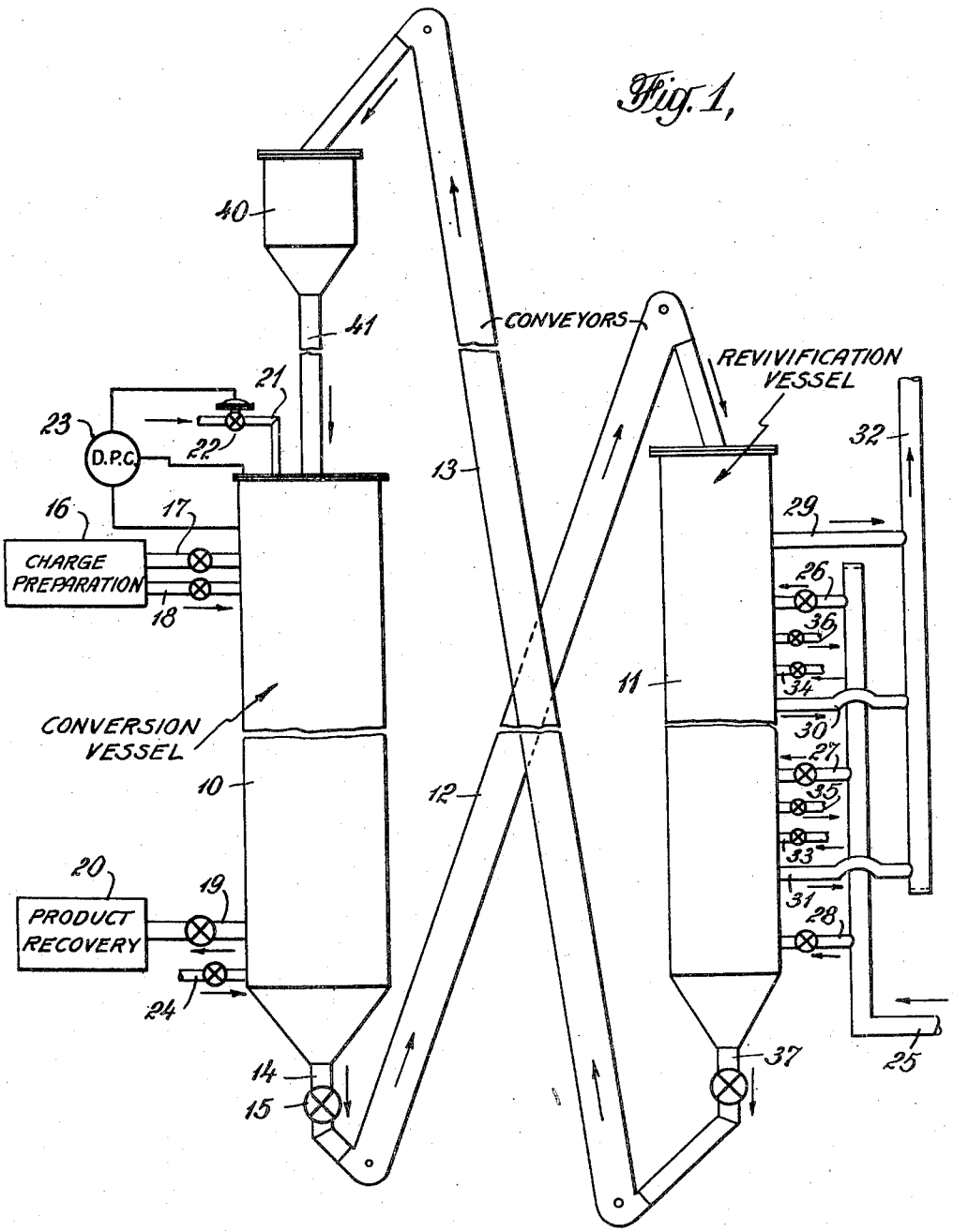
Jan. 11, 1949. F. E. RAY 2,459,096

METHOD AND APPARATUS FOR FLUID HYDROCARBON CONVERSION

Filed Nov. 7, 1946 3 Sheets-Sheet 1

Fig. 1,



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METHOD AND APPARATUS FOR FLUID HYDROCARBON CONVERSION

Filed Nov. 7, 1946 3 Sheets-Sheet 2

Fig. 2,

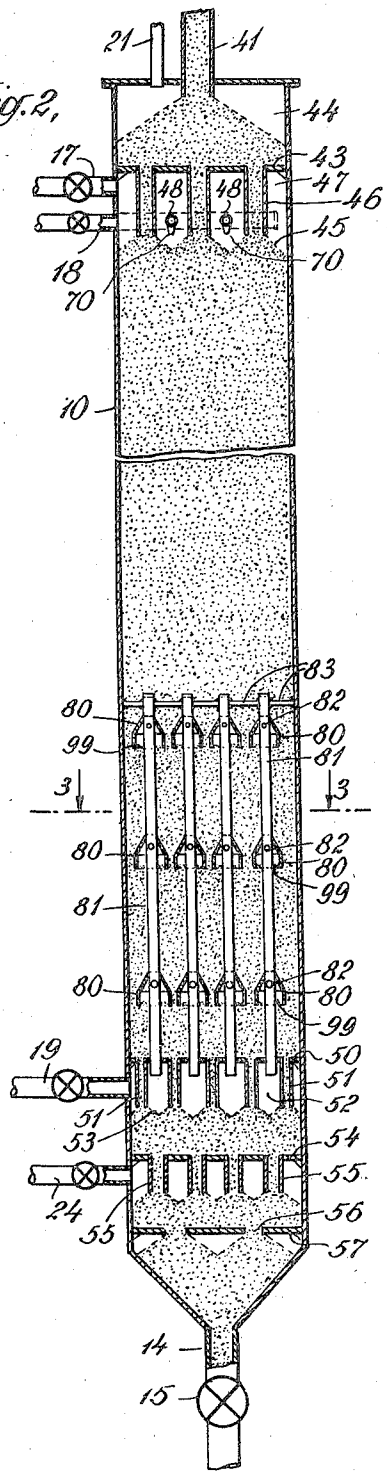


Fig. 3,

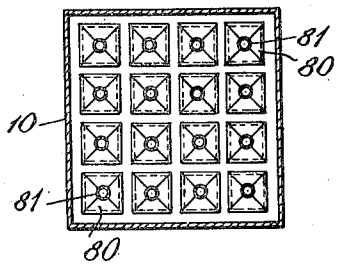


Fig. 4,

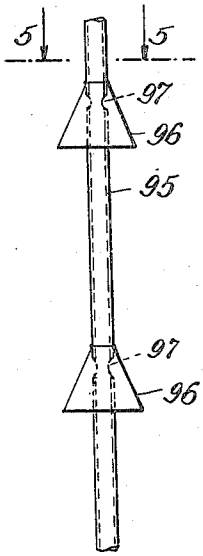
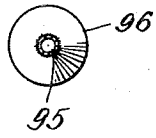


Fig. 5,



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METHOD AND APPARATUS FOR FLUID HYDROCARBON CONVERSION

Filed Nov. 7, 1946 3 Sheets-Sheet 3

Fig. 6,

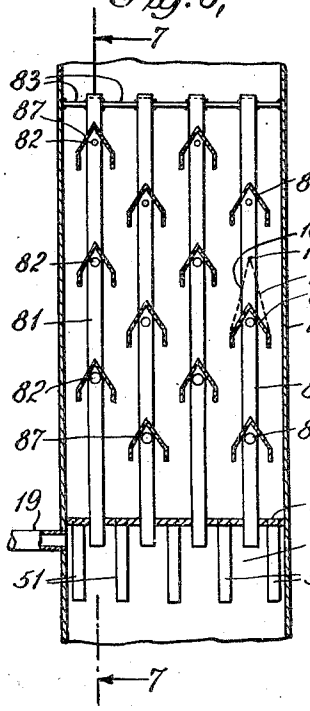


Fig. 7,

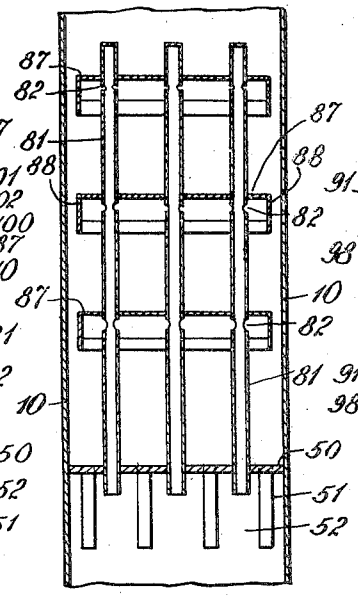


Fig. 8,

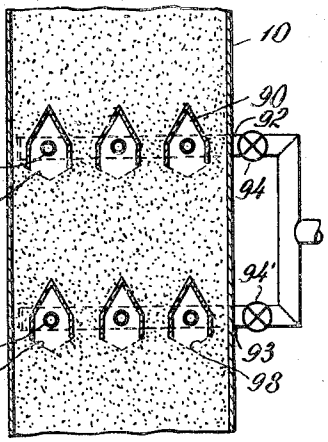
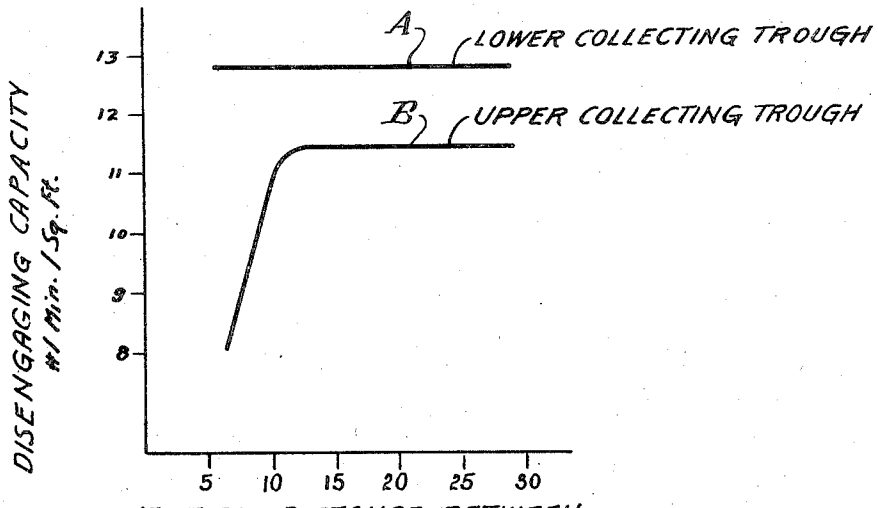


Fig. 9.



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UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR FLUID HYDROCARBON CONVERSION

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Application November 7, 1946, Serial No. 708,245

9 Claims. (Cl. 196—52)

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This invention has to do with a method and apparatus for conversion of fluid hydrocarbons in the presence of a particle-form solid contact material which may or may not be catalytic in nature.

Exemplary of the processes to which this invention may be applied are the catalytic cracking conversion of high boiling fluid hydrocarbons, the catalytic hydrogenation, dehydrogenation, aromatization, polymerization, alkylation, isomerization, reforming, treating or desulfurizing of selected hydrocarbon fractions. Also exemplary are the thermal cracking, viscosity breaking and coking of hydrocarbon fractions in the presence of heated inert, solid materials.

Typical of such processes is the catalytic cracking conversion of hydrocarbons, it being well known that high boiling fluid hydrocarbons may be converted to lower boiling gaseous, gasoline containing hydrocarbon products by exposure to a suitable adsorbent type catalytic material at temperatures of the order of about 800° F. and higher and at pressures usually above atmospheric. Such a process has recently been developed commercially into a continuous cyclic process wherein the solid catalyst is passed cyclically through a conversion zone wherein it is contacted with fluid hydrocarbons to effect the conversion thereof and through a regeneration zone wherein it is contacted with a combustion supporting gas such as air which acts to burn off from the catalyst a carbonaceous contaminant deposited thereon in the conversion zone.

This invention is particularly concerned with such cyclic conversion processes or gas-solid contacting processes wherein the particle-form contact material moves through the conversion zone or contacting zone as a substantially compact column and wherein gaseous reaction products or contacting gas and the used contact material are separately withdrawn from the conversion or contacting zone.

In such cyclic processes wherein the contact material is a catalyst it may partake of the nature of natural or treated clays, bauxite, inert carriers upon which catalytic materials such as metallic oxides have been deposited or certain synthetic associations of silica, alumina or silica and alumina to which small amounts of other materials such as metallic oxides may be added for special purposes. In processes wherein the contact material is not catalytic in nature its purpose is usually that of a heat carrier and may take any of a number of forms, for example spheres or particles of metals, stones or refractory materials such as mullite, zirkite, or corhart material. In order to permit practical rates of gas flow through the contact material which is maintained as a substantially compact column in the conversion zone, the contact material should be made up of particles falling within the size range of about .005 to 1" diameter and preferably .03 to 0.3 inch diameter.

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In such processes wherein the direction of gas flow through the reaction zone is countercurrent to the downward flow of the contact material, the maximum rate of gas flow should be limited to that which will not cause "boiling of the contact material" or serious interference with its flow otherwise serious difficulties arise such as channeling of the solid and gas flow and excessive attrition of the solid material. In many processes such as, for example the conversion of liquid hydrocarbons to lower boiling gaseous products it is desirable to pass the reactant fluid downwardly through the conversion zone concurrently with the contact material flow. In such processes a serious difficulty arises in the withdrawal of gaseous reactants from the contact material column within the conversion zone. In one form of operation practiced heretofore a row of inverted, spaced, collecting troughs, open along their bottoms was positioned in the column of contact material within the lower section of the reactor, and gas was withdrawn from the ends of these troughs. Such an arrangement has proved unsatisfactory for most concurrent flow operations, which are characterized by very high rates of gas flow through the conversion zone, due to the entrainment of a substantial amount of the contact material particles from the conversion zone in the gas streams withdrawn from the row of collector troughs. This entrainment is for the most part caused by the fact that such an arrangement for gaseous material withdrawal from a column of contact material does not provide sufficient gas-solid disengaging area and due to the very high linear velocity of the disengaged gas under the collector troughs.

A major object of this invention is the provision in a process wherein a gaseous material is contacted with a substantially compact column of particle-form contact material of an improved method and apparatus for withdrawal of gas from said column without substantial entrainment of contact material particles.

Another object of this invention is the provision of an improved method and apparatus for conversion of a high boiling fluid hydrocarbon to a lower boiling gaseous hydrocarbon product in

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a confined zone in the presence of a substantially compact column of contact material particles flowing downwardly through said zone in the direction of the reactant flow.

A specific object is the provision in a system wherein gaseous material is contacted with a substantially compact column of downwardly moving contact material particles of an improved arrangement of gas outlet collector members which permits uniform withdrawal of gas from the contact material column without substantial entrainment of contact material.

These and other objects of this invention will become apparent from the following detailed description of the invention. Before proceeding with the description certain expressions employed herein in describing and in claiming this invention will be defined. The term "gaseous" as used herein, unless specifically otherwise modified, is intended broadly to cover material existing in the gaseous phase under the particular operating conditions involved regardless of what may be the normal phase of that material under ordinary atmospheric conditions. The expression "contact material," unless otherwise specifically modified, is used herein in a broad sense to cover any solid material having suitable heat carrying and stability properties for the particular process application in which it is employed, and the expression is intended to broadly cover catalytic and non-catalytic materials.

The invention may be most readily understood by reference to the drawings attached hereto of which

Figure 1 is an elevational view of an arrangement of a cyclic conversion system to which this invention is applied,

Figure 2 is an elevational view, partially in section of a conversion vessel constructed according to this invention,

Figure 3 is a plan view, partially in section, taken along line 3—3 of Figure 2,

Figure 4 is a detailed view of a portion of a modified gas collecting member which may be substituted for the gas collecting members shown in Figure 2,

Figure 5 is a sectional plan view taken at 5—5 in Figure 4,

Figure 6 is an elevational view, partially in section, of a portion of a conversion vessel provided with a modified arrangement of gas collecting members,

Figure 7 is an elevational sectional view taken along line 7—7 of Figure 6,

Figure 8 is an elevational view, partially in section, of a portion of a conversion vessel provided with still another modified arrangement for collecting gas, and

Figure 9 is a graphical demonstration of the relationship between gas collector spacing and the disengaging capacity of said collectors. All of these drawings are highly diagrammatic in form.

Turning now to Figure 1, there is shown a conversion vessel 10, a regeneration or revivification vessel 11 and conveyors 12 and 13 for transfer of contact material between the conversion and regeneration vessels. In operation particle-form contact material is supplied from hopper 40 through gravity feed leg 41 into the upper section of the conversion vessel 10. Used contact material is withdrawn from the lower end of vessel 10 through drain conduit 14. The rate of contact material flow is controlled by valve 15 on conduit 14 so that a substantially compact column of contact material is maintained within the conversion zone. The hydrocarbon charge to vessel 10 may exist in the gaseous phase or liquid phase or both. The charge may be vaporized and/or heated and separated into vapor and liquid fractions in a suitable charge preparation system 16 which may be of conventional design. Heated charge vapors may be admitted to the upper section of the conversion zone through conduit 17 and heated liquid charge may be admitted through conduit 18. Gaseous conversion products are withdrawn separately of the contact material, from the lower section of the conversion zone through conduit 19 through which it passes to a conventional product recovery system 20. An inert seal gas such as steam or flue gas may be admitted through conduit 21 into a seal zone maintained at the upper end of vessel 10 for the purpose of preventing hydrocarbon escape through the gravity feed leg. The rate of seal gas introduction may be so controlled by means of diaphragm actuated valve 22 and differential pressure control instrument 23 as to maintain a seal gas pressure in the seal zone slightly above the hydrocarbon pressure in the upper section of the conversion zone. An inert purge gas such as steam or flue gas may be introduced into the contact material column below the level of gaseous reactant through conduit 24 withdrawal for the purpose of purging gaseous reaction products from the outflowing used contact material. The used contact material is transferred by conveyor 12, which may be a continuous bucket elevator for example, to the upper end of regeneration vessel 11. The regeneration vessel shown is of the multi-stage type, well adapted for the regeneration of spent cracking catalysts. Air or oxygen containing gas is introduced from manifold 25 into several superposed burning stages through inlet conduits 26, 27 and 28. Flue gas may be withdrawn from these stages through conduits 29, 30 and 31, all connecting into outlet manifold 32. The contact material temperature may be controlled by passing a suitable cooling fluid through cooling tubes located in vessel 11 between the burning stages. Cooling fluid may be introduced into the cooling tubes (not shown) through communicating inlets 33 and 34 and withdrawn therefrom through communicating outlets 35 and 36. Regenerated contact material is withdrawn from vessel 11 through drain conduit 37 through which it passes to conveyor 13. The hot regenerated contact material is transferred by conveyor 13 to reactor supply hopper 40. While the regenerator described hereinabove is of the multi-stage type it will be understood that other types of regenerators adapted for regenerating contact materials may be employed within the scope of this invention. The type of regenerator or revivification vessel to be employed will vary depending upon the particular process involved. Any apparatus adapted to condition the contact material to a state satisfactory for re-use in the particular conversion process involved is contemplated to be within the scope of this invention. It should be further understood that this invention is not considered as limited to any particular positioned arrangement of conversion and regeneration vessels or to the particular apparatus described hereinabove for contact material introduction into the conversion vessel.

The improvement of this invention as applied to the conversion vessel 10 is shown in Figure 2 wherein 10 is the conversion vessel having solid

inlet 41 at its upper end and outlet 14 at its lower end. A partition 43 is positioned across the upper section of the vessel 10 to provide a seal chamber 44 in the upper end of vessel 10. Contact material passes from seal chamber 44 onto the surface of the contact material column 45 in the conversion chamber therebelow through uniformly distributed tubes 46 which depend from partition 43. The partition 43 and tubes 46 combine to provide a gas distribution space 47 above the contact material column in the conversion chamber. Vaporized hydrocarbons may be introduced into the gas space through conduit 17. Liquid hydrocarbons enter through conduit 18 which extends across the vessel and is closed on its end within the vessel. A number of liquid distributing tubes 48 extend horizontally across the gas space 47. These tubes are closed on the ends thereof which terminate within the vessel and are connected on their opposite ends on the outside of the vessel into a liquid charge inlet manifold 18. A number of spray nozzles 70 are connected at intervals along the tubes 48 so as to direct a liquid hydrocarbon spray downwardly onto the surface of the column 45. Across the lower section of vessel 10 there is provided a horizontal partition 50 from which depend a plurality of tubes 51 communicating with the contact material column above the partition 50 terminating a spaced distance therebelow. Thus there is provided a solid settling space and plenum chamber 52 from which gravity flow of solid from the column of contact material is excluded and a number of confined passages for solid material flow from the column through the settling space onto the surface of the compact bed of contact material 53 maintained in the lowest portion of vessel 10. Contact material is withdrawn from the bottom of the bed 53 defined by another partition 54 through a number of uniformly distributed tubes 55. The streams from tubes 55 are proportionately combined into a smaller number of streams flowing through orifices 56 in still another partition 57 within the lower section of vessel 10 and the streams from orifices 56 are proportionately combined into a single discharge steam flowing from the conversion vessel in conduit 14. The number of orifices within partition 57 are only one quarter the number of tubes depending from partition 54 and that the orifices 56 are horizontally staggered with respect to tubes 54. By the gradual proportionate combination of streams into a single discharge stream as described hereinabove uniform withdrawal of contact material from all portions of the cross-sectional area of the conversion vessel is insured. The number of rows of partitions with orifices or depending tubes employed depends of course on the horizontal cross-sectional area of the vessel involved. If the vessel 10 is of circular cross-sectional shape the tubes in each partition may be conveniently arranged as concentric circular rows of tubes. On the other hand for a vessel of rectangular cross-sectional shape the tubes in each partition may be conveniently arranged in spaced apart parallel rows of tubes extending across the vessel. A gas outlet conduit 19 connects into the vessel shell at the level of space 52. Studying now Figures 2 and 3 together within the lower section of vessel 10 there are provided a plurality of spaced vertical tubes 81 extending upwardly from gas space 52, through the partition 50 to which they are fastened and upwardly to a fixed level above partition 50. The tubes 81 are closed on their upper

ends and open on their lower ends and are uniformly distributed over the cross-sectional area of the partition 50. Rods 83 serve to latterly support the tubes 81 near their upper ends. Along each tube 81 are fastened a plurality of vertically spaced apart inverted cups 80 having upwardly tapered roofs. Thus there is provided a number of uniformly distributed gas collecting cups at a series of vertical levels within the lower section of vessel 10. As will be seen in Figure 3, the cups are of approximately square horizontal cross-sectional shape. Orifices 82 are provided in each tube at a level just under the roof of each cup so as to communicate the interior of each tube 81 with the underside of each cup fastened thereto.

In operation contact material enters the seal chamber 44 through conduit 40 and passes from the bottom of the seal chamber through tubes 46 onto the surface of the contact material column 45 in the conversion chamber. The contact material flows downwardly through an upper portion of the conversion chamber as a substantially compact bed or column of gravity flowing particles. The rate of solid flow is controlled by throttling by means of valve 15 on the outlet 14 from vessel 10. Contact material passes from the bottom of the column through tubes 51 onto the surface of bed 53 from which it is withdrawn as described hereinabove. Vaporized hydrocarbon reactants enter through conduit 17 into the distributing space 47 over the contact material column and then pass downwardly through the column concurrently with the solid flow. If the reactant exists in the liquid phase it is introduced through conduit 18 and sprayed onto the contact material column by means of spray devices 70. The resulting gaseous conversion products disengage from the column under the vertically spaced cups 80 from which it is withdrawn through orifices 82 into tubes 81. The gaseous products pass from the lower ends of tubes 81 into gas space 52 and are withdrawn from the vessel through conduit 19.

While the arrangement described hereinabove is a preferred arrangement, certain modified arrangements are also contemplated to be within the scope of this invention. For example, in Figures 4 and 5 there is shown a single gas collecting tube 95 to which are attached two vertically spaced apart inverted cups 96 of frusto-conical shape. Perforations 97 in tube 95 communicate the interior of the tube with the space under the cups 96. A number of such tubes 95 and cups 96 may be substituted for the tubes 81 and cups 80 in the apparatus of Figure 2. In general it has been found desirable to provide vertical skirts along the lower edge of the tapered roof of gas collecting members as shown in Figure 2. The height of the skirts should be at least ½-inch and preferably at least one inch for highest disengaging capacity. If desired, means other than the plenum chamber 52 and outlet 19 may be substituted in the apparatus of Figure 2 for the purpose of gas withdrawal from tubes 81. For example, rows of tubes 81 may connect on their lower ends into a row of spaced horizontal gas outlet ducts or tubes which in turn communicate through suitable conduits with the exterior of vessel 10.

While in all forms of this invention it is important that the gas collecting members be provided at more than one level, the number of levels at which they may be required may vary de-

pending upon the particular operations involved. Moreover, while in the preferred form of this invention the gas collecting members should take the form of inverted cups, still in less preferable forms considered to be within the scope of this invention the collecting members may take certain other forms. Such another form is shown in Figures 6 and 7, Figure 6 being a vertical view, partially in section, of that portion of a conversion vessel 10 in which the gas collecting members are provided and Figure 7 being a sectional view taken along line 7—7 in Figure 6. In Figures 2, 6 and 7, elements which are identical bear like numerals. In the modification shown in Figures 6 and 7, there are provided within the vessel 10 and above the partition 50 a plurality of spaced horizontaly extending gable roofed, inverted gas collecting troughs 87 arranged in a plurality of spaced vertical rows of vertically spaced troughs adjacent troughs in adjacent rows being offset vertically. End plates 88 close off the ends of the trough 87. A row of horizontally spaced tubes 81 extend upwardly through partition 50 and through all the troughs in any vertical row of troughs, the tubes 81 passing tightly through the gable roof so as to serve as support for the troughs. Holes 82 are provided in the tubes 81 to communicate the underside of the troughs 87 with the interior of the tubes 81.

Other methods for withdrawal of gas from under the gas collector members may be substituted for the tubes 81 in less preferred modifications of the invention. For example in Figure 8 there is shown a portion of a conversion vessel 10 in which there are provided two vertically spaced rows of gas collector troughs 90. Tubes 91 extend a short distance under each trough and connect to external manifolds 92 and 93 so as to provide for withdrawal of gas from one end of all the troughs 90 in the upper row thereof into manifold 92 and for withdrawal of gas from one end of all the troughs 90 in the lower row thereof into manifold 93. Valves 94 and 95 are provided on manifolds 92 and 93 to permit independent control of the rate of gas withdrawal from the troughs at each level.

In all the above described arrangements there is provided within the conversion vessel a plurality of vertical spaced apart gas collecting members, each of which members are adapted to define a gas space which shielded from gravity flow of contact material from the column thereof and open along their bottoms so as to communicate with the column of contact material. A disengaging surface is formed along the underside of each collecting member. When the rate of gas flow is low this surface may correspond to the V-shaped surface 98 formed under each trough 90 in Figure 8. The exact slope of the surface depends in such a case on the angle of repose of the particular contact material involved and may vary for clay-type catalysts from about 25 to 40 degrees. However, for relatively high rates of gas disengagement, the scope of the disengaging surface may flatten out and the surface may even rise a short distance under the collecting member as indicated along dotted line 99 in Figure 2. It has been found that entrainment of solids cannot be satisfactorily limited if the disengaging surface is permitted to rise more than about 3 inches under the usual collecting troughs. Preferably the operation should be controlled so that the solid level does not rise more than about one inch under the gas collecting members.

Also it has been discovered that when gas collecting members are positioned one above the other within a column of downwardly moving solid material, and gas from that portion of the column above said members is collected under said members, then for most operations gas may be disengaged and collected under the lowermost level of collecting members at a higher rate than it can be disengaged and collected under members thereabove for the same amount disengaging surface buildup under all the collectors. In other words, gas may be collected under the lowermost collectors without entrainment of contact material at a higher rate than it can from any collectors above the lowermost collectors in each vertical row thereof. Furthermore it has been found that unless the collecting members in any vertical row are spaced further apart than a certain critical vertical distance the disengaging capacity of any collector above the lowermost collector falls off very sharply. This may be best demonstrated by reference to Figure 9 which is a graphical representation of data obtained on a trough arrangement similar to that shown in Figure 8 in which each trough measured about 6 inches in width, and 6¼ inches in height, of which height about 5¼ inches was taken up by the gable roof portion of the trough. In obtaining this data the contact material employed was a spherical catalyst of about ⅛-inch diameter and having a density of about 45 pounds per cubic foot. The rate of gas disengagement was at the maximum capacity of the collecting troughs. In Figure 9, line A represents the lowermost collecting trough and it will be noted that the disengaging capacity of the lowermost trough is substantially constant and independent of the spacing of the next trough thereabove. Line B represents the trough next above or any trough above the lowermost trough in a vertical series and it may be noted that when the spacing is such that the distance between the base of the upper trough and the base of the gable roof of the trough next below in this example is less than about 11½ inches the capacity of the upper trough drops off critically and rapidly. On the other hand when the spacing is increased above about 11½ inches no substantial change in the capacity of the upper collecting trough may be realized. For the particular trough arrangement represented by Figure 9, in order to insure satisfactory operation of any troughs above the lowermost trough, it is important that the vertical spacing of the troughs should be at least greater than a certain critical value, in the case of the example given above about 11½ inches. The critical spacing value has been found to vary for different trough or collecting cup sizes and constructions and for different contact materials. It has been found that for any given application the collecting members should be so spaced that the distance between the base of a given member and the highest level along the member next below at which its horizontal cross-sectional area is at the maximum is greater than the distance between said highest level along the member next below at which its horizontal cross-sectional area is at the maximum and the point of convergence above said member next below of converging lines drawn upwardly at opposite angles with the horizontal substantially equal to the angle of internal flow of said contact material from points positioned at 180 degrees with respect to each other on the periphery of said member next below at said highest level of maximum horizontal area.

For example, in the troughs shown in Figure 6, the highest level of maximum horizontal area along any lower trough corresponds to the level of the base of the gable roof of the trough. Dotted lines 100 and 101 are drawn upwardly from opposite sides of the lower trough at the level of the base of its gable roof, at opposite angles with the horizontal equal to the characteristic angle of internal flow of the contact material involved. It will be noted that the point of convergence 102 of lines 100 and 101 is below the base of the upper trough. In the case of conical cups such as are shown in Figure 5, the highest level of maximum horizontal cross-sectional area is obviously the base of the cup. The angle of internal flow of contact material may best be determined by filling a flat bottomed container of large diameter with contact material and withdrawing contact material from the bottom of the container through a small central outlet while observing the average angle with the horizontal formed at the interphase between particles flowing downwardly towards the outlet and the fringe of particles which are substantially stagnant as regards flow. In general the angle of internal flow for most granular pelleted and spherical catalysts of clay or gel and of the size range about 4 to 60 mesh by Standard Tyler screen analysis has been found to fall within the range about 67 to 78 degrees and on the average about 75 degrees.

The above required vertical spacing arrangement for gas collecting troughs is the broadest aspect of the instant invention. It may be expressed, if desired, in a simpler form as follows: the vertical distance between the base of a given gas collecting member and the highest level of maximum horizontal projected area along the collecting member next below said given member should be greater than the vertical distance d, where

$$d=\frac{W}{2}X \text{ tangent } b$$

in which W is the maximum width of the collecting member which is below said given member and where b is the characteristic angle of internal flow of the particular contact material involved. It has been found preferable that the vertical spacing specified above should be greater than d by an amount at least equal to

$$\frac{W'}{2}\tan c$$

where W' is the width of the upper given collecting member at its base and c is the normal angle of repose of the particular contact material involved. In other words for the best operation, the vertical distance between the base of a gas collecting member D and the highest level of maximum horizontal projected area along a second collecting member F below D should be either equal to or at least as great as

$$d=\frac{W}{2}\tan b+\frac{W'}{2}\tan c$$

or where the members are of the same construction

$$d'=\frac{W}{2}(\tan b+\tan c)$$

Since for most hydrocarbon conversion processes the contact materials used have an average angle of internal flow of about 75° and an average angle of repose of about 30°, it may be said that for such processes the vertical distance between the base of a gable roofed trough or cup and the base of the gable-roof on a similar trough or cup therebelow should be equal to or at least as great as the product of about 2.1 times maximum width of the troughs or cups.

It will be noted from Figure 9 that even when the gas collecting members in concurrent flow gas-solid contacting vessels are properly spaced as discussed hereinabove, still the disengaging capacity of the upper collecting members is somewhat below that of the lowermost members. Because of this and also in order to overcome the additional gas flow resistance offered by the column of contact material between the uppermost level of collectors and lower levels of collectors, the rate of gas withdrawal from under the collectors at any given level should be independently controlled. This may be accomplished in the arrangement shown in Figure 8 by means of valves 94 and 95 on manifolds 92 and 93 respectively. On the other hand in the arrangement shown in Figure 2, the orifices 82 in tubes 80 should be progressively greater in size at each successive level of troughs in a downward direction and the size of such orifices should be so proportioned as to adjust the rate of gas withdrawal from all the collectors at all levels such as will be consistent with substantially uniform and equally efficient disengaging conditions at all levels. Thus for the particular trough arrangement, and contact material involved in Figure 9, the gas flow from all troughs above the lowermost troughs should be only about 90% of what it is from the lowermost troughs. It will be apparent from the above that the expression "substantially uniform disengaging conditions" as used herein in describing and claiming the invention is not intended to mean that the gas flow is equal in amount but that the efficiency of the disengagement without solid entrainment is substantially uniform for all the levels of gas collectors. The total number of gas collecting troughs and the number in each vertical row of troughs will, of course, depend upon the particular operational application involved.

The method and apparatus of this invention may be employed in a wide variety of processes involving contact of gas with a column of particle-form solid material. The invention is particularly applicable to catalytic processes for the cracking conversion of liquid or vaporous hydrocarbon charges or both. In general such hydrocarbon conversion operations are conducted under temperatures within the range about 800° F. to 1100° F., the higher temperatures being employed for liquid charging stocks. Low pressures of the order of 5 to 30 pounds per square inch are generally employed in the conversion zone for cracking conversions. The oil charge space velocity may vary from about 0.3 to 10.0 volumes of oil (measured as liquid at 60° F.) per hour per volume of catalyst column within the reaction zone. The catalyst to oil throughput ratio may vary within the range about 1 to 20 parts of catalyst per part of oil by weight. In general the reactant charge is preheated to a temperature of the order of 600° F.–900° F. and all or part of the heat required for the conversion may be carried into the conversion zone in the catalyst.

It should be understood that the particular details of apparatus construction and of operation and the examples of application of this invention given hereinabove are intended as exemplary and are not to be construed as limiting the scope of this invention except as it may be limited by the following claims.

I claim:

1. A method for conversion of fluid hydrocarbons to lower boiling gaseeous hydrocarbons in the presence of a moving particle-form contact material which method comprises: introducing particle-form contact material into the upper section of a confined, elongated conversion zone at a suitable temperature for said hydrocarbon conversion; passing said contact material downwardly through said zone as a substantially compact column of downwardly flowing particles; withdrawing used contact material from the lower section of said zone, introducing fluid hydrocarbons into the upper section of said conversion zone; passing said fluid hydrocarbons downwardly through the major portion of the length of said column of contact material within said conversion zone to effect conversion of said hydrocarbons to lower boiling gaseous hydrocarbon products; baffling the flow of contact material in the lower section of said column at a plurality of vertically spaced locations to provide a plurality of vertically spaced apart gas collecting spaces of equal width which are shielded from gravity flow of contact material from said column but open to said column along their lower sides, said gas spaces being so vertically spaced one from another that the open base of any given gas space above the lowermost gas collecting space is positioned a greater vertical distance above the highest horizontal plane of maximum cross-sectional area across the gas space next below than the distance, d, as expressed by the formula,

$$d=\frac{W}{2}(\tan b+\tan c)$$

where W is the maximum width of said gas spaces, b is the characteristic angle of internal flow of said contact material, and c is the angle of repose of said contact material; collecting said gaseous products in all of said gas collecting spaces, withdrawing the gaseous products from said collecting spaces as confined streams and imposing a fixed throttle on the gas flowing from each collecting space at the location of its exit from the collecting space, the throttle being progressively less for flow from successively lower collecting spaces.

2. An apparatus for conversion of fluid hydrocarbons in the presence of a particle-form contact material which comprises in combination: means defining a conversion vessel adapted to confine gaseous material and a column of contact material; means to introduce particle-form contact material into the upper section of said vessel; means to withdraw contact material from the lower section thereof; means to introduce fluid hydrocarbons into the upper section of said vessel; a plurality of inverted gas collecting cups positioned within the lower section of said vessel, said cups being arranged at a plurality of levels within the lower section of said vessel and having horizontal dimensions which are in all directions relatively small as compared with the corresponding dimensions of said vessel, gas withdrawal tubes registering with the under sides of said cups, said tubes having orifices therein establishing communication between the tubes and cups at the points of registry, said orifices being progressively larger for cups at successively lower levels.

3. An apparatus for conversion of fluid hydrocarbons in the presence of a particle-form contact material which comprises in combination: means defining a conversion vessel adapted to confine gaseous material and a column of contact material; means to introduce particle-form contact material into the upper section of said vessel; means to withdraw contact material from the lower section thereof; means to introduce fluid hydrocarbons into the upper section of said vessel; a plurality of horizontally spaced vertical rows of inverted horizontally extending, vertically spaced gas connecting troughs positioned within the lower section of said vessel, the uppermost troughs being spaced a substantial vertical distance below said fluid hydrocarbon inlet means so as to provide space for a substantial vertical length of column between said hydrocarbon inlet means and the uppermost troughs, a plurality of collecting tubes at least one tube extending upwardly through each trough in each vertical row of troughs, each of said tubes being closed in its upper end and being perforated to provide communication between the interior thereof and the space below each trough through which it passes, the perforation area in said tubes below said troughs being progressively greater below the troughs at successively lower levels; and means to withdraw gas from said collecting tubes; wherein said troughs are so vertically spaced that the vertical distance between the base of any given trough in any vertical row and the highest level of maximum horizontal projected area along the trough next below in that vertical row is at least equal to the product of the sum of the tangent of the angle of internal flow of the contact material introduced into said vessel and the tangent of the angle of repose of said contact material times one half the maximum width of said troughs.

4. An apparatus for conversion of fluid hydrocarbons in the presence of a particle-form contact material which comprises in combination: means defining a conversion vessel adapted to confine gaseous material and a column of contact material; means to introduce particle-form contact material into the upper section of said vessel; means to withdraw contact material from the lower section thereof; means to introduce fluid hydrocarbons into said vessel; a plurality of inverted gas collecting cups within the lower section of said vessel, said cups being arranged in a plurality of horizontally spaced vertical series of vertically spaced cups, the uppermost of said cups being spaced a substantial vertical distance below said means to introduce fluid hydrocarbons and a plurality of vertical tubes, one tube passing through each cup in each vertical series of cups, each of said tubes being closed on its upper end and having orifices therein to provide communication between the interior thereof and the interior of each cup through which it passes, the size of said orfices being progressively greater under the cups at successively lower levels; means to withdraw gas from said tubes.

5. An apparatus for gas solid contacting which comprises in combination: a closed, substantially vertical contacting vessel; means to introduce particle-form contact material into the upper section of said vessel; means to withdraw contact material from the lower section of said vessel; means to introduce a contacting fluid into the upper section of said vessel; within only the lower section of said vessel above the level of said means for contact material withdrawal a plurality of horizontally spaced vertical rows of ver-

tically spaced apart gas collecting members, each adapted to define gas collecting space from which gravity flow of solid material is shielded and which is open on its bottom, said gas collecting members in each vertical row being vertically spaced apart in such a manner that the vertical distance between the base of a given collecting member and the highest level of maximum horizontal projected area along the collecting member next below said given member is at least equal to 2.1 times the maximum width of said collecting members, a plurality of vertically spaced tubes within the lower section of said vessel, at least one tube passing through each collecting member in each vertical row thereof, orifices in said tubes underneath each trough, the orifices being of progressively greater total area under successively lower troughs, and means to withdraw the gas from at least one end of said tubes while excluding solid material from flowing into the tubes.

6. An apparatus for conversion of fluid hydrocarbons in the presence of a particle-form contact material which comprises in combination: means defining a conversion vessel adapted to confine gaseous material and a column of contact material; means to introduce particle-form contact material into the upper section of said vessel; means to withdraw contact material from the lower section thereof; means to introduce fluid hydrocarbons into said vessel; a plurality of inverted gas collecting cups within the lower section of said vessel, said cups being arranged in a plurality of horizontally spaced vertical series of vertically spaced cups, said cups being substantially equal in size and having upwardly sloping roofs and said cups in any vertical series being so spaced that the vertical distance between the base of a given cup and the highest level along the cup next below at which its horizontal dimensions are at the maximum is at least equal to about 2.1 times the maximum horizontal dimension of said cup next below, a plurality of vertical tubes, one tube passing through each cup in each vertical series of cups, each of said tubes being closed on its upper end and being perforated to provide communication between the interior thereof and the interior of each cup through which it passes; the perforations in each tube being progressively greater in size at the level of each successive cup in a downward direction, and means to pass gas from said tubes to a location outside of said vessel.

7. A method for conversion of fluid hydrocarbons to lower boiling gaseous hydrocarbons in the presence of a moving particle-form contact material which method comprises: introducing particle-form contact material into the upper section of a confined, elongated conversion zone at a suitable temperature for said hydrocarbon conversion; passing said contact material downwardly through said zone as a substantially compact column of downwardly flowing particles; withdrawing used contact material from the lower section of said zone; introducing heated fluid hydrocarbons into the upper section of said zone, passing said fluid hydrocarbons downwardly within said column to effect their conversion to gaseous hydrocarbon products; collecting said gaseous products in the lower section of said column in a plurality of vertically spaced, superposed, equal, shielded gas collecting spaces which are open at their lower ends to said column of contact material, any two vertically adjacent gas collecting spaces being so spaced that the lower end of the upper space is spaced a vertical distance above the highest level across the lower space at which its horizontal width is at a maximum, which vertical distance is greater than the product of one half the maximum horizontal width of said lower space times the tangent of the angle of internal flow of said contact material; and withdrawing gaseous products from said gas collecting spaces while independently imposing fixed throttles within said conversion zone on the gas flow from the spaces at each level, the fixed throttles being progressively less on the flow from collecting spaces at successively lower levels so as to maintain substantially uniform gas disengaging conditions under all the collecting spaces.

8. A method for conversion of fluid hydrocarbons to lower boiling gaseous hydrocarbons in the presence of a moving particle-form contact material which method comprises: introducing particle-form contact material into the upper section of a confined, elongated conversion zone at a suitable temperature for said hydrocarbon conversion; passing said contact material downwardly through said zone as a substantially compact column of downwardly flowing particles; withdrawing used contact material from the lower section of said zone; introducing fluid hydrocarbons into the upper section of said zone, passing said fluid hydrocarbons downwardly within said column to effect their conversion to gaseous hydrocarbon products; collecting said gaseous products in the lower section of said column in a plurality of shielded gas collecting spaces which are all positioned a substantial distance below the level of said hydrocarbon introduction and which are open at their lower ends to said column of contact material, each of said gas collecting spaces having maximum horizontal dimensions in all directions amounting to only a small fraction of the corresponding horizontal dimensions of said column, said gas collecting spaces being arranged in the lower section of said column in a plurality of horizontally spaced vertical series of vertically spaced collecting spaces, any two vertically adjacent gas collecting spaces in any given vertical series being so spaced that the lower end of the upper space is spaced a vertical distance above the highest level across the lower space at which its horizontal width is at a maximum, which vertical distance is greater than the product of one half the maximum horizontal width of said lower space times the tangent of the angle of internal flow of said contact material; and withdrawing gaseous products from said gas collecting spaces while maintaining within said conversion zone a fixed restriction to the gas flow from the spaces at each level, said restriction being progressively less to the flow from each successively lower level of collecting spaces so as to maintain substantially uniform gas disengaging conditions under all the collecting spaces.

9. A method for conversion of fluid hydrocarbons to lower boiling gaseous hydrocarbons in the presence of a moving particle-form contact material which method comprises: introducing particle-form contact material into the upper section of a confined, elongated conversion zone at a suitable temperature for said hydrocarbon conversion; passing said contact material downwardly through said zone as a substantially compact column of downwardly flowing particles; withdrawing used contact material from the lower section of said zone; introducing heated

fluid hydrocarbons into the upper section of said zone, passing said fluid hydrocarbons downwardly within said column to effect their conversion to gaseous hydrocarbon products; collecting said gaseous products in the lower section of said column in a plurality of horizontally spaced vertical series of vertically spaced gas collecting spaces which are open along their bottoms to said column of contact material, said plurality of vertical series being uniformly distributed over the horizontal cross sectional area of the lower section of said column and the uppermost collecting spaces being positioned within said column a substantial distance below the level of said fluid hydrocarbon introduction into said zone, and each of said gas collecting spaces having a maximum horizontal dimension in any direction amounting to only a small fraction of the corresponding horizontal dimension of said column, any two adjacent gas collecting spaces in any one of said vertical series being so vertically spaced one from another that the vertical distance between the lower extremity of one collecting space and the highest horizontal plane

of maximum cross-sectional area across the gas space next below is greater than that distance corresponding to the tangent of the angle of internal flow of said contact material times one half the maximum width of the lower gas collecting space, flowing said gaseous products through a confined passage from within each of said collecting spaces to a location outside of said conversion zone and imposing a fixed restriction on the gas flow within each collecting space at the point of entry to said confined passage, the restriction being progressively less under collecting spaces at successively lower levels.

FREDERICK E. RAY.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,386,846	Dunham	Oct. 16, 1945
2,409,956	Simpson et al.	Oct. 15, 1946

Certificate of Correction

Patent No. 2,459,096. January 11, 1949.

FREDERICK E. RAY

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 7, line 64, for the word "scope" read *slope*; column 9, line 27, after "gel" insert *type*; column 11, line 3, claim 1, for "boliing gaseeous" read *boiling gaseous*; column 12, line 10, claim 3, for "connecting" read *collecting*; line 61, claim 4, for "orfices" read *orifices*; column 13, line 2, claim 5, after "define" insert *a*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 2nd day of August, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.