid particles and extending within said vessel from adjacent its lower end to adjacent its upper end, a plurality of vertically disposed conduits extending through said vessel from one end to the other, means for introducing finely divided solid particles to the upper end of said vessel, means for withdrawing said solid particles from the lower end of said vessel and directing them into and through said vertically disposed conduit, means for introducing fluid to the lower end of said vessel and means for withdrawing fluid from the upper end of said vessel.

9. An apparatus for contacting finely divided solid particles with a fluid which comprises in combination a vertically elongated closed vessel, at least one conduit extending through said vessel from one end to the other thereof, at least one perforate helical flight extending within said vessel from adjacent its lower end to adjacent its upper end, said conduit and helical flight being so arranged that they in combination occupy substantially the entire cross-sectional area of said vessel, means for introducing finely divided solid particles to the upper end of said vessel, means for withdrawing said solid particles from the lower end of said vessel, means for introducing fluid to the lower end of said vessel, means for withdrawing fluid from the upper end of said vessel and means for passing a heat convective fluid through said at least one conduit.

10. A conversion process which comprises passing a subdivided solid catalyst downwardly with substantially uniform cross-sectional particle distribution through a reaction zone, simultaneously passing hydrocarbon vapors upwardly in a helical path through said zone, endothermically reacting the vapors while in countercurrent contact with the catalyst in said zone, removing carbonized catalyst from the reaction zone and passing the same with oxygen-containing gas in an upward direction in indirect heat exchange relation with the vapors and catalyst in the reaction zone, burning carbonaceous matter from the catalyst during its upward passage and transmitting resultant heat of combustion to the vapors and catalyst in the reaction zone, and subsequently returning the reactivated catalyst to the reaction zone to pass downwardly therethrough as aforesaid.

11. A conversion apparatus comprising a vertical reaction chamber, means for passing solid particles downwardly through said chamber, means for passing a fluid reactant upwardly through said chamber in countercurrent contact with said particles, a conduit extending vertically through said chamber, a perforated helical baffle disposed within the reaction chamber around said conduit, a separator communicating with the upper end of said conduit, means for passing solid particles from the lower portion of said chamber upwardly through said conduit into the separator, and means for returning solid particles from the separator to the chamber.

12. A method of catalyzing a conversion reaction with finely divided solid catalyst particles which comprises passing a fluid to be converted upwardly through a reaction zone in a helical path around a helical baffle, maintaining said zone under conversion conditions, simultaneously passing the solid particles in a downward direction through said zone in contact with the fluid, and dropping said particles from flight to flight of the helical baffle to provide substantially uniform cross-sectional particle distribution through said zone.

13. A method of converting hydrocarbons in the presence of subdivided solid catalyst particles, which comprises passing a hydrocarbon vapor upwardly through a reaction zone in a helical path around a helical baffle, maintaining said zone under conversion conditions, simultaneously passing the solid particles in a downward direction through said zone in contact with the vapor, and dropping said particles from flight to flight of the helical baffle to provide substantially uniform cross-sectional particle distribution through said zone.

14. A catalytic cracking process which comprises passing hydrocarbon vapors at cracking temperature upwardly through a reaction zone in a helical path around a helical baffle, simultaneously passing subdivided particles of a solid cracking catalyst in a downward direction through said zone in contact with the vapors, and dropping said particles from flight to flight of the helical baffle to provide substantially uniform cross-sectional particle distribution through said zone.

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