Sept. 29, 1959 W. J. CROSS, JR 2,906,705

METHOD FOR CONTACTING LIQUID WITH GRANULAR CONTACT MATERIAL

Filed May 21, 1954 2 Sheets-Sheet 1

Fig. 1.

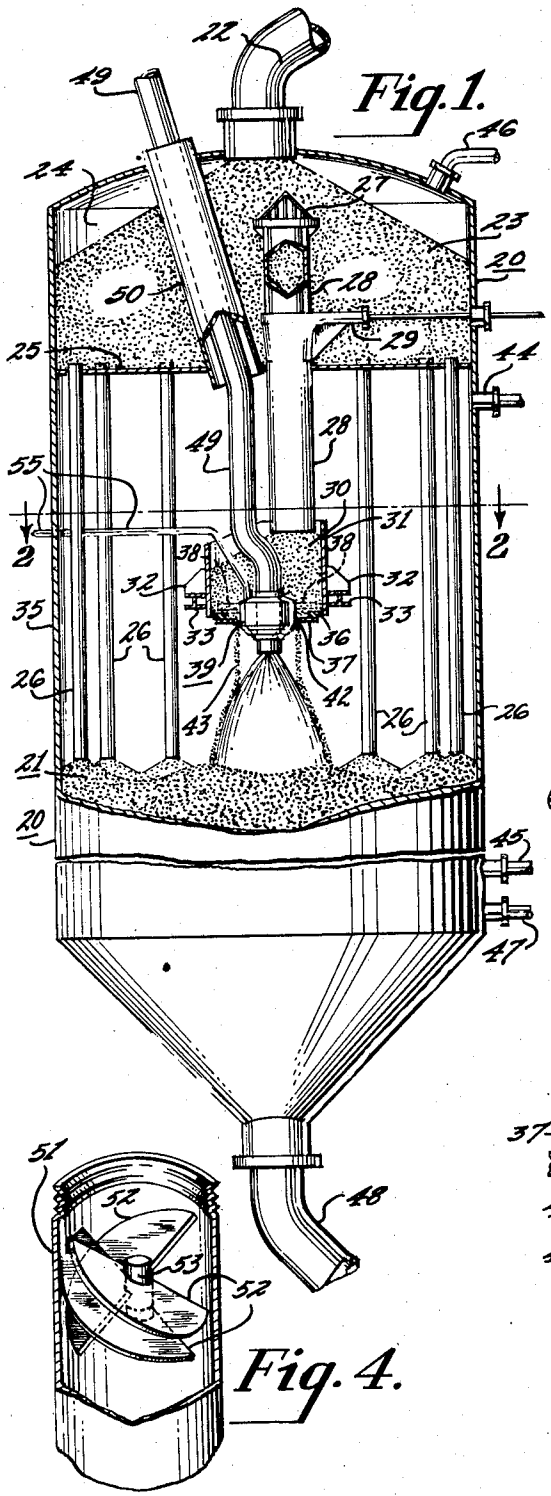


Fig. 2.

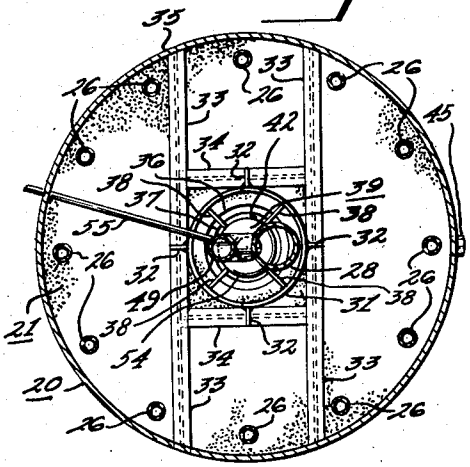


Fig. 3.

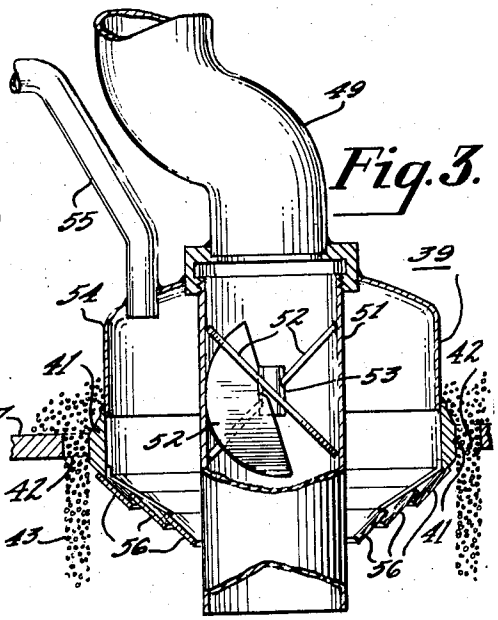


Fig. 4.

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Filed May 21, 1954 2 Sheets-Sheet 2

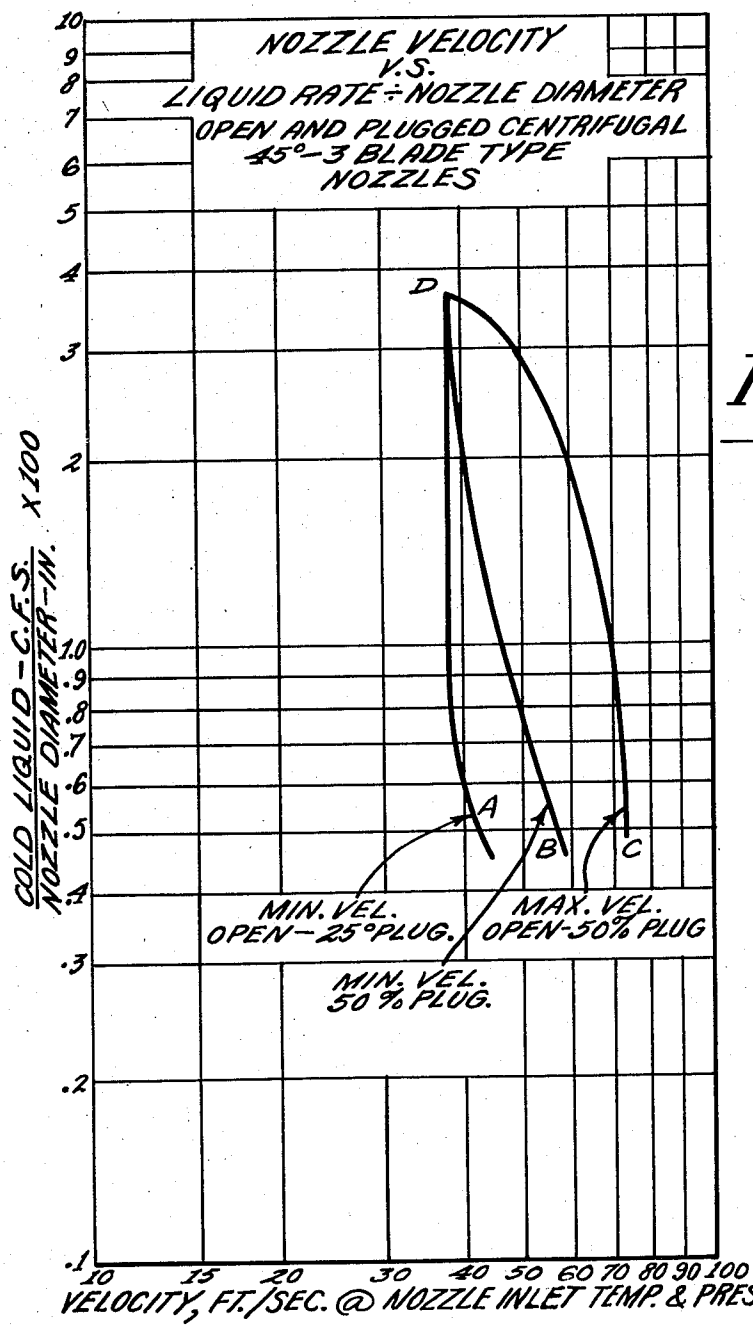


Fig. 5.

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ATTORNEY

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2,906,705

METHOD FOR CONTACTING LIQUID WITH GRANULAR CONTACT MATERIAL

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Application May 21, 1954, Serial No. 431,376

16 Claims. (Cl. 208—167)

The present invention relates to systems and methods for the conversion of liquid hydrocarbons by contacting such hydrocarbons with granular contact material. Typical of the conversion processes and systems to which the invention is applicable is the cracking of relatively high-boiling liquid hydrocarbons to gasoline, using granular, adsorptive, hydrocarbon cracking catalyst, or the viscosity breaking or coking of such hydrocarbons, using relatively catalytically-inert granular solids of the type known as heat carriers. This application is a continuation-in-part of my copending application Serial No. 178,778, filed August 11, 1950, now abandoned, for Methods and Apparatus for Contacting Liquid with Granular Contact Material.

The use of higher boiling fractions of the crude oil, such as tar separator bottoms, reduced crudes, heavy fuel oil and the like, as charging stock for the preparation of gasoline and/or light fuel oil presents difficulties because of the ease with which such fractions thermally decompose to form coke, whether or not volatile cracked products are also formed. For example, many of such fractions coke up the tubes of heating furnaces when heated to temperatures of 850° F. or higher and, hence, even if vaporizable at temperatures of 900° to 1000° F., cannot be handled as vapor, because such practice would result in frequent shut-down of the heating equipment. As a consequence, it has been the practice to contact such charging stocks in liquid form with hot granular contact material so as to convert the liquid hydrocarbons to volatile products, with attendant formation of a hydrocarbonaceous deposit including heavy, non vaporizable hydrocarbons, on the contact material. The hydrocarbonaceous deposit on the contact material generally further decomposes during the conversion period to form additional volatile hydrocarbons and coke, the latter being removed by combustion with an oxygen-containing gas during a subsequent regenerating operation.

However, when the aforementioned charging stocks and other liquid charges, such as, virgin or cracked light gas oils and naphthas, contact reactor walls and other metallic surfaces within the reactor which are at hydrocarbon cracking temperatures, the resulting cracking reactions tend to produce a cumulative deposit of coke on such surfaces. Such deposits accrete above the level of solid contact material within the reaction vessel and from time to time break off as large pieces or chunks of coke and fall into the moving contact material. These chunks of coke thereafter interfere with the proper movement of the contact material, even to the point of stopping the flow of contact material out of the reactor. The prior art has diligently and actively sought methods which avoid these difficulties. A commercially successful method is disclosed in U.S. Patent No. 2,520,146 to Reuben T. Savage. It involves the projection of liquid hydrocarbons toward a sheetlike curtain of free-falling particles of granular contact material, which curtain has such density and thickness as to intercept the liquid hydrocarbons directed thereto.

With atomizing nozzles of special design to project the liquid hydrocarbons, such method is successful in effecting contact between liquid hydrocarbons and moving contact material without substantial deposition of coke on the reactor walls.

It was discovered, however, that with a mixed-phase hydrocarbon stream containing varying amounts of vapor, such as are within the necessary range of commercial operation, the conditions of contact changed, with consequent undesirable effects, caused principally by the variable flow of fluid through the nozzle. At excessive nozzle velocities, the falling contact material is outwardly displaced by the liquid, with resultant particle-to-particle and particle-to-wall collision of sufficient impact to cause attrition. At very low nozzle velocities, the liquid fails, at least in part, to reach the curtain and, hence, is not uniformly distributed on the contact material. These difficulties are overcome by the present invention which provides an improved and more flexible method of operation.

In accordance with my invention, I pass a mixed-phase stream of fluid, comprising liquid hydrocarbons and either hydrocarbon vapors or steam, or both, downwardly through a confined separating zone, which may comprise a length of pipe, terminating above the surface of a compact moving bed of contact material maintained in the lower portion of a conversion zone, while imparting rotary motion to said stream, and discharge said fluid from the bottom of said confined zone as a rotating stream so that said liquid hydrocarbons travel downwardly and outwardly in the space between the bottom of said confined zone and the surface of said bed.

In passing downwardly through the confined separating zone, rotary motion is imparted to the mixed-phase stream at a level spaced a substantial distance above the lower end of the confined zone. After rotation has been imparted in the stream, it flows as a gaseous stream surrounded by a centrifugally separated liquid layer through the remaining portion of the confined zone to the point of discharge at its open lower end without substantial diminution of its original flow area, the length of such portion being sufficient to concentrate the liquid into a peripheral layer of uniform thickness. Upon discharge, the rotating layer of liquid hydrocarbons disperses into droplets which are cast outwardly toward the confining walls of the conversion zone. The outwardly moving droplets of liquid hydrocarbons are intercepted by a circumferentially-complete curtain of free-falling particles of contact material concentrically surrounding the discharged mixed-phase stream of fluid. Contact between the liquid and the contact material is effected in the minimum practicable vertical distance, so that the falling particles do not receive a substantial impact upon reaching the surface of the bed. Furthermore, under normal conditions, the lateral velocity of the discharged liquid hydrocarbons is such that the impact of the liquid hydrocarbons on the falling particles of contact material is insufficient to disrupt or to pass through the falling curtain, thereby preventing excessive coke formation on the walls of the reactor.

It has been observed that, within certain limits, there is a relatively wide range in the respective quantities of vapor and liquid which may be introduced in admixture through a given nozzle in accordance with the invention, and that the proportions of vapor and liquid may vary independently, insofar as proper nozzle performance is concerned, regardless of any substantial variation in process conditions in the conversion unit as a whole. It was found that the maximum amount of liquid hydrocarbons that can satisfactorily be introduced in accordance with the invention is a function of the diameter, or circumference, of the confined path. Expressed in

terms of circumference, the ratio of cold liquid (cu. ft./sec.) to nozzle diameter (inches) should be less than 0.040, and preferably less than about 0.0365, regardless of the vapor velocity. It was noted also that with an acceptable ratio of quantity of liquid to circumference of confined path the operable range of vapor velocity was approximately 25 to 75 (and preferably 36 to 65) feet/second. At lower vapor velocities the desired rotary motion and dispersion of the discharging liquid stream could not be obtained, and at higher velocities the liquid tended to penetrate or break up the falling curtain.

Since it is essential to maintain a certain minimum vapor velocity, in those cases where the normal vapor velocity is below such minimum, in a nozzle sized to handle the quantity of liquid present, then either additional vapor in the form of steam may be added ahead of the nozzle or the nozzle may be restricted in the region wherein the rotary motion is imparted.

In a preferred embodiment of the invention, the mixed-phase stream is rotated by a plurality of inclined vanes located within a cylindrical confined zone at a common level spaced at least one zone diameter from the bottom of the cylindrical zone, the vanes and their associated supporting structure being of such configuration as to effect a minimum constriction of the flow path at such level, consistent with the attainment of sufficient vapor or gas velocity to maintain the desired liquid flow. Where the quantity of vapor accompanying the liquid is insufficient to provide at least the minimum practicable vapor velocity, the region occupied by the inclined vanes is centrally obstructed to provide a limited restriction in flow area, with resultant increase of velocity to the desired value.

Fig. 1 is an elevational view, in partial section, of a typical hydrocarbon conversion unit in which a mixed-phase stream comprising liquid hydrocarbons is contacted with granular contact material in accordance with the present invention;

Fig. 2 is a horizontal section of Fig. 1 taken along the line 2—2;

Fig. 3 is an enlarged fragmentary view, in partial section, of the central portion of Fig. 1, showing the details of the mixed-phase hydrocarbon feed nozzle;

Fig. 4 is an enlarged fragmentary isometric view, in partial section, showing the arrangement of the device for imparting rotary motion to the mixed-phase hydrocarbon stream passing through the feed nozzle; and

Fig. 5 is a chart which may be used as a basis for the design of mixed-phase feed nozzles for moving bed hydrocarbon conversion systems.

Referring to the drawing, Fig. 1 shows a vessel or housing, indicated generally at **20**, comprising a contact chamber or zone containing solid particles of hydrocarbon cracking catalyst, or other contact material, in the form of a downwardly moving compact bed, indicated generally at **21**.

The catalyst particles, ranging in size from about 0.05 to about 0.5 inch in average diameter, and comprising freshly regenerated solid hydrocarbon cracking catalyst, such as granular acid-activated montmorillonite clay, synthetic silica-alumina gel in pellet or bead form, or other solid refractory compositions known to those skilled in the art to be hydrocarbon cracking catalysts, are introduced into the upper end of vessel **20** through conduit **22**. The introduced catalyst forms a compact moving bed **23** within a storage or sealing chamber **24** located at the top of the vessel, the bed **23** being supported upon a horizontal tube-sheet **25** separating the storage chamber **24** from the contact chamber containing the bed **21**.

A portion of the catalyst in bed **23** is withdrawn from the lower peripheral region thereof through a plurality of elongated conduits or downcomers **26** equispaced along a circumference concentric to the axis of vessel **20** and is deposited directly onto the surface of bed **21** constituting the main reaction zone.

The remaining, and preferably major, portion of the catalyst in bed **23**, such as from 50 to 90 percent thereof, is withdrawn through a grating **27**, covering the upper end of a relatively-large withdrawal conduit or downcomer **28** located adjacent to the axis of vessel **20**, and then through conduit **28**, provided with a shut-off slide valve **29**, to the surface of a relatively-small compact moving bed **30** supported axially within the reaction chamber at an intermediate level between the tube-sheet **25** and the surface of bed **21**.

Conduits **26** serve to maintain a fixed level of catalyst in bed **21**, the upper surface of which bed is determined by the level of the lower ends of conduit **26**. It is to be understood, however, that the invention is not limited to partial withdrawal of the catalyst from bed **23** through peripheral conduits. If desired, conduits **26** may be omitted and all the catalyst transferred from bed **23** to bed **21** may pass through conduit **28**, provided the level of bed **21** is controlled by other suitable means known to the art.

Bed **30** is laterally confined within a cylindrical receptacle **31** having externally secured thereto a plurality of lugs **32**. Lugs **32** rest upon horizontal support members or beams **33** extending across the contact chamber on each side of receptacle **31** and also upon support members **34** on each side of receptacle **31** normal to the support members **33**.

Flat circular plates or rings **36** and **37**, of different diameters and arranged contiguously in overlapping relation, partially close the lower end of receptacle **31**, leaving a central opening to receive a gas-liquid or mixed phase hydrocarbon introduction device. Radial bar members **38**, resting upon the uppermost ring **36**, support the hydrocarbons introduction device, generally indicated at **39**, concentrically within the receptacle **31**. A ring **41** secured about the receptacle **31** at the level of ring **37** defines an annular metering passageway **42** with the inner edge of the latter.

Annular passageway **42** has a smaller flow area than conduit **28** and its associated grating **27**, thereby assuring the formation of a continuous compact moving mass of catalyst extending from the annular passageway **42** upwardly through receptacle **31** to conduit **28**, and through conduit **28** into the bed **23**.

The width and area of passageway **42** is such that a thick, dense, sheetlike curtain **43** of catalyst particles discharges therefrom and falls freely and unobstructedly to the surface of bed **21**. While falling, the catalyst particles are contacted with liquid hydrocarbons in a manner hereinafter to be described. The particles of catalyst are at a temperature substantially higher than the temperature of the hydrocarbons, such as about 50–500° F. higher. Since the hydrocarbons are usually at a temperature in the range of about 400–850° F., a considerable portion of the liquid hydrocarbons in the mixed-phase charge stream is vaporized upon contact.

The hydrocarbon vapors initially present in the mixed-phase charge stream and the hydrocarbon vapors formed by contact of the liquid components of the charge stream with the hot catalyst, together with any additional gaseous material which may be introduced into the reaction chamber, such as hydrocarbon vapors introduced at the upper end of the chamber through inlet **44**, pass downwardly through reactor bed **21**, and the resultant gaseous reaction products are disengaged from the catalyst bed at the bottom of the reaction chamber in known manner and apparatus, not shown. The disengaged gaseous reaction products are withdrawn from vessel **20** through conduit **45** for appropriate processing for the production of gasoline and/or light fuel oil and other products.

The hydrocarbon vapors are prevented from flowing upwardly out of the reaction chamber by the introduction of an inert gaseous sealing medium, such as steam, flue gas, and the like, into the storage or sealing chamber **24** through conduit **46** at a pressure slightly higher than the

pressure within the reaction chamber. A portion of the sealing gas flows upwardly through the compact moving column of catalyst in conduit **22**, while the remainder flows through the compact moving columns of catalyst in conduits **26** and **28**.

The catalyst particles, still flowing as a compact mass, are thereafter passed downwardly through a purging zone in the lower region of vessel **20** where they are contacted countercurrently with a non-oxidizing purging gas, such as steam, flue gas, etc., introduced into the vessel through conduit **47** and distributed throughout the catalyst mass by known gas-distributing means, not shown.

The purging gas, in passing upwardly through the descending catalyst mass, displaces any remaining gaseous hydrocarbons and prevents their migration out of the vessel with the purged catalyst. The purged catalyst, containing a deposit of coke formed thereon within the reaction zone, is withdrawn from the bottom of vessel **20** through conduit **48** and is passed to a regeneration vessel or zone, not shown, wherein the coke deposit is removed by combustion in the presence of oxygen-containing gas, following which the regenerated catalyst is returned to the upper end of vessel **20** for recirculation.

The liquid-containing or mixed phase hydrocarbon charge stream is introduced into vessel **20** through conduit **49** which enters the top of the vessel and passes downwardly through storage chamber **24** and tube-sheet **25** into the reaction chamber. The conduit then passes downwardly into receptacle **31** and is connected to the upper end of the gas-liquid introduction device **39**. To avoid overheating of the mixed phase charge stream by indirect heat exchange with the hot regenerated catalyst in bed **23**, the portion of conduit **49** passing through storage chamber **24** is provided with an insulating sleeve **50**. If desired, conduit **49** may be admitted to the reaction chamber through the side of vessel **20**, that is, without passing through chamber **24**.

In the particular embodiment of the invention illustrated in the drawing the lower or discharge end of conduit **49** is joined to the upper end of a mixed-phase hydrocarbon feed nozzle **51** in the form of a short cylindrical member having inlet and outlet ends of equal flow area. The lower end of nozzle or conduit **51** terminates a short distance axially below the lower end of annular catalyst metering passageway **42**. If desired, nozzle **51** may be omitted, and conduit **49** may have its lower end portion adapted and arranged to serve as the nozzle. Preferably, the nozzle is separate and detachable from the conduit **49** in order to facilitate its removal for the purpose of cleaning, repair or replacement.

Nozzle or conduit **51** is provided with a plurality of internal inclined vanes or baffles, such as the semi-elliptical vanes **52**, so arranged as to impart an axial rotation to the mixed-phase stream at a level within the nozzle sufficiently remote from the lower end thereof to permit the multiple streams resulting from the splitting of the mixed-phase stream in the vaned portion of the nozzle to reform into a single stream comprising a rotating peripheral layer of liquid surrounding a core of gaseous material, the liquid layer being circumferentially continuous and of substantially uniform thickness.

Referring to Figs. 3 and 4 of the drawing, I have shown three semi-elliptic vanes **52** secured along their curved edges, as by welding, in contiguous relation to the inner walls of the nozzle. The vanes **52** are inclined at an angle of from 20° to 70°, and preferably about 45°, to the horizontal and are positioned at uniform angular spacing about the axis of the nozzle. The vanes are notched at the center of their straight edge in order to receive a short circular rod **53**, to which they are attached for the purpose of providing rigidity. The rod **53** is normally of minimum diameter consistent with the attainment of the required rigidity. For process reasons, as aforementioned in connection with the necessity for providing sufficient velocity of the gaseous stream to effect the desired flow of liquid from the nozzle, rod **53** may be of a diameter sufficient to provide a substantial constriction of the flow area of the nozzle within the region wherein the rotation is imparted. In any case, sufficient distance of unobstructed or undiverted flow is provided in the lower end of the nozzle to assure that the liquid will have sufficient time to form into a liquid layer of uniform thickness. To achieve such flow, the vanes are placed at least one nozzle diameter, and preferably not more than 1½ nozzle diameters, above the lower end of the nozzle.

Referring to Fig. 3, device **39** comprises a shell or housing **54** of greater diameter than nozzle **51** and concentrically surrounding and enclosing all but the lowermost portion thereof. The enclosed annular space between members **51** and **54** provides a chamber into which steam or other inert gas supplied from an external source is introduced through conduit **55**.

The lower end of housing **54** converges downwardly and is louvered, as at **56**, so as to direct the steam or other gas discharging from the chamber toward the lower outer periphery of nozzle **51**, thereby maintaining the exposed lower end of the nozzle relatively free from contact with hydrocarbon vapors and particles of liquid hydrocarbons, and consequently tending to prevent the formation of a deposit of coke thereon.

Referring to the hydrocarbon charge stock to be introduced through conduit **49**, the boiling range of the particular charge stock is immaterial. While, generally, a mixed-phase charge stock comprising a liquid fraction of hydrocarbons having a boiling range above 850° F. may be provided, it is to be understood that the invention is in no way limited thereto. If desired, the liquid fraction of the hydrocarbon charge stock may consist of relatively light hydrocarbons.

For example, the charge stock may comprise liquid hydrocarbons obtained from straight-run or virgin material, or from hydrocarbon material that has been thermally or catalytically cracked. Or it may comprise light fuel oil or heavy naphtha. The gaseous fraction may comprise hydrocarbon vapors obtained from the same source as the liquid hydrocarbons, as where a wide-cut portion of crude oil is heated to produce both liquid and gaseous components, or the liquid and gaseous portions of the charge stock may be derived from separate sources. The gaseous material may, for example, comprise propane or butane obtained from the same conversion unit or from a separate unit. The gaseous material may comprise also any gas which is readily available, cheap, and unreactive with hydrocarbons, such as, steam, flue gas, nitrogen, etc., or it may comprise mixtures of gaseous hydrocarbons and unreactive gas. Furthermore, the gaseous and the liquid fractions may be obtained at different temperatures from different sources, and may be blended or admixed before being introduced through conduit **49**, with or without pre-heating.

It is a feature of the invention that the nozzle is capable of successful operation despite process fluctuations in other portions of the system which may change the characteristics of the charge stock, thus providing a considerable measure of flexibility in the system as a whole.

As the stream of gaseous and liquid material flows downwardly through nozzle **51** it is caused to follow a helical path by the vanes **52**, thereby imparting a rotation to the mixed-phase stream and effecting a centrifugal separation of the gaseous and liquid components. After passing through the vaned portion of the nozzle the liquid component becomes concentrated in the peripheral region of the stream and collects as a liquid film or rotating cylinder of liquid on the internal side walls of the cylindrical nozzle **51**. The separated gaseous portion of the stream flows axially within the rotating cylinder of liquid. As stated, the distance of travel from the vaned portion of the nozzle to its lower end is sufficient for the gas stream to straighten out its lines of flow.

While there is a slight increase in velocity of the moving stream as it passes through the vaned region of the nozzle, by reason of the diminution of its flow area by the vanes **52** and the rod **53**, such velocity increase is held to a minimum by making the vanes **52** and the rod **53** as thin as possible. In those cases, however, where the quantity of gaseous material is insufficient to obtain a velocity of flow within the aforementioned practicable limits, the rod **53** is increased in diameter so as to temporarily obtain the gas velocity necessary for complete centrifugal separation of the liquid material through constriction of the flow area of the nozzle.

The stream of material discharging from the lower end of nozzle **51** has inner and outer regions of different physical characteristics, containing different components of the original charge. The outer region of the stream contains a rotating cylinder or annular stream of liquid hydrocarbons which, immediately upon release from confinement by the walls of nozzle **51**, disperses into droplets of liquid hydrocarbons. The droplets of liquid hydrocarbons travel downwardly and outwardly at relatively low velocity toward the surface of bed **21** and are intercepted by the particles of catalyst in the falling curtain **43**. The inner region of the discharge stream contains the gaseous material which expands immediately upon release from the nozzle and, in some slight measure, assists the outward movement of the liquid particles.

In any event, the outward movement of the dispersed liquid particles is at such low velocity that the impact force exerted by the liquid against the catalyst particles is insufficient to cause serious disruption of the curtain and migration of the liquid to the walls and other exposed structural surfaces within the vessel **20**. Contact between the falling curtain of catalyst particles and the outwardly directed spray of liquid hydrocarbons is such as to produce a relatively uniform distribution of the liquid upon the falling catalyst.

While the flow of gaseous material accompanying the liquid hydrocarbons through nozzle **51** may be quite substantial, and its velocity of discharge from the nozzle correspondingly high, there is little adverse effect upon either the discharging stream of liquid hydrocarbons or the falling curtain of catalyst particles because the gaseous material flows axially from the discharge end of the nozzle through a relatively wide opening having a flow area at least as great as the total flow area of the mixed-phase stream as it passes through the vaned or baffled portion of the nozzle.

In commercial practice it has been found desirable to maintain a relatively-short vertical distance, consistent with good coverage and distribution of the liquid, between the lower end of the annular catalyst metering zone **42** and the surface of the catalyst bed. In general, such desirable spacing would be approximately in the range of 1 to 5 feet. By reason of such arrangement the distance through which the catalyst particles fall freely is such that their velocity upon reaching the surface of the bed is not great enough to cause excessive attrition as a result of particle-to-particle impact.

A series of tests was carried out for the purpose of determining a basis for the design of mixed-phase feed nozzles for commercial moving-bed catalytic cracking units. The nozzles tested were all of the centrifugal type disclosed herein, and they comprised short pipe sections sized at various diameters between 2 and 8 inches, with approximately a 3 to 1 ratio of length to diameter. Nozzles of constant internal diameter were employed, and some were provided with an internal constrictor ring at the discharge end to determine whether such arrangement would provide better liquid distribution. To obtain centrifugal flow, thin inclined semielliptic vanes or blades were secured at uniform angular spacing and at a common level within the nozzle. Two, three, and four-vane nozzles, with the vanes or blades inclined at an angle of 45° and overlapping each other in vertical projection, were tested. Basic or open-type nozzles were internally unobstructed except for the diminution in flow area provided by the thickness of the plurality of thin vanes. Modified or plugged-type nozzles, also tested, had cylindrical plugs or cores axially positioned in the vaned section of the nozzle. The plugs were sized to obstruct 25%, 50%, and 75%, respectively, of the nozzle flow area. Flat, hemispherical, and pointed (60° included angle) shapes were each employed at the ends of the plugs. The vaned section was placed at various levels between the ends of the nozzle.

As to the cylindrical curtain of free-falling catalyst surrounding the nozzle and its spray discharge, curtains having a thickness in the range of 0.75–2.00 inches and having an outside diameter in the range of 27–36 inches were tried.

In all tests, the fluid stream consisted of a mixture of liquid and gas simulating a fluid stream of hydrocarbon liquid-vapor, plus steam. The flow of fluid across the nozzle in all cases was such as to produce a pressure drop not exceeding 7 p.s.i.

To test the effect of feed-pipe size the fluid was supplied to the nozzles from feed pipes having flow areas both larger and smaller than the flow areas of the nozzles.

A visual basis for determining spray acceptability was obtained by test with a catalyst curtain. A spray of even distribution with relatively-fine drop size, but without sufficient kinetic energy to penetrate or disrupt the curtain of free-falling catalyst, was considered acceptable. On the other hand, even though a spray was satisfactory as to velocity considerations, if it produced relatively large-size droplets of liquid it was not considered acceptable. The optimum spray was considered to be of fine droplet size, uniformly distributed about the nozzle and evenly and completely deposited on the catalyst curtain.

From the foregoing tests, and measured on the above-mentioned basis, it was determined that:

A 3-blade 45° pitch nozzle, with 120° angular spacing and 60° overlap of the blades, produces the most desirable spray, and the optimum position for the blades or vanes is about 1 to 1½ nozzle diameters above the nozzle outlet. Greater spacing from the discharge end merely increases the overall length of the nozzle without appreciable improvement in the spray characteristics, while lesser spacing results in relatively poor liquid distribution around the periphery of the spray.

Internal axial plugs centrally blocking up to 50% of the nozzle flow area may be utilized without adverse effect upon the spray pattern or liquid distribution. Both open and plugged nozzles produce desirable hollow-cone sprays which are comparable in all respects. The plugged-type nozzle has substantially the same liquid throughput capacity as the open-type, but permits the desired characteristics of discharge to be obtained with a smaller quantity of gaseous material.

The maximum allowable vapor velocity varies with the liquid load per unit of nozzle diameter, whereas the minimum allowable vapor velocity is fairly constant at about 35 to 40, such as about 38, feet per second.

The centrifugal-type nozzles are characterized by a relatively-low operating pressure drop, such as up to about 5–10 p.s.i., and nozzle operation is generally best along the line of maximum nozzle velocity. Above the line of maximum nozzle velocity, undesirable penetration or disruption of the falling catalyst curtain may occur.

The size of the mixed-phase fluid feed line with respect to the size of the nozzle affects the nozzle operation. While a feed pipe having a flow area larger than the flow area of the nozzle has substantially no effect upon the maximum allowable nozzle velocity, a feed pipe appreciably smaller than the nozzle has a pronounced effect, particularly for nozzles up to 25% plugged. The

minimum allowable nozzle velocity is not appreciably affected. While it is possible that such effect becomes less pronounced with substantial increase in pipe and nozzle sizes, it is preferred that the feed-pipe flow area and the nozzle flow area be approximately the same, at least for a distance of several pipe diameters above the nozzle.

The centrifugal-type nozzle is characterized by relatively-low operating pressure drop. Whereas nozzles of the type which attain atomization of the liquid as a result of high velocity flow through restricted orifices or slots commonly have an operating pressure drop in the order of 60 to 150 p.s.i., centrifugal nozzles have an operating pressure drop in the order of less than 10 p.s.i.

What is claimed is:

1. In a hydrocarbon conversion process wherein liquid and vaporous hydrocarbons are converted in the presence of a compact moving bed of granular contact material which gravitates through a conversion zone and is continuously replenished by particles of said material introduced downwardly into said zone as an annular curtain of solids falling freely onto the surface of said bed, the method for contacting said particles with said liquid hydrocarbons which comprises the steps of: passing a mixed-phase stream of fluid comprising said liquid hydrocarbons downwardly along a straight, non-tapered confined path within said conversion zone, which path, except for an intermediate portion spaced at least one path diameter from the lower end thereof, is of substantially uniform flow area throughout its length; flowing said mixed-phase stream helically along said intermediate portion to cause the liquid component of said stream to rotate about the axis of said path, the centrifugal force of said rotation causing said liquid to flow along the remaining lower end portion of said confined path as a rotating circumferentially-complete annular stream having a hollow substantially liquid-free central portion forming an unobstructed flow path for the vaporous portion of said mixed-phase stream; and discharging said mixed-phase stream of hydrocarbons axially downward at an upper central location within said falling curtain of granular material, whereby said discharged annular rotating stream of liquid is directed downwardly and outwardly from the lower perimeter of said confined path toward said annular curtain as an expanding hollow stream of dispersed liquid droplets which are substantially entirely intercepted by the falling granular material before the latter reaches the surface of said bed.

2. The method as defined in claim 1, wherein said rotary motion is imparted to said fluid by flowing the latter along said intermediate portion of the vertical confined path as a plurality of separate parallel streams of equal flow area, said parallel streams being directed along substantially helical paths disposed about the longitudinal axis of said confined path.

3. A method as defined in claim 2 in which said parallel streams are three in number, at a angular spacing of 120°.

4. The method as defined in claim 1, in which said fluid comprises gaseous material, and characterized in that said gaseous material is separated from said liquid hydrocarbons by said rotation and is conveyed centrally within said rotating annular stream of liquid hydrocarbons.

5. The method as defined in claim 4, in which said gaseous material comprises steam.

6. A method as defined in claim 1 in which said stream of fluid is partially in gaseous phase, and in which said rotary motion is imparted to said fluid by flowing the latter along said intermediate portion of the vertical confined path as a plurality of separate parallel streams of equal flow area, said parallel streams being directed along substantially helical paths disposed uniformly about the longitudinal axis of said confined path, said separate paths being contiguous to the envelope of said confined path and having a total flow area of from slightly less than to 50% of the total flow area of said confined path, the reduction in flow area between said confined path and the total of said separate helical paths being such as to assure a vapor velocity greater than 35 ft./sec. within said vertical confined path.

7. A method as defined in claim 6 in which the velocity of discharge from said vertical confined path is the maximum consistent with the formation of a discharging liquid spray of fine droplet size and uniform peripheral distribution without appreciable formation of mist.

8. A method as defined in claim 7 in which said fluid is supplied to said vertical confined path in such manner that the introduction of fluid thereto is effected without appreciable reduction in the velocity of the fluid stream.

9. A method as defined in claim 8 wherein said total flow area of said separate confined streams is such as to achieve a vapor velocity within the envelope defined by lines AD and CD of the chart in the accompanying drawings, in which chart the log of the liquid throughput per inch of diameter of said confined path is plotted as a function of the log of the velocity of the total material therein, the curve AD of said chart representing the limit of minimum discharge velocity for values of said reduction in flow area up to 25%, the curve BD representing the limit of minimum discharge velocity at 50% reduction in flow area, and the curve CD representing the limit of maximum discharge velocity for reductions in flow area up to 50% of the total area of said confined path.

10. In apparatus for the conversion of mixed-phase hydrocarbons in the presence of a compact moving bed of granular contact material contained within a reactor vessel including means for introducing said contact material downwardly into said vessel as a free-falling annular curtain of particles depositing upon the surface of said bed, the combination therewith of a mixed-phase fluid supply conduit having its discharge end extending axially downward into the space within said falling curtain, said lower end portion comprising a straight, non-tapered cylindrical member; a plurality of inclined vanes uniformly distributed about the axis of said cylindrical member at a common intermediate level therein and at a distance of at least one diameter above the lower end thereof, said vanes being inclined to the axis of said cylindrical member at an angle of about 45°, thereby providing a plurality of helical flow paths at said intermediate level through which the liquid component of a mixed-phase stream is rotated sufficiently to cause said liquid component to flow through the remaining portion of said cylindrical member as a rotating circumferentially-complete annular stream of liquid and be discharged therefrom as an expanding hollow stream of dispersed liquid droplets.

11. Apparatus as defined in claim 10, in which said vanes are positioned a distance from the lower end of said conduit at least equal to the diameter of said conduit.

12. Apparatus as defined in claim 10 including a cylindrical plug member concentrically positioned in the region of said nozzle occupied by said vanes and integral therewith at their lines of intersection, said plug member obstructing the flow of fluid in the central region of said nozzle.

13. Apparatus as defined in claim 12 in which said plug member obstructs up to 50% of the flow area of said nozzle.

14. Apparatus as defined in claim 13 in which said plug member has a length at least equal to its diameter.

15. Apparatus as defined in claim 10 in which said vanes are three in number and have an annular spacing of 120° about the axis of said cylindrical member.

16. Apparatus as in claim 10 in which the flow area of said fluid supply conduit is substantially undiminished

for a distance of at least several conduit diameters above the level of said vanes.

References Cited in the file of this patent

UNITED STATES PATENTS

1,894,696	Lindeman	Jan. 17, 1933
2,296,426	Coutant	Sept. 22, 1942
2,435,605	Rowell	Feb. 10, 1948
2,446,882	Morrison	Aug. 10, 1948
2,538,195	Henkel	Jan. 16, 1951
2,636,805	Lassiat et al.	Apr. 28, 1953
2,663,677	Savage et al.	Dec. 22, 1953
2,683,109	Norris	July 6, 1954
2,694,603	Griffin	Nov. 16, 1954
2,786,801	McKinley et al.	Mar. 26, 1957