

Description

The invention relates to an apparatus for the separation of solid and fluid phases.

The invention is concerned particularly with a horizontal cyclone separator whereby the two phases are first separated by a primary mass flow separation, and thereafter, the resultant fluid phase, with a minority of entrained solids, is treated to recover, via secondary centrifugal separation forces, nearly all of the quantity of solids not originally excised by the primary mass flow separation. This invention is further concerned with any process in which solid particles necessitate separation from a fluid phase. The most preferred use of this apparatus is in conjunction with a riser reactor or a downcomer reactor employed in a fluid catalytic cracking (FCC) process to selectively channel and segregate solid catalytic particles from gaseous hydrocarbon products or a gasiform phase. Other uses contemplated for this type of apparatus include a pressure feeder device, any device necessitating a stripping function of solid particles or in the preparation of synfuels, such as in a coal gasification process scheme.

In the field of FCC units, the use of zeolite cracking catalysts has evolved which requires short fixed contact times of the catalyst and reactants. Cyclone separation, a well known and crowded art area, has thus taken on a new role in gasoline productivity and catalyst regeneration abilities. Even with current advances in this area, numerous problems regarding rapid vapor/catalyst disengagement remain to be solved.

The advantages of the instant vapor/catalyst disengagement apparatus include a high tolerance of backflow, a lowering of pressure drop throughout the vessel, a light loading in the downstream parts of the cyclonic separator, a high separation efficiency, a short vapor residence time, an ability to handle high solids loading, and possession of a smaller and easier cyclonic separation device to retrofit into existing FCC units. The resultant process benefits derivative of these advantages include a greater gasoline yield, a less pronounced gasoline density gradient, a faster feed vaporization, a lower gas mix and an improved flexibility of operation.

The instant apparatus is designed as an elongated, yet relatively short and stubby, cyclonic separation device which will necessitate much less volume for high temperature reactors and not demand the presence of a great quantity of head room. In fact, 50 to 60% of the head room of a vertical cyclonic separator can be eliminated; a fortiori, the ability to retrofit is readily apparent.

A disadvantage of utilizing a stripping gas in a vessel in open communication with a cyclonic separator is backflow problems of the stripping gas passing up through the cyclonic separator. The use of the instant helical secondary centrifugal separation device, and especially use of the preferred vortex stabilizing unit, will vitiate or at least mitigate ubiquitous backflow problems.

Thus, stripping can occur in this apparatus even with the stripper in open communication with the cyclone separation function. This will eliminate the necessity to use cyclone diplegs to coordinate the separation and the stripping functions of the respective vessels.

A cyclonic separator was disclosed in U.S. Patent 3,392,513 with a spiral inlet portion and exit (for clean gas) with discharge dampers for emptying dust collecting bins which thereby permits continuous operation of the separator. U.S. Patent 4,205,965 describes an apparatus for eliminating dust particles from a gas having a lighter density than the particles. Essentially, the admixture is charged to a bent channel and partially introduced into a whirling chamber which takes advantage of primary eddy flows, circular secondary eddy flows and sink flows. The primary eddy flow is accelerated approximately 300 times the acceleration created by gravity by the combination of a tangential curved wall through the flow channel extending over the entire chamber height. The concentrated sink flow is maintained in the central portion of the whirling chamber and is substantially localized due to suction pipes in communication with operative fans. U.S. Patents 2,103,809 and 1,953,948 disclose an apparatus which utilizes angular velocity of solid particles to separate the same from a gaseous material. Essentially, the gas is charged to a circular flow path in admixture with the solid materials, which during acceleration are transmitted to a trench overlaying a conical funnel. The gases continue throughout the apparatus and exit therefrom through a longitudinal situated outlet port.

In U.S. Patent 3,366,247 a cyclonic apparatus is disclosed wherein solids charged to the cyclone are separated from a gas by imparting to the suspension centrifugal accelerations of the order of 300 to 400 times the acceleration of gravity. A feed inlet pipe communicates tangentially with the separation chamber which contains a tubular vortex finder. The granular materials fall to the bottom of the cyclone separator while an overflow discharge pipe extracts water flow separated from the granular material. In U.S. Patent 3,177,634 an apparatus is disclosed for the recovery of solids from gas in which a deflector cone separates a helical gas stream to cause fluid droplets to be deflected against the wall of the cyclone separator and thereby removal of the fluid gases through louvers situated in a direction opposite in flow from the helical gas motion.

In U.S. Patent 2,888,096 a horizontal centrifugal separator is disclosed wherein primary mass separation and secondary cylindrical separation are utilized within a horizontal cyclone separator (but absent an inclined slot solid dropout means interconnecting the upstream portion of the horizontal cyclone separator and a vertical downcomer attached to the relative opposite end or downstream end of the cyclonic separator). See also U.S. Patent 2,901,420 and DE 2,935,279. In U.S. Patent 4,455,220 catalyst and hydrocarbon

vapors are separated in a vertical cyclone separation zone by use of a vortex stabilizing means which separates the cyclone zone from the stripping zone and allows stripping gas from the stripping zone to be passed upwardly into the cyclone zone countercurrent to the downflow of separated catalyst. This improves both the separation and stripping of the gaseous hydrocarbons from the separated catalyst and reduces the catalyst hydrocarbon contact time, thereby improving gasoline yield and olefin content.

The instant invention is an improvement upon the apparatus of U.S. Patent 4,455,220 because it possesses a higher tolerance for the backflow of stripping gases and eliminates the necessity for a right angle turn atop the riser reactor feeding the applicable cyclonic separation device. In addition, the instant cyclonic separation device attains fast separation of heavy solid loaded-admixtures in the very front part of the cyclone separator, which results in the downstream or secondary centrifugal separator operating in a light load manner despite the initial high inlet loadings of the cyclonic separator. The prior art fails to recognize the combinative primary mass flow and secondary centrifugal separation mechanisms with the inclined slot solid dropout means to pass the majority of the catalyst therethrough to the bottom of a downcomer vertical conduit interconnecting a stripping zone at the other extreme.

The invention, therefore, relates to an apparatus for the separation of solid and fluid phases which comprises

a) a horizontal elongated vessel having a horizontal body comprising a top, a first imperforate sidewall, a bottom and a second perforate sidewall for penetration of a fluid phase outlet withdrawal conduit;

b) an elongated tubular reactor interconnecting a portion of said vessel at a position off center from the parallel center line of said vessel, as defined by a vertical plane through the diameter of said horizontal body, for passage during operation of an admixture of said solid phase admixed with said fluid phase into said horizontal elongated vessel;

c) a downcomer elongated relatively vertical conduit interconnecting said horizontal elongated vessel bottom for passage downward through said downcomer elongated vertical conduit of said solid phase during operation;

d) a fluid phase outlet withdrawal conduit situated in said perforated second sidewall of said vessel juxtaposed to said elongated tubular reactor interconnection with said horizontal elongated vessel for the continuous removal during operation of said fluid phase, wherein the apparatus further comprises

e) an inclined slot solid dropout means interconnecting said bottom of said horizontal elongated vessel at a position juxtaposed to said tubular reactor interconnection with said horizontal elongated vessel bottom and interconnecting said downcomer elongated relatively vertical conduit for the primary mass separation during oper-

ation of said solid phase from said fluid phase by centrifugal acceleration of said solid phase about an angle in said horizontal elongated vessel wherein said solid particles are accelerated against said horizontal body of said horizontal elongated vessel to cause primary separation of said solid phase from said fluid phase and to pass the majority of said solid phase through said inclined slot solid dropout means to said downcomer vertical conduit which interconnects said horizontal elongated vessel bottom at the relatively far end of said horizontal elongated vessel opposite interconnection of said vessel bottom with said elongated tubular reactor for passage of a relatively small amount of said solid phase; and

f) wherein said fluid phase withdrawal conduit, horizontal elongated vessel and said tubular reactor are constructed to insure that the diameter of said fluid phase withdrawal conduit is smaller than the diameter of said horizontal elongated vessel and said off center ingress of said solid and fluid phases into said elongated vessel through the diameter cross-section of said tubular reactor forms a swirl ratio during operation of greater than 0.2 as defined by the tangential velocity of said fluid into said horizontal elongated vessel (U_i) divided by the superficial axial velocity of said fluid through said withdrawal conduit (V_i), wherein

$$\frac{U_i}{V_i} = \frac{R_e}{R_i} \times \frac{1}{F}$$

and wherein

R_e = the radius from the axis of the horizontal cyclone to the center line of said tubular reactor;

R_i = the radius of said fluid withdrawal conduit; and

F = the cross-section area of the tubular reactor divided by the cross-sectional area of the fluid withdrawal conduit,

to form a vortex of said fluid phase in a helical path extending from said first imperforate wall opposite said fluid phase withdrawal conduit and extending in a helical flow path to exit through said fluid phase withdrawal conduit and to cause secondary centrifugal separation and disengagement of entrained solid phase from said fluid phase and thereby passage of said disengaged solid phase to the point of interconnection of said horizontal elongated vessel with said downcomer vertical conduit to pass said disengaged and secondarily separated solid phase downward through said downcomer elongated vertical conduit.

The present invention is elucidated with Figures 1-6,

Figure 1 is a side view of a horizontal cyclone separator of this invention. Figure 2 is a cross-section perspective looking along the lines 2-2 of Figure 1. Figure 3 is a cross-section perspective looking at the short side of the horizontal cyclone separator. Figure 4 is perspective view showing

the opening in the downcomer and the slot solids dropout means. Figure 5 is a side view of a horizontal cyclone separator in interconnection with a downflow tubular reactor. Figure 6 is a cross-section view perspective looking at the short side of the horizontal separator of Figure 5.

Figure 1 demonstrates a side view of a preferred embodiment of this invention. The openings for the inclined slot solid dropout means and the catalyst entry into the downcomer elongated relatively vertical conduit can be seen in Figures 2, 3, 4 and 6. Fluid and solid particles are charged to a riser reactor 3 at the bottom of same for conversion of hydrocarbonaceous materials contained therein to hydrocarbonaceous products of smaller molecular size. After a relatively short and predetermined contact time, it becomes necessary to disengage the hydrocarbonaceous product from the catalytic materials. The horizontal cyclone separator 5 accomplished this disengagement task. The horizontal cyclone separator is comprised of an imperforate top section 7 and an imperforate side member 9 with a second side member 11 being equipped with at least one aperture for penetration of at least one continuous fluid phase withdrawal conduit 13. It is preferred that this fluid phase withdrawal conduit occupies no less than the axial distance intercepted by the inlet to less than or equal that to the edge of downcomer conduit 17. The helical formation pattern of the fluid material will form on sidewall 9 and continue uninterrupted into fluid phase withdrawal conduit 13. It is contemplated and preferred in this invention, but not absolutely necessary, that imperforate side member 9 is equipped with a vortex stabilizer in the shape of a spike or obelisk to guarantee formation and existence of a helical flow of fluid (vapor) material. A minority portion of solid catalyst particles is entrained in the helical fluid flow where secondary centrifugal separation forces act to disengage the solid catalyst particles from the helical-moving fluid phase.

It is necessary to form the instant helical flow path of vaporous or fluid material by maintaining a swirl ratio of greater than 0.2 in the horizontal cyclone separator. This swirl ratio is defined by division of the tangential velocity of the fluids passing into the horizontal vessel by the superficial axial velocity of the fluid through the withdrawal conduit. This ensures the helical vortex of the fluid phase. In furtherance of the fluid mechanics of this swirl ratio, the same is defined by the relationship of:

$$\frac{U_i}{V_i} = \frac{R_e}{R_i} \times \frac{1}{F}$$

wherein

R_e = the radius from the axis of the horizontal cyclone to the center line of the tubular reactor;

R_i = the radius of the fluid withdrawal conduit; and

F = the cross-section area of the tubular reactor

divided by the cross-sectional area of the fluid withdrawal conduit.

A majority of the solid particles are excised from the multiple solid and fluid phases by a primary mass flow separation of the materials. After this separation, a majority of these solids are passed by means of inclined slot solid dropout means 15 interconnecting the bottom of the horizontal cyclone separator and the downcomer vertical conduit 17. This open communication is shown in Figures 2 and 4. Support means 19 are provided in the three-dimensional vessel in order to ensure proper support throughout the total inclined slot solid dropout means. Vortex stabilizer 21 is attached to the imperforate wall of the horizontal cyclone separator, but again, is an optional component of this cyclone separator.

Figure 2, a view alongside 2-2 of Figure 1, shows downcomer vertical conduit 17 communicating with imperforate side 9 which in turn communicates with vortex stabilizer 21. Openings or apertures 31 exemplify suitable catalyst entry means to the downcomer which is in open communication with the bottom of the horizontal cyclone separator. Adequate supports 33 are provided to ensure the integrity of the shown apertures.

Figure 3 demonstrates the primary mass separation flow utilizing the centrifugal acceleration of the solid particles. The fluid and solid materials rise through riser reactor 3 and are passed against the side of horizontal separator 5 in an angular relationship such that catalyst particles are pinned and passed along the sides of the circular cyclonic separator over a passage of 270° before entering inclined slot solids dropout means 15. A portion of entrained catalyst, normally a minority portion, is separated by secondary centrifugal separation and then passed downward through vertical downcomer conduit 17 and into a relatively dense bed of catalyst contained in stripper section 41. Figure 3 also shows entry of the upflow riser reactor at a position off center with respect to the vertical axis of the cyclonic separator. Figure 4 is a perspective view showing the relative openings in the bottom of cyclone separator 51 and intercommunication of same with vertical downcomer 17 via inclined slot solid dropout means 15 (openly communicating via apertures 31 as referred to earlier in Figure 2). A large majority of the solid catalyst particles pass from the horizontal cyclone separator to downcomer 17 by means of inclined slot solid dropout means 15. A minority of the catalyst particles is entrained in the vaporous phase, but will quickly become disengaged by means of the vortex and secondary centrifugal forces existent in the horizontal cyclone separator. This minority share of catalysts pass through vertical downcomer 17 to a stripping bed of catalyst situated in the top of vertical downcomer conduit 17 and in open communication with the horizontal cyclone separator.

The bed of catalyst particles in the bottom of the vertical downcomer is referred to as a rela-

tively dense phase of catalyst. These particles are contacted with a stripping gas, such as steam, to disengage any adsorbed hydrocarbonaceous materials on the surface of the catalyst particles to avoid further coking and thereby ease regeneration operations in the overall FCC system. In stripping steps of the past, extraneous stripping gas, such as steam or nitrogen, would rise from a point near the top or interface of the catalyst bed and, absent a cumbersome baffle or dipleg would flow into the horizontal cyclone separator. However, in this invention utilizing the inclined slot solid dropout means in conjunct interaction with the helical vortex, the stripping gas does not create adverse back flow effects normally encountered as a result of open communication of the stripping zone and the horizontal cyclone separator.

Figure 5 is a side view of an FCC apparatus having a downflow tubular reactor. Communication between the bottom of the horizontal cyclone separator and the vertical downcomer (to the steam stripping section) is very similar to that of Figures 2 and 4 in the upflow riser reactor. In Figure 5, a downflow tubular reactor 100 passes fluid and solid phase materials in a downward direction into the top of horizontal cyclone separator 105. This structure has a top 107 with at least one aperture present for entry of the downflow tubular reactor and at least one perforation in side 109 for insertion of fluid withdrawal conduit 111. Unlike the 270° turn in an annular direction of the catalyst particles in Figure 1, Figure 6 depicts a 90° turn before entry to inclined solids dropout means 121. Imperforate side 113 contains an optional vortex stabilizer 115 in the shape of a truncated cone or obelisk. The same swirl ratio must be maintained at greater than 0.2 in order to formulate the helical flow pattern of vapor initiating at imperforate side 113, containing a vortex stabilizer, and continuing in a horizontal direction in a vortex or cyclical flow path via fluid outlet conduit 111. Catalyst particles are charged to horizontal cyclone separator 105 at an off center location from downflow reactor 100 to inclined slot solids dropout means 121 into the opening of the downcomer 333. The inclined slot solid dropout means 121 is shown with supports 123 in order to provide physical integrity to the overall separation device. It is also contemplated that these supports may be evenly spaced from side to side of the cyclone separator in order to provide better support. A majority of the catalyst particles traverse inclined slot solid dropout means 121, while a minority of the catalyst pass by means of vertical downcomer 151 which also has stripping steam rising therethrough from stripping steam inlet 153 in relatively dense bed 152 of catalyst particles. Both embodiments here have shown one imperforate wall 9 or 13 at an extreme opposite the reactor inlet to the separator and a withdrawal conduit juxtaposed to the reactor inlet to the separator. It is completely within the confines of this invention that the two entities be modified with respect to the reactor

inlet. Imperforate sides 9 and 13 can be placed juxtaposed to the reactor inlet with the vapor withdrawal conduit being positioned at the opposite extreme to the reactor inlet and yet still have an equivalently functioning apparatus. The functioning combination of inclined slot solid dropout means 121 and the vortex formed within the interior of the cyclone separator, prevents or at least mitigates backflow problems resultant from stripping steam rising through the vertical downcomer and into the horizontal cyclone separator. This eliminates the necessity of a dipleg or baffle in any location throughout the cyclone separator unit.

Illustrative Embodiment

In this illustrative embodiment, two FCC apparatus were tested with a horizontal cyclone interconnecting a reactor and a regenerator. The apparatus was constructed of a transparent material so that the catalyst particles and fluid could be observed on a continuing basis from a point extraneous from inside the horizontal cyclone vessel. Fluidized cracking catalyst was used in accompaniment with air (substituted for normal hydrocarbons) and the separatory powers of the horizontal cyclone separator were observed.

Two different embodiments were undertaken, one with and one without a solid slot dropout means such as depicted in Figures 1-6. The first horizontal cyclone/stripper vessel was operated without a solid slot dropout means. A 15 cm diameter horizontal cyclone stripper was tested for pressure drop, solids separation efficiency and mass throughput capacity. This cyclone was fed with air and fluidized cracking catalysts through a 6 cm diameter vertical riser. The riser was connected to the cyclone through a 4 cm wide and 7.5 cm tall inlet of rectangular cross section into the bottom of the horizontal cyclone separator. A quantity of 22.7 kg/min of 76 micron average size catalyst powder was conveyed with 4.25 m³ of air at near ambient temperature and pressure. About 0.17 m³ of stripping air was introduced simultaneously through the bottom of the 15 cm diameter down to simulate a stripping function. The horizontal cyclone exhibited high losses of about 0.5 to 1 kg/min through the vapor overhead conduit and the pressure drop was considerably higher than theoretically predicted.

Visual observations through the transparent side of the first horizontal cyclone/stripper vessel confirmed that excessive catalyst accumulated in the body of the horizontal cyclone because of the combined effect of the weight of the catalyst and the adverse flow of the stripping vapor up through the downcomer from the interface of catalyst particles simulating stripping therein. Various attempts were made to eliminate accumulation of these catalyst particles such as modifying the helical inlet section, modifying the extended vapor outlet conduit and narrowing the tangential inlet to increase inlet velocity. None of these solutions resulted in a viable horizontal cyclone separator.

Unexpectedly, a long cut slot formation into the bottom of the horizontal cyclone separator connecting with the stripper-downcomer greatly reduced pressure drop and also reduced solids lost by a factor of 10^2 to 10^3 . A 2.5 cm wide by 7.5 cm long solids dropout slot was cut into the bottom of the horizontal cyclone separator at a point juxtaposed to the riser reactor inlet to form a second horizontal cyclone/stripper vessel. The slot was connected directly to an opening of the solids downcomer by a 53° inclined chute. This solid slot dropout means is the same as depicted in Figures 1 through 4 of the instant drawings. Selective placement of the solids slot dropout means converted the horizontal cyclone separator from a singular type of separator to a plural two-stage separator. These stages include a first mass flow separation (of a majority of the catalyst particles through the dropout slot) and a second high efficiency centrifugal separation to eliminate entrained catalysts from the vapor via a helical vortex formed in an axial plane relatively parallel to the axial plane of the horizontal cyclone separator. The second horizontal cyclone separator reduced solids lost by a factor of 10^2 to 10^3 to about 2 grams per minute (0.01% weight at solids loading of about 22.6 kg/min) at riser air velocities of 1.0 to 1.8 metre per sec at near ambient temperature and pressure. The pressure drop between the riser inlet and the vapor outlet was reduced to about 10 cm for 1.27 m/sec riser velocity. Losses from the horizontal cyclone/stripper were primarily due to reentrainment by the stripper gas flowing in an upward direction through the vertical downcomer thereby disturbing the separation of the solids from the fluid material.

Several different vortex stabilizers with different geometries were inserted axially through the end of the horizontal cyclone separator opposite that of the vapor outlet conduit. This once again formed an imperforate side to the horizontal cyclone separator with the different vortex stabilizers secured thereto. It was found that the different vortex stabilizers reduced pressure drop 10 to 20% and improved the secondary separation efficiency of the catalyst and fluid phases, especially when the stripping gas flow rate exceeded 8% of the riser gas flow rate.

Several different combinations of the solid dropout slot means were tried with varying widths and lengths. It was determined that the narrowest slots were optimal at low gas and low solid flow rates. Narrow slots were also optimal at high gas flow rates but low solid loadings. Wide slots were found to be optimal for low gas but high solids flow rate. The widest slots were optimal for combined high gas and solids flow rates. As an example, with an 2.5 cm by 28 cm square slot in the 15 cm diameter horizontal cyclone separator with a riser reactor velocity of 1.8 m/sec, more than 0.7 m^3 of adverse stripping air was blown up the downcomer without increasing the magnitude of solid losses above the 10^2 to 10^3 times better efficiency vis-a-vis the first

embodiment (no slot solids dropout means). The cyclone pressure drop with this particular 2.5 cm $\times$ 28 cm slot was 9.4 cm. The mass mean particle diameter of the solid losses was 12 microns versus 76 microns for the circulating solids inventory.

This showing is very important, i.e. most refiners desire to operate at high mass loading conditions. The instant slot solid dropout means, when properly supported and configured in the horizontal cyclone separator acts to greatly reduce the quantity of lost catalyst particles, which would otherwise require an addition to the total catalyst inventory and which, if not removed by other cyclone separation means, would contaminate the vapor products and cause overcracking to undesired vapor and solid byproducts.

Claims

1. An apparatus for the separation of solid and fluid phases which comprises

a) a horizontal elongated vessel having a horizontal body comprising a top, a first imperforate sidewall, a bottom and a second perforate sidewall for penetration of a fluid phase outlet withdrawal conduit;

b) an elongated tubular reactor interconnecting a portion of said vessel at a position off center from the parallel center line of said vessel, as defined by a vertical plane through the diameter of said horizontal body, for passage during operation of an admixture of said solid phase admixed with said fluid phase into said horizontal elongated vessel;

c) a downcomer elongated relatively vertical conduit interconnecting said horizontal elongated vessel bottom for passage downward through said downcomer elongated vertical conduit of said solid phase during operation;

d) a fluid phase outlet withdrawal conduit situated in said perforate second sidewall of said vessel juxtaposed to said elongated tubular reactor interconnection with said horizontal elongated vessel for the continuous removal during operation of said fluid phase, characterized in that, the apparatus further comprises

e) an inclined slot solid dropout means (15) interconnecting said bottom of said horizontal elongated vessel (51) at a position juxtaposed to said tubular reactor (3) interconnection with said horizontal elongated vessel bottom (51) and interconnecting said downcomer elongated relatively vertical conduit (17) for the primary mass separation during operation of said solid phase from said fluid phase by centrifugal acceleration of said solid phase about an angle in said horizontal elongated vessel (5) wherein said solid particles are accelerated against said horizontal body of said horizontal elongated vessel (5) to cause primary separation of said solid phase from said fluid phase and to pass the majority of said solid phase through said inclined slot solid dropout means (15) to said downcomer vertical conduit (17) which interconnects said horizontal elon-

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c) a downcomer elongated relatively vertical conduit interconnecting said horizontal elongated vessel bottom for passage downward through said downcomer elongated vertical conduit of said solid phase during operation;

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gated vessel bottom (51) at the relatively far end of said horizontal elongated vessel (5) opposite interconnection of said vessel bottom (51) with said elongated tubular reactor (3) for passage of a relatively small amount of said solid phase, and

f) wherein said fluid phase withdrawal conduit (13), horizontal elongated vessel (5) and said tubular reactor (3) are constructed to insure that the diameter of said fluid phase withdrawal conduit (13) is smaller than the diameter of said horizontal elongated vessel (5) and said off center ingress of said solid and fluid phases into said elongated vessel (5) through the diameter cross-section of said tubular reactor (3) forms a swirl ratio during operation of greater than 0.2 as defined by the tangential velocity of said fluid into said horizontal elongated vessel (5) divided by the superficial axial velocity of said fluid through said withdrawal conduit (13) wherein

$$\frac{U_i}{V_i} = \frac{R_e}{R_i} \times \frac{1}{F_i}$$

and wherein

Re = the radius from the axis of the horizontal cyclone (5) to the center line of said tubular reactor (3);

Ri = the radius of said fluid withdrawal conduit (13); and

F = the cross-section area of the tubular reactor (3) divided by the cross-sectional area of the fluid withdrawal conduit (13),

to form a vortex of said fluid phase in a helical path extending from said first imperforate wall (9) opposite said fluid phase withdrawal conduit (13) and extending in a helical flow path to exit through said fluid phase withdrawal conduit (13) and to cause secondary centrifugal separation and disengagement of entrained solid phase from said fluid phase and thereby passage of said disengaged solid phase to the point of interconnection of said horizontal elongated vessel (5) with said downcomer vertical conduit (17) to pass said disengaged and secondarily separated solid phase downward through said downcomer elongated vertical conduit (17).

2. An apparatus according to claim 1 wherein said horizontal elongated vessel (5) possesses a vortex stabilizer (21) in attachment with said first imperforate sidewall (9) to stabilize said helical flow of said fluid phase in a direction towards said fluid phase withdrawal conduit (13).

3. An apparatus according to claim 2 wherein said downcomer vertical conduit (17) communicates with a solid phase stripping zone.

4. An apparatus according to claims 1-3 wherein said elongated tubular reactor (3) is substantially vertical.

5. An apparatus according to claim 4 wherein said elongated tubular reactor (3) is an upflow reactor interconnected with the bottom of said horizontal elongated vessel (5).

6. An apparatus according to claim 4, wherein said elongated tubular reactor (3) is a downflow

reactor interconnected with the top of said horizontal elongated vessel (3).

7. Use of an apparatus according to claims 1-6 in a fluid catalytic cracking process for the separation of solid catalytic particles from gaseous hydrocarbon products.

Patentansprüche

1. Vorrichtung zum Trennen von festen und fluiden Phasen mit

a) einem langgestreckten horizontalen Gefäß mit einem horizontalen Körper, der einen Ober- und einen Unter- und eine zweite ungelochte Seitenwand für den Durchtritt einer Auslaß-Abzugsleitung für eine fluide Phase aufweist;

b) einem langgestreckten rohrförmigen Reaktor, der an einen Teil des Gefäßes an einer exzentrisch zu der durch eine Durchmesservertikalebene des horizontalen Körpers bestimmten parallelen Mittellinie des Gefäßes liegenden Stelle anschließt, um während des Betriebes ein Gemenge aus fester und fluider Phase in das langgestreckte horizontale Gefäß zu leiten;

c) einem langgestreckten, relativ vertikalen Fallrohr, welches an den Unter- und einen Teil des langgestreckten horizontalen Gefäßes für den Fallstrom der festen Phase durch das langgestreckte vertikale Fallrohr während des Betriebes anschließt;

d) einer Auslaß- und Abzugsleitung für die fluide Phase, die in der gelochten zweiten Seitenwand des Gefäßes nahe der Verbindung des langgestreckten rohrförmigen Reaktors mit dem langgestreckten horizontalen Gefäß zum kontinuierlichen Abziehen der fluiden Phase während des Betriebes angeordnet ist, dadurch gekennzeichnet, daß die Vorrichtung ferner aufweist

e) eine geneigte schlitzförmige Feststoffausfalleinrichtung (15), welche an den Unter- und einen Teil des langgestreckten horizontalen Gefäßes an einer Stelle nahe dem Anschluß des rohrförmigen Reaktors (3) an den langgestreckten horizontalen Gefäßunter- und einen Teil (51) anschließt und an das langgestreckte, relativ vertikale Fallrohr (17) für die Hauptmassenabscheidung der festen Phase von der fluiden Phase während des Betriebes durch Zentrifugalbeschleunigung der festen Phase um einen Winkel im langgestreckten horizontalen Gefäß (5) anschließt, wobei die Feststoffteilchen gegen den horizontalen Körper des langgestreckten horizontalen Gefäßes (5) beschleunigt werden, damit die Hauptabscheidung der festen Phase von der fluiden Phase erfolgt und der Hauptanteil der festen Phase durch die geneigte schlitzförmige Feststoffausfalleinrichtung (15) in das vertikale Fallrohr (17) strömt, welches an den Unter- und einen Teil (51) des langgestreckten horizontalen Gefäßes an jenem Ende des langgestreckten horizontalen Gefäßes (5), welches dem Anschluß des Gefäßunter- und eines Teiles (51) an den langgestreckten rohrförmigen Reaktor (3) gegenüberliegt, für den Durchtritt einer relativ kleinen Menge der festen Phase anschließt; und



f) wobei die Abzugsleitung (13) für die fluide Phase, das langgestreckte horizontale Gefäß (5) und der rohrförmige Reaktor (3) so konstruiert ist, daß sichergestellt ist, daß der Durchmesser der Abzugsleitung (13) für die fluide Phase kleiner ist als der Durchmesser des langgestreckten horizontalen Gefäßes (5), und der exzentrische Einlaß für die feste und die fluide Phase in das langgestreckte Gefäß (5) über den Durchmesserquerschnitt des rohrförmigen Reaktors (3) während des Betriebes ein Verwirbelungsverhältnis von größer als 0,2 bildet, definiert durch die Tangentialgeschwindigkeit des Fluids in das langgestreckte horizontale Gefäß (5), dividiert durch die oberflächliche Axialgeschwindigkeit des Fluids durch die Abzugsleitung (Vi), worin

$$\frac{U_i}{V_i} = \frac{R_e}{R_i} \times \frac{1}{F},$$

und worin

R_e = der Radius von der Achse des horizontalen Zyklons (5) zur Mittellinie des rohrförmigen Reaktors (3) ist;

R_i = der Radius der Fluidabzugsleitung (13) ist; und

F = die Querschnittsfläche des rohrförmigen Reaktors (3) dividiert durch die Querschnittsfläche der Fluidabzugsleitung (13) ist, um einen Wirbel der fluiden Phase auf einem wendelförmigen Weg zu bilden, der sich von der ersten ungelochten Wand (9) gegenüber der Abzugsleitung (13) für die fluide Phase und auf einem wendelförmigen Strömungsweg zum Austritt durch die Abzugsleitung (13) für die fluide Phase erstreckt, und um eine Sekundärzentrifugalabscheidung und ein Lösen der mitgerissenen festen Phase von der fluiden Phase und dadurch eine Strömung der gelösten festen Phase zum Anschlußpunkt des langgestreckten horizontalen Gefäßes (5) an das vertikale Fallrohr (17) zu bewirken, um die gelöste und sekundär abgeschiedene feste Phase durch das langgestreckte vertikale Fallrohr (17) nach unten zu leiten.

2. Vorrichtung nach Anspruch 1, bei welcher das langgestreckte horizontale Gefäß (5) einen Wirbelstabilisator (21) aufweist, der an der ersten ungelochten Seitenwand (9) befestigt ist, um die wendelförmige Strömung der fluiden Phase in Richtung gegen die Abzugsleitung (13) für die fluide Phase zu stabilisieren.

3. Vorrichtung nach Anspruch 2, bei welcher das vertikale Fallrohr (17) mit einer Strippzone für die feste Phase in Verbindung steht.

4. Vorrichtung nach einem der Ansprüche 1 bis 3, bei welcher der langgestreckte rohrförmige Reaktor (3) im wesentlichen vertikal ist.

5. Vorrichtung nach Anspruch 4, bei welcher der langgestreckte rohrförmige Reaktor (3) ein Steigreaktor ist, der mit dem Unterteil des langgestreckten horizontalen Gefäßes (5) in Verbindung steht.

6. Vorrichtung nach Anspruch 4, bei welcher der langgestreckte rohrförmige Reaktor (3) ein

Fallreaktor ist, der mit dem Oberteil des langgestreckten horizontalen Gefäßes (3) in Verbindung steht.

7. Verwendung einer Vorrichtung nach einem der Ansprüche 1 bis 6 in einem fluidkatalytischen Krackverfahren zum Abscheiden von festen katalytischen Teilchen aus gasförmigen Kohlenwasserstoffprodukten.

Revendications

1. Appareil pour la séparation de la phase solide et de la phase fluide, comportant

a) un récipient horizontal de forme allongée, présentant un corps horizontal comprenant une partie supérieure, une première paroi de face, non perforée, une partie inférieure et une seconde paroi de face perforée, pour permettre la pénétration d'un conduit d'évacuation de la phase fluide;

b) un réacteur tubulaire de forme allongée interconnectant une portion dudit récipient en une position excentrée par rapport à l'axe géométrique parallèle dudit récipient, tel que défini par un plan vertical passant par le diamètre dudit corps horizontal, pour permettre, en fonctionnement, le passage d'un mélange de ladite phase solide mélangée avec ladite phase fluide pour venir dans ledit récipient horizontal de forme allongée;

c) une colonne descendante, relativement verticale, de forme allongée, interconnectant la partie inférieure dudit récipient horizontal de forme allongée pour permettre, en cours de fonctionnement, le passage vers le bas, à travers ladite colonne descendante verticale de forme allongée, de ladite phase solide;

d) un conduit d'évacuation de la phase fluide situé dans ladite seconde paroi de face perforée dudit récipient juxtaposée à l'interconnexion dudit réacteur tubulaire de forme allongée avec ledit récipient horizontal de forme allongée pour permettre, en cours de fonctionnement, l'évacuation continue de ladite phase fluide, caractérisé par le fait que l'appareil comporte en outre

e) un moyen incliné (15), à fente, de chute des produits solides, interconnectant ladite partie inférieure (51) dudit récipient horizontal de forme allongée en une position juxtaposée à l'interconnexion dudit réacteur tubulaire (3) avec ladite partie inférieure (51) du récipient horizontal de forme allongée et interconnectant ladite colonne descendante, relativement verticale, de forme allongée (17), pour provoquer, en cours de fonctionnement, la séparation primaire de masse de ladite phase solide d'avec ladite phase fluide, par accélération centrifuge de ladite phase solide, l'interconnexion se faisant sur un certain angle dans ledit récipient horizontal de forme allongée (5), étant précisé que lesdites particules solides sont accélérées contre ledit corps horizontal dudit récipient horizontal de forme allongée (5) pour provoquer la séparation principale de ladite phase solide d'avec ladite phase fluide et pour faire passer la majorité de ladite phase solide par ledit moyen incliné, à fente, (15), de chute des



produits solides, pour la faire passer dans ladite colonne descendante verticale (17) qui interconnecte le fond (51) dudit récipient horizontal de forme allongée, à l'extrémité, relativement éloignée, dudit récipient horizontal de forme allongée (5) opposée à l'interconnexion du fond (51) dudit récipient avec ledit réacteur tubulaire de forme allongée (3), pour permettre le passage d'une proportion relativement faible de ladite phase solide, et

f) étant précisé que ledit conduit (13) d'évacuation de la phase fluide, ledit récipient horizontal de forme allongée (5) et ledit réacteur tubulaire (3) sont construits de façon que le diamètre dudit conduit (13) d'évacuation de la phase fluide soit inférieur au diamètre dudit récipient horizontal de forme allongée (5) et que ladite entrée excentrée desdites phases solide et fluide dans ledit récipient de forme allongée (5) par la section diamétrale dudit réacteur tubulaire (3) forme, en cours de fonctionnement, un rapport de tourbillonnement de valeur supérieure à 0,2, tel que défini par la vitesse tangentielle (U_i) dudit fluide dans ledit récipient horizontal de forme allongée divisée par la vitesse axiale superficielle (V_i) dudit fluide dans ledit conduit d'évacuation, avec

$$\frac{U_i}{V_i} = \frac{R_e}{R_i} \times \frac{1}{F},$$

et avec

R_e = le rayon allant de l'axe du cyclone horizontal (5) à l'axe géométrique dudit réacteur tubulaire (3);

R_i = le rayon dudit conduit (13) d'évacuation du fluide; et

F = la surface de section droite du réacteur tubulaire (3) divisée par la surface de section droite du conduit (13) d'évacuation du fluide, pour former un tourbillon de ladite phase fluide selon un chemin hélicoïdal s'étendant depuis ladite première paroi non perforée (9) opposée

audit conduit (9) d'évacuation de la phase fluide et s'étendant selon un chemin hélicoïdal pour sortir par ledit conduit (13) d'évacuation de la phase fluide et pour provoquer la séparation centrifuge secondaire et le dégagement de la phase solide entraînée d'avec ladite phase de fluide et, de ce fait, le passage de ladite phase solide dégagée jusqu'au point d'interconnexion dudit récipient horizontal de forme allongée (5) avec ladite colonne descendante verticale (17) pour faire passer ladite phase solide, dégagée et séparée par la séparation secondaire, vers le bas par ladite colonne descendante verticale de forme allongée (17).

2. Appareil selon la revendication 1, dans lequel ledit récipient horizontal de forme allongée (5) possède un stabilisateur de tourbillon (21) fixé à ladite première paroi de face non perforée (9) pour stabiliser ledit flux hélicoïdal de ladite phase fluide en direction dudit conduit (13) d'extraction de la phase fluide.

3. Appareil selon la revendication 2, dans lequel ladite colonne verticale descendante (17) communique avec une zone d'extraction de la phase solide.

4. Appareil selon les revendications 1-3, dans lequel ledit réacteur de forme allongée (3) est sensiblement vertical.

5. Appareil selon la revendication 4, dans lequel ledit réacteur tubulaire de forme allongée (3) est un réacteur à flux montant interconnecté avec la partie inférieure dudit récipient horizontal de forme allongée (5).

6. Appareil selon la revendication 4, dans lequel ledit réacteur tubulaire de forme allongée (3) est un réacteur à flux descendant interconnecté avec la partie supérieure dudit récipient horizontal de forme allongée (3).

7. Emploi d'un appareil conforme aux revendications 1-6 dans un procédé de craquage catalytique d'un fluide pour la séparation des particules catalytiques solides d'avec les produits hydrocarbonés gazeux.

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