

Description

Chemical reaction systems utilizing solids in contact with a gaseous or vaporized stream have long been employed. The solids may participate in the reaction as catalyst, provide heat required for an endothermic reaction, or both. Alternatively the solids may provide a heat sink in the case of an exothermic reaction. Fluidized bed reactors have substantial advantages, most notably an isothermal temperature profile. However, as residence time decreases the fluidized bed depth becomes shallower and increasingly unstable. For this reason tubular reactors employing solid-gas contact in pneumatic flow have been used and with great success, particularly in the catalytic cracking of hydrocarbons to produce gasolines where reaction residence times are between 2 and 5 seconds.

As residence times become lower, generally below 2 seconds and specifically below 1 second, the ability to separate the gaseous products from the solids is diminished because there is insufficient time to do so effectively. This occurs because the residence time requirements of separation means such as cyclones begin to represent a disproportionate fraction of the allowable reactor residence time. The problem is acute in reaction systems such as thermal cracking of hydrocarbons to produce olefins and catalytic cracking to produce gasoline using improved catalysts where the total reactor residence time is between 0.2 and 1.0 seconds. In these reaction systems conventional separation devices may consume more than 35% of the allowable contact time between the two phases resulting in product degradation, coke formation, low yields and varying severity.

In non-catalytic, temperature dependent endothermic reactions, rather than separating the phases, it is possible to quench the entire product stream after the requisite reaction period. However, these solids are usually recycled and are regenerated by heating to high temperatures. A quench of the reactor effluent prior to separation would be thermally inefficient. However, it is economically viable to make a primary separation of the particulate solids before quench of the gaseous stream. The residual solids in the quenched stream may then be separated in a conventional separator inasmuch as solids gas contact is no longer a concern.

In some reaction systems, specifically catalytic reactions at low or moderate temperatures, quench of the product gas is undesirable from a process standpoint. In other cases the quench is ineffective in terminating the reaction. Thus, these reaction systems require immediate separation of the phases to remove catalyst from the gas phase. Once the catalyst has been removed the mechanism for reaction is no longer present.

The prior art has attempted to separate the

phases rapidly by use of centrifugal force or deflection means.

Nicholson U.S. Patent 2,737,479 combines reaction and separation steps within a helically wound conduit containing a plurality of complete turns and having a plurality of gaseous product drawoffs on the inside surface of the conduit to separate solids from the gas phase by centrifugal force. Solids gravitate to the outer periphery of the conduit, while gases concentrate at the inner wall, and are removed at the drawoffs. Although the Nicholson reactor-separator separates the phases rapidly, it produces a series of gas product streams each at a different stage of feed conversion. This occurs because each product stream removed from the multiple product draws offs, which are spaced along the conduit is exposed to the reaction conditions for a different time period in a reaction device which has inherently poor contact between solids and gases.

Ross et al U.S. Patent 2,878,891 attempted to overcome this defect by appending to a standard riser reactor a modification of Nicholson's separator. Ross's separator is comprised of a curvi-linear conduit making a separation through 180° to 240° turn. Centrifugal force directs the heavier solids to the outside wall of the conduit allowing gases that accumulate at the inside wall to be withdrawn through a single drawoff. While the problem of product variation is decreased to some extent, other drawbacks of the Nicholson apparatus are not eliminated.

Both devices effect separation of gas from solids by changing the direction of the gas 90° at the withdraw point, while allowing solids to flow linearly to the separator outlet. Because solids do not undergo a directional change at the point of separation, substantial quantities of gas flow past the withdrawal point to the solids outlet. For this reason both devices require a conventional separator at the solids outlet to remove excess gas from the solid particles. Unfortunately, product gas removed in the conventional separator has remained in intimate contact with the solids, has not been quenched, and is, therefore, severely degraded.

Another drawback of these devices is the limitation on scale-up to commercial size. As conduit diameter increases the path travelled by the mixed phase stream increases proportionately so that large diameter units have separator residence times approaching those of conventional cyclones. Increasing velocity can reduce residence time, but as velocities exceed 18—22.5 m/sec (60 to 75 ft/sec.) erosion by particles impinging along the entire length of the curvilinear path becomes progressively worse. Reduction of the flow path length by decreasing the radius of curvature of the conduit also reduces residence time, but increases the angle of impact of solids against the wall thereby accelerating erosion.

Pappas U.S. Patent 3,074,878 devised a low residence time separator using deflection

means wherein the solid gas stream flowing in a tubular conduit impinges upon a deflector plate causing the solids, which have greater inertia, to be projected away from a laterally disposed gas withdrawal conduit located beneath said deflector plate. Again, solids do not change direction while the gas phase changes direction relative to the inlet stream by only 90° resulting in inherently high entrainment of solids in the effluent gas. While baffles placed across the withdrawal conduit reduce entrainment, these baffles as well as the deflector plate are subject to very rapid erosion in severe operating conditions of high temperature and high velocity. Thus, many of the benefits of separators of the prior art are illusory because of limitations in their efficiency, operable range, and scale-up potential.

It is an object of the separator of this invention to obtain a primary separation of particulate solids from a mixed phase gas-solid stream.

It is also an object of the separator to effect the separation rapidly and with a minimum of erosion.

An additional object of this invention is to provide a separator that obtains essentially complete separation of gas from the solids phase, although a controlled flow of gas with the solids phase is consistent with the operation of the device.

Another object of this invention is to provide a separator to provide essentially complete separation of solids from the mixed phase stream.

A further object is to effect a separation at high temperature and/or high velocity conditions with a minimum of gas product degradation.

Another object of this invention is to provide a method for rapidly attaining a primary separation of solids from a mixed phase gas-solid stream.

These and other objects of this invention will be apparent from an inspection of the specification and figures and claims.

According to the invention, there is provided a solids-gas separator designed to effect rapid removal of particulate solids from a dilute mixed phase stream of solids and gas, the separator comprising a chamber for disengaging solids from the incoming mixed phase stream, said chamber having a mixed phase inlet, a gas phase outlet, and a solids phase outlet, with the inlet at one end of the chamber and the solids outlet at the other end of the chamber, said solids outlet being suitable for downflow of discharged solids by gravity, and the gas outlet therebetween being oriented to effect a 180° change in direction of the gas with respect to the chamber inflow, characterized in that said chamber has rectilinear or slight arcuate longitudinal walls to form a flow path between the inlet and solids outlet which is essentially rectangular in cross section with said inlet and

outlets all being disposed normal to said flow path.

Said flow path may have a height H, which is at least equal to the internal diameter D_i of the inlet, and, additionally, not less than 10.16 cm (4 inches).

The separator may have a mixed phase inlet of inside diameter D_i , a flow path with a preferred width W between 0.75 and 1.25 D_i , and a gas outlet located between the mixed phase inlet and solids outlet at a preferred distance from the inlet which is no greater than 4.0 D_i as measured between their respective centerlines. Such a separator may comprise a secondary solids-gas separator, said secondary separator removing essentially all of the residual solids, a first conduit connecting the gas outlet from the chamber to the secondary separator, a vessel for the discharge of solids, a second conduit connecting said vessel and the chamber, and pressure control means to maintain a height of solids in said second conduit to provide a positive seal between the chamber and vessel.

The invention also comprises a method for separating by centrifugal force particulate solids from a dilute mixed phase stream of gas and solids, the method comprising the steps of adding the mixed phase stream to a chamber having a flowpath of essentially rectangular cross section from an inlet of inside diameter D_i disposed normal to the flow path, said flow path having a height H equal to D_i or 4 inches (10.16 cm) whichever is greater, and a width W greater than or equal to 0.75 D_i but less than or equal to 1.25 D_i , disengaging solids from gas by centrifugal force within said chamber along a bed of solids found at a wall opposite to the inlet as the gas flows through said flow path, the gas changing direction 180° and the solids being projected 90° toward a solids outlet, withdrawing the gaseous portion of the inlet stream from a gas outlet disposed 180° from the inlet, said gas outlet located between the solids outlet and inlet, the gas outlet being at a distance no greater than 4 D_i from the inlet as measured between respective centerlines and withdrawing the solids by gravity through the solids outlet.

The invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a schematic flow diagram of the separator of the present invention as appended to a typical tubular reactor.

Figure 2 is a cross sectional elevational view of the preferred embodiment of the separator.

Figure 3 is a cutaway view through section 3—3 of Figure 2.

Figure 4 is a cutaway view through section 3—3 of Figure 2 showing an alternative geometric configuration of the separator shell.

Figure 5 is a sketch of the separation device of the present invention indicating gas and solids phase flow patterns in a separator not having a weir.

Figure 6 is a sketch of an alternative embodiment of the separation device having a weir and an extended separation chamber.

Figure 7 is a sketch of an alternate embodiment of the separation device wherein a stepped solids outlet is employed, said outlet having a section colinear with the flow path as well as a gravity flow section.

Figure 8 is a variation of the embodiment of Figure 7 in which the solids outlet of Figure 7 is used, but is not stepped.

Figure 9 is a sketch of a variation of the separation device of Figure 7 wherein a venturi restriction is incorporated in the colinear section of the solids outlet.

Figure 10 is a variation of the embodiment of Figure 9 oriented for use with a riser type reactor.

Description of invention

Figure 1 is a schematic flow diagram showing the installation of the separator of the present invention in a typical tubular reactor system handling dilute phase solid-gas mixtures. Solids and gas enter tubular reactor 13 through lines 11 and 12 respectively. The reactor effluent flows directly to separator 14 where a separation into a gas phase and a solids phase stream is effected. The gas phase is removed via line 15, while the solid phase is sent to stripping vessel 22 via line 16. Depending upon the nature of the process and the degree of separation, an inline quench of the gas leaving the separator via line 15 may be made by injecting quench material from line 17. Usually, the product gas contains residual solids and is sent to a secondary separator 18, preferably a conventional cyclone. Quench material should be introduced in line 15 in a way that precludes back flow of quench material to the separator. The residual solids are removed from separator 18 via line 21, while essentially solids free product gas is removed overhead through line 19. Solids from lines 16 and 21 are stripped of gas impurities in fluidized bed stripping vessel 22 using steam or other inert fluidizing gas admitted via line 23. Vapors are removed from the stripping vessel through line 24 and, if economical or if need be, sent to downstream purification units. Stripped solids removed from the vessel 22 through line 25 are sent to regeneration vessel 27 using pneumatic transport gas from line 26. Off gases are removed from the regenerator through line 28. After regeneration the solids are then recycled to reactor 13 via line 11.

The separator 14 should disengage solids rapidly from the reactor effluent in order to prevent product degradation and ensure optimal yield and selectivity of the desired products. Further, the separator 14 operates in a manner that eliminates or at least significantly reduced the amount of gas entering the stripping vessel 22 inasmuch as this portion of the gas product would be severely degraded by remaining in

intimate contact with the solid phase. This is accomplished with a positive seal which has been provided between the separator 14 and the stripping vessel 22. Finally, the separator 14 operates so that erosion is minimized despite high temperature and high velocity conditions that are inherent in many of these processes. The separator system of the present invention is designed to meet each one of these criteria as is described below.

Figure 2 is a cross sectional elevational view showing the preferred embodiment of solids-gas separator 14 of the present invention. The separator 14 is provided with a separator shell 37 and is comprised of a solids-gas disengaging chamber 31 having an inlet 32 for the mixed phase stream, a gas phase outlet 33, and a solids phase outlet 34. The inlet 32 and the solids outlet 34 are preferably located at opposite ends of the chamber 31, while the gas outlet 33 lies at a point therebetween. Clean-out and maintenance manways 35 and 36 may be provided at either end of the chamber 31. The separator shell 37 and manways 35 and 36 preferably are lined with erosion resistant linings 38, 39 and 41 respectively which may be required if solids at high velocities are encountered. Typical commercially available materials for erosion resistant lining include Carborundum Precase Carbofrax D, (Trademark) Carborundum Precast Alfrax 201 (Trademark) or their equivalent. A thermal insulation lining 40 may be placed between shell 37 and lining 38 and between the manways and their respective erosion resistant linings when the separator is to be used in high temperature service. Thus, process temperatures above 1500°F (870°C) are not inconsistent with the utilization of this device.

Figure 3 shows a cutaway view of the separator along section 3—3. For greater strength and ease of construction the separator 14 shell is preferably fabricated from cylindrical sections such as pipe 50, although other materials may, of course, be used. It is essential that longitudinal side walls 51 and 52 should be rectilinear, or slightly arcuate as indicated by the dotted lines 51a and 52a. Thus, flow path 31A through the separator is essentially rectangular in cross section having a height H and width W as shown in Figure 3. The embodiment shown in Figure 3 defines the geometry of the flow path by adjustment of the lining width for walls 51 and 52. Alternatively, baffles, inserts, weirs or other means may be used. In like fashion the configuration of walls 53 and 54 transverse to the flow path may be similarly shaped, although this is not essential. Figure 4 is a cutaway view along Section 3—3 of Figure 2 wherein the separation shell 37 is fabricated from a rectangular conduit. Because the shell 37 has rectilinear walls 51 and 52 it is not necessary to adjust the width of the flow path with a thickness of lining. Linings 38 and

40° could be added for erosion and thermal resistance respectively.

Again, referring to Figure 2, inlet 32 and outlets 33 are disposed normal to flow path 31A (shown in Figure 3) so that the incoming mixed phase stream from inlet 32 is required to undergo a 90° change in direction upon entering the chamber. As a further requirement, however, the gas phase outlet 33 is also oriented so that the gas phase upon leaving the separator has completed a 180° change in direction.

Centrifugal force propels the solid particles to the wall 54 opposite inlet 32 of the chamber 31, while the gas portion having less momentum, flows through the vapor space of the chamber 31. Initially, solids impinge on the wall 54, but subsequently accumulate to form a static bed of solids 42 which ultimately form in a surface configuration having a curvilinear arc 43 of approximately 90°. Solids impinging upon the bed are moved along the curvilinear arc 43 to the solids outlet 34, which is oriented for downflow of solids by gravity. The exact shape of the arc 43 is determined by the geometry of the particular separator and the inlet stream parameters such as velocity, mass flowrate, bulk density, and particle size. Because the force imparted to the incoming solids is directed against the static bed 42 rather than the separator 14 itself, erosion is minimal. Separator efficiency, defined as the removal of solids from the gas phase leaving through outlet 33 is, therefore, not affected adversely by high inlet velocities, up to 45 m/sec (150 ft/sec.) and the separator 14 is operable over a wide range of dilute phase densities, preferably between 0.15 and 35.0 kg/m³ (0.1 and 10.0 lbs/ft³). The separator 14 of the present invention achieves efficiencies of about 80%, although the preferred embodiment, discussed below, can obtain over 90% removal of solids.

It has been found that separator efficiency is dependent upon separator geometry inasmuch as the flow path must be essentially rectangular and the relationship between height H, and the sharpness of the U-bend in the gas flow.

Referring to Figures 2 and 3 we have found that for a given height H of chamber 31, efficiency increases as the 180° U-bend between inlet 32 and outlet 33 becomes progressively sharper, that is, as outlet 33 is brought progressively closer to inlet 32. Thus, for a given H the efficiency of the separator increases as the flow path and, hence, residence time decreases. Assuming an inside diameter D_i of inlet 32, the preferred distance CL between the centerlines of inlet 32 and outlet 33 is less than 4.0 D_i , while the most preferred distance between said centerlines is between 1.5 and 2.5 D_i . Below 1.5 D_i better separation is obtained but difficulty in fabrication makes this embodiment less attractive in most instances. Should this latter embodiment be desired, the separator 14 would probably require a unitary casting design because inlet 32 and outlet 33

would be too close to one another to allow welded fabrication.

It has been found that the height of flow path H should preferably be at least equal to the value of D_i or 10.16 cm (4 inches) in height, whichever is greater. Practice teaches that if H is less than D_i or 4 inches the incoming stream is apt to disturb the bed solids 42 thereby re-entraining solids in the gas product leaving through outlet 33. Preferably H is of the order of twice D_i to obtain even greater separation efficiency. While not otherwise limited, it is apparent that too large an H eventually merely increases residence time without substantive increases in efficiency. The width W of the flow path is preferably between 0.75 and 1.25 times D_i , most preferably between 0.9 and 1.10 D_i .

Outlet 33 may be of any suitable diameter. However, velocities greater than 22.5 m/sec (75 ft/sec) can cause erosion because of residual solids entrained in the gas. The inside diameter of outlet 34 should be sized so that a pressure differential between the stripping vessel 22 shown in Figure 1 and the separator 14 exist such that a static height of solids is formed in solids outlet line 16. The static height of solids in line 16 forms a positive seal which prevents gases from entering the stripping vessel 22. The magnitude of the pressure differential between the stripping vessel 22 and the separator 14 is determined by the force required to move the solids in bulk flow to the solids outlet 34 as well as the height of solids in line 16. As the differential increases the net flow of gas to the stripping vessel 22 decreases. Solids, having gravitational momentum, overcome the differential, while gas preferentially leaves through the gas outlet 33.

By regulating the pressure in the stripping vessel 22 it is possible to control the amount of gas going to the stripper. The pressure regulating means may include a check of "flapper" valve 29 at the outlet of line 16, or a pressure control 29a device on vessel 22. Alternatively, as suggested above, the pressure may be regulated by selecting the size of the outlet 34 and conduit 16 to obtain hydraulic forces acting on the system that set the flow of gas to the stripper 32. While such gas is degraded, we have found that an increase in separation efficiency occurs with a bleed of gas to the stripper of less than 10%, preferably between 2 and 7%. Economic and process considerations would dictate whether this mode of operation should be used. It is also possible to design the system to obtain a net backflow of gas from the stripping vessel. This gas flow should be less than 10% of the total feed gas rate.

By establishing a minimal flow path, consistent with the above recommendations, residence times as low as 0.1 seconds or less may be obtained, even in separators having inlets over 0.9 m (3 feet) in diameter. Scale-up to 1.8 m (6 feet) in diameter is possible in many

systems where residence times approaching 0.5 seconds are allowable.

In the preferred embodiment of Figure 2 a weir 44 is placed across the flow path at a point at or just beyond the gas outlet to establish a positive height of solids prior to solids outlet 34. By installing a weir (or an equivalent restriction) at this point a more stable bed is established thereby reducing turbulence and erosion. Moreover, the weir 44 establishes a bed which has a crescent shaped curvilinear arc 43 of slightly more than 90°. An arc of this shape diverts gas towards the gas outlet and creates the U-shaped gas flow pattern illustrated diagrammatically in line 45 in Figure 2. Without the weir 44 an arc somewhat less than or equal to 90° would be formed, nad which would extend asymptotically toward outlet 34 as shown by dotted line 60 in the schematic diagram of the separator of Figure 5. While neither efficiency nor gas loss (to the stripping vessel) is affected adversely, the flow pattern of line 61 increases residence time, and more importantly, creates greater potential for erosion at areas 62, 63 and 64.

The separator of Figure 6 is a schematic diagram of another embodiment of the separator 14, said separator 14 having an extended separation chamber in the longitudinal dimension. Here, the horizontal distance L between the gas outlet 34 and the weir 44 is extended to establish a solids bed of greater length. L is preferably less than or equal to 5 D_i. Although the gas flow pattern 61 does not develop the preferred U-shape, a crescent shaped arc is obtained which limits erosion potential to area 64. Embodiments shown by Figures 5 and 6 are useful when the solids loading of the incoming stream is low. The embodiment of Figure 5 also has the minimum pressure loss and may be used when the velocity of the incoming stream is low.

As shown in Figure 7 it is equally possible to use a stepped solids outlet 65 having a section 66 co-linear with the flow path as well as a gravity flow section 67. Wall 68 replaces weir 44, and arc 43 and flow pattern 45 are similar to the preferred embodiment of Figure 2. Because solids accumulate in the restricted co-linear section 66, pressure losses are greater. This embodiment, then, is not preferred where the incoming stream is at low velocity and cannot supply sufficient force to expel the solids through outlet 65. However, because of the restricted solids flow path, better deaeration is obtained and gas losses are minimal.

Figure 8 illustrates another embodiment of the separator 14 of Figure 7 wherein the solids

outlet is not stepped. Although a weir is not used, the outlet restricts solids flow which helps form the bed 42. As in Figure 6, an extended L distance between the gas outlet and solids outlet may be used.

The separator of Figure 7 or 8 may be used in conjunction with a venturi, an orifice, or an equivalent flow restriction device as shown in Figure 9. The venturi 69 having dimensions D_v (diameter at venturi inlet), D_{vt} (diameter at venturi throat) and θ (angle of cone formed by projection of convergent venturi walls) is placed in the co-linear section 66 of the outlet 65 to greatly improve deaeration of solids. The embodiment of Figure 10 is a variation of the separator shown in Figure 9. Here, inlet 32 and outlet 33 are oriented for use in a riser type reactor. Solids are propelled to the wall 71 and the bed thus formed is kept in place by the force of the incoming stream. As before the gas portion of the feed follows the U-shaped pattern of line 45. However, an asymptotic bed will be formed unless there is a restriction in the solids outlet. A weir would be ineffective in establishing bed height, and would deflect solids into the gas outlet. For this reason the solids outlet of Figure 9 is preferred. Most preferably, the venturi 69 is placed in co-linear section 66 as shown in Figure 10 to improve the deaeration of the solids. Of course, each of these alternate embodiments may have one or more of the optional design features of the basic separator discussed in relation to Figures 2, 3 and 4.

The separator of the present invention is more clearly illustrated and explained by the examples which follow. In these examples, which are based on data obtained during experimental testing of the separator design, the separator has critical dimensions specified in Table 1. These dimensions (in centimetres except as noted) are indicated in the various drawing figures and listed in the Nomenclature below:

CL	Distance between inlet and gas outlet centerlines
D _i	Inside diameter of inlet
D _{og}	Inside diameter of gas outlet
D _{os}	Inside diameter of solids outlet
D _v	Diameter of venturi inlet
D _{vt}	Diameter of venturi throat
H	Height of flow path
H _w	Height of weir or step
L	Length from gas outlet to weir or step as indicated in Figure 6
W	Width of flow path
θ	Angle of cone formed by projection of convergent venturi walls, degrees

TABLE 1
Dimension of Separators in Examples 1 to 10, centimetres*

Example Dimension	1	2	3	4	5	6	7	8	9	10
CL	9842.5	9842.5	9842.5	9842.5	14922.5	14922.5	27.94	27.94	8.91	8.91
D _i	5.08	5.08	5.08	5.08	5.08	5.08	15.24	15.24	5.08	5.08
D _{os}	4.425	4.425	4.425	4.425	4.425	4.425	10.16	10.16	2.54	2.54
D _{os}	5.08	5.08	5.08	5.08	5.08	5.08	15.24	15.24	5.08	5.08
D _v	—	—	—	—	—	—	—	—	—	5.08
D _{vt}	—	—	—	—	—	—	—	—	—	2.54
H	10.16	10.16	10.16	10.16	10.16	10.16	30.48	30.48	19.05	17.145
H _w	1.906	1.906	1.906	1.906	1.906	1.906	5.718	5.718	0	12.065
L	0	5.08	5.08	0	0	0	0	0	25.4	0
W	5.08	5.08	5.08	5.08	5.08	5.08	15.24	15.24	5.08	5.08
degrees	—	—	—	—	—	—	—	—	—	28.1°

*except as noted

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Example 1

In this example a separator of the preferred embodiment of Figure 2 was tested on a feed mixture of air and silica alumina. The dimensions of the apparatus are specified in Table 1. Note that the distance L from the gas outlet to the weir was zero.

The inlet stream was comprised of 85 ft³/min (2.55 m³/min) of air and 52 lbs/min (23.4 kg/min) of silica alumina having a bulk density of 70 lbs/ft³ (31.5 kg/m³) and an average particle size of 100 microns.

The stream density was 0.612 lbs/ft³ (1 kg/m³) and the operation was performed at ambient temperatures and atmospheric pressure. The velocity of the incoming stream through the 2 inch (5 cm) inlet was 65.5 ft/sec (19.6 m/sec) while the output gas velocity was 85.6 ft/sec (25 m/sec) through a 1.75 inch (4.4 cm) diameter outlet. A positive seal of solids in the solids outlet prevented gas from being entrained in the solids leaving the separator. Bed solids were stabilized by placing a 0.75 inch (1.9 cm) weir across the flow path.

The observed separation efficiency was 89.1% and was accomplished in a gas phase residence time of approximately 0.008 seconds. Efficiency is defined as the percent removal of solids from the inlet stream.

Example 2

The gas-solids mixture of Example 1 was processed in a separator having a configuration illustrated by Figure 6. In the example the L dimension is 2 inches (5 cm); all other dimensions are the same as Example 1. By extending the separation chamber along its longitudinal dimension, the flow pattern of the gas began to deviate from the U-shaped discussed above. As a result residence time was longer and turbulence was increased. Separation efficiency for this example was 70.8%.

Example 3

The separator of Example 2 was tested with an inlet stream comprised of 85 ft³/min (2.4 m³/min) of air and 102 lbs/min (46 kg/min) of silica alumina which gave a stream density of 1.18 lbs/ft³ (17 kg/m³) or approximately twice that of Example 2. Separation efficiency improved to 83.8%.

Example 4

The preferred separator of Example 1 was tested at the inlet flow rate of Example 3. Efficiency increased slightly to 91.3%.

Example 5

The separator of Figure 2 was tested at the conditions of Example 1. Although the separation dimensions are specified in Table 1 note that the distance CL between inlet and gas outlet centerlines was 5.875 inches (14.5 cm) or about three times the diameter of the inlet. This dimension is outside the most preferred

range for CL which is between 1.50 and 2.50 D_i. Residence time increased to 0.01 seconds, while efficiency was 73.0%.

Example 6

Same conditions apply as for Example 5 except that the solids loading was increased to 10% lbs./min (46 kg/min) to give a stream density of 1.18 lbs/ft³ (17 kg/m³). As observed previously in Examples 3 and 4, the separator efficiency increased with higher solids loading to 90.6%.

Example 7

The preferred separator configuration of Figure 7 was tested in this Example. However, in this example the apparatus was increased in size over the previous examples by a factor of nine based on flow area. A 6 inch (15 cm) inlet and 4 inch (10 cm) outlet were used to process 472 ft³/min (14 m³/min) of air and 661 lbs/min (297.5 kg/min) of silica alumina at 180°F (96°C) and 12 psig (9 kg/cm²). The respective velocities were 40 and 90 ft/sec (12 and 27 m/sec). The solids had a bulk density of 70 lbs/ft³ (1050 kg/m³) and the stream density was 1.37 lbs/ft³ (50 kg/m³). Distance CL between inlet and gas outlet centerlines was 11 inches (2.75 cm), or 1.83 times the inlet diameter; distance L was zero. The bed was stabilized by a 2.25 inch (5.5 cm) weir, and gas loss was prevented by a positive seal of solids. However, the solids were collected in a closed vessel, and the pressure differential was such that a positive flow of displaced gas from the collection vessel to the separator was observed. This volume was approximately 9.4 ft³/min (.28 m³/min). Observed separator efficiency was 90.0% and the gas phase residence time approximately 0.02 seconds.

Example 8

The separator used in Example 7 was tested with an identical feed of gas and solids. However, the solids collection vessel was vented to the atmosphere and the pressure differential adjusted such that 9% of the feed gas, or 42.5 ft³/min (1.2 m³/min) exited through the solids outlet at a velocity of 3.6 ft/sec. (0.98 m/sec). Separator efficiency increased with this positive bleed through the solids outlet to 98.1%.

Example 9

The separator of Figure 8 was tested in a unit having a 2 inch (5 cm) inlet and a 1 inch (2.5 cm) gas outlet. The solids outlet was 2 inches (5 cm) in diameter and was located 10 inches (25 cm) away from the gas outlet (dimension L). A weir was not used. The feed was comprised of 85 ft³/min (2.5 m³/min) of air and 105 lbs/min (47 kg/min) of spent fluid catalytic cracker catalyst having a bulk density of 45 lbs/ft³ (630 kg/m³) and an average particle size of 50 microns. This gave a stream density of 1.20 lbs/ft³ (18 kg/m³). Gas inlet velocity was 65

ft./sec (19.5 m/sec) while the gas outlet velocity was 262 ft./sec. (87 m/sec). As in Example 7 there was a positive counter-current flow of displaced gas from the collection vessel to the separator. This flow was approximately 1.7 ft.³/min (0.051 m³/min) at a velocity of 1.3 ft./sec (0.39 m/sec). Operation was at ambient temperature and atmospheric pressure. Separator efficiency was 95.01%.

Example 10

The separator of Figure 9 was tested on a feed comprised of 85 ft.³/min (2.5 m³/min) of air and 78 lbs/min (35 kg/min) of spent fluid Catalytic Cracking catalyst. The inlet was 2 inches (5 cm) in diameter which resulted in a velocity of 65 ft./sec (19.5 m/sec) the gas outlet was 1 inch (2.5 cm) in diameter which resulted in an outlet velocity of 262 ft./sec (79 m/sec). This separator had a stepped solids outlet with a venturi in the co-linear section of the outlet. The venturi south was 2 inches (5 cm) in diameter, while the throat was 1 inch (2.5 cm). A cone of 28.1° was formed by projection of the convergent walls of the venturi. An observed efficiency of 92.6% was measured, and the solids leaving the separator were completely deaerated except for interstitial gas remaining in the solids' voids.

Claims

1. A solids-gas separator designed to effect rapid removal of particulate solids from a dilute mixed phase stream of solids and gas, the separator comprising a chamber for disengaging solids from the incoming mixed phase stream, said chamber having a mixed phase inlet (14), a gas phase outlet (15), and a solids phase outlet (16), with the inlet (14) at one end of the chamber and the solids outlet (16) at the other end of the chamber, said solids outlet (16) being suitable for downflow of discharged solids by gravity, and the gas outlet (15) therebetween being oriented to effect a 180° change in direction of the gas with respect to the chamber inflow, characterised in that said chamber has rectilinear or slight arcuate longitudinal walls to form a flow path between the inlet (14) and solids outlet (16) which is essentially rectangular in cross section with said inlet (14) and outlets (15, 16) all being disposed normal to said flow path.

2. The separator of Claim 1 wherein said flow path has a height, H, which is at least equal to the internal diameter, D_i, of the inlet, and, additionally, not less than 10.16 cm (4 inches).

3. The separator of claim 2 having a mixed phase inlet of inside diameter D_i and which is further characterized by a flow path with a width W between 0.75 and 1.25 D_i, and having a gas outlet located between the mixed phase inlet and solids outlet at a distance from the inlet which is no greater than 4.0 D_i as measured between their respective centerlines.

4. The separator of Claim 3 wherein the distance between inlet and gas outlet centerlines is no less than 1.5 D_i but no greater than 2.5 D_i.

5. The separator of claim 3 or 4 wherein the height H of the flow path is twice D_i.

6. The separator of Claim 5 wherein the width S of the flow path is no less than 0.9 D_i but no greater than 1.10 D_i.

7. The separator of claim 3 having a solids removal outlet the first section of which is co-linear with the flow path and the second section normal to the first section, and aligned for down-flow of solids by gravity.

8. The separator of Claim 7, further comprising a flow restriction placed within the co-linear section of the solids removal outlet.

9. The separator of Claim 8 wherein the flow restriction is an orifice.

10. The separator of Claim 8 wherein the flow restriction is a venturi.

11. The separator of claim 1, 2 or 3, further comprising a weir placed across the flow path beyond or at the gas outlet but before the solids outlet.

12. The separator of Claim 1, 2 or 3, having a chamber fabricated of circular cross section, said separator further comprising flow path shaping means whereby the flow path geometry is made essentially rectangular.

13. The separator of claim 12 wherein the shaping means is a lining of a ceramic material placed upon the chamber walls.

14. The separator of claim 12 wherein the shaping means are baffles inserted into the separator chamber.

15. The separator of claim 1, 2 or 3, whose chamber walls are lined with an erosion resistant lining.

16. The separator of claim 1, 2, 3, 6 or 7 whose chamber walls are lined with a thermal insulation lining.

17. The separator of claim 15 further comprising a thermal insulation lining placed between the chamber walls and the erosion resistant lining.

18. The separator of claim 1, 2, 3, 7 or 8 having a chamber whose longitudinal dimension is extended beyond the gas outlet by a length L.

19. The separator of claim 18 whose length L of the chamber extension is less than or equal to 5 D_i.

20. The separator of claim 1, 2, 3 or 7 further comprising a clean-out manway on one or both ends of the separator chamber.

21. The separator of claim 3, further comprising a secondary solids-gas separator, said secondary separator removing essentially all of the residual solids, a first conduit connecting the gas outlet from the chamber to the secondary separator, a vessel for the discharge of solids, a second conduit connecting said vessel and the chamber, and, pressure control means to maintain a height of solids in said second conduit to

ft./sec (19.5 m/sec) while the gas outlet velocity was 262 ft/sec. (87 m/sec). As in Example 7 there was a positive counter-current flow of displaced gas from the collection vessel to the separator. This flow was approximately 1.7 ft.³/min (0.051 m³/min) at a velocity of 1.3 ft./sec (0.39 m/sec). Operation was at ambient temperature and atmospheric pressure. Separator efficiency was 95.01%.

Example 10

The separator of Figure 9 was tested on a feed comprised of 85 ft.³/min (2.5 m³/min) of air and 78 lbs/min (35 kg/min) of spent fluid Catalytic Cracking catalyst. The inlet was 2 inches (5 cm) in diameter which resulted in a velocity of 65 ft./sec (19.5 m/sec) the gas outlet was 1 inch (2.5 cm) in diameter which resulted in an outlet velocity of 262 ft./sec (79 m/sec). This separator had a stepped solids outlet with a venturi in the co-linear section of the outlet. The venturi south was 2 inches (5 cm) in diameter, while the throat was 1 inch (2.5 cm). A cone of 28.1° was formed by projection of the convergent walls of the venturi. An observed efficiency of 92.6% was measured, and the solids leaving the separator were completely deaerated except for interstitial gas remaining in the solids' voids.

Claims

1. A solids-gas separator designed to effect rapid removal of particulate solids from a dilute mixed phase stream of solids and gas, the separator comprising a chamber for disengaging solids from the incoming mixed phase stream, said chamber having a mixed phase inlet (14), a gas phase outlet (15), and a solids phase outlet (16), with the inlet (14) at one end of the chamber and the solids outlet (16) at the other end of the chamber, said solids outlet (16) being suitable for downflow of discharged solids by gravity, and the gas outlet (15) therebetween being oriented to effect a 180° change in direction of the gas with respect to the chamber inflow, characterised in that said chamber has rectilinear or slight arcuate longitudinal walls to form a flow path between the inlet (14) and solids outlet (16) which is essentially rectangular in cross section with said inlet (14) and outlets (15, 16) all being disposed normal to said flow path.

2. The separator of Claim 1 wherein said flow path has a height, H, which is at least equal to the internal diameter, D_i of the inlet, and, additionally, not less than 10.16 cm (4 inches).

3. The separator of claim 2 having a mixed phase inlet of inside diameter D_i and which is further characterized by a flow path with a width W between 0.75 and 1.25 D_i, and having a gas outlet located between the mixed phase inlet and solids outlet at a distance from the inlet which is no greater than 4.0 D_i as measured between their respective centerlines.

4. The separator of Claim 3 wherein the distance between inlet and gas outlet centerlines is no less than 1.5 D_i but no greater than 2.5 D_i.

5. The separator of claim 3 or 4 wherein the height H of the flow path is twice D_i.

6. The separator of Claim 5 wherein the width S of the flow path is no less than 0.9 D_i but no greater than 1.10 D_i.

7. The separator of claim 3 having a solids removal outlet the first section of which is co-linear with the flow path and the second section normal to the first section, and aligned for down-flow of solids by gravity.

8. The separator of Claim 7, further comprising a flow restriction placed within the co-linear section of the solids removal outlet.

9. The separator of Claim 8 wherein the flow restriction is an orifice.

10. The separator of Claim 8 wherein the flow restriction is a venturi.

11. The separator of claim 1, 2 or 3, further comprising a weir placed across the flow path beyond or at the gas outlet but before the solids outlet.

12. The separator of Claim 1, 2 or 3, having a chamber fabricated of circular cross section, said separator further comprising flow path shaping means whereby the flow path geometry is made essentially rectangular.

13. The separator of claim 12 wherein the shaping means is a lining of a ceramic material placed upon the chamber walls.

14. The separator of claim 12 wherein the shaping means are baffles inserted into the separator chamber.

15. The separator of claim 1, 2 or 3, whose chamber walls are lined with an erosion resistant lining.

16. The separator of claim 1, 2, 3, 6 or 7 whose chamber walls are lined with a thermal insulation lining.

17. The separator of claim 15 further comprising a thermal insulation lining placed between the chamber walls and the erosion resistant lining.

18. The separator of claim 1, 2, 3, 7 or 8 having a chamber whose longitudinal dimension is extended beyond the gas outlet by a length L.

19. The separator of claim 18 whose length L of the chamber extension is less than or equal to 5 D_i.

20. The separator of claim 1, 2, 3 or 7 further comprising a clean-out manway on one or both ends of the separator chamber.

21. The separator of claim 3, further comprising a secondary solids-gas separator, said secondary separator removing essentially all of the residual solids, a first conduit connecting the gas outlet from the chamber to the secondary separator, a vessel for the discharge of solids, a second conduit connecting said vessel and the chamber, and, pressure control means to maintain a height of solids in said second conduit to



provide a positive seal between the chamber and vessel.

22. The separator of claim 21 further comprising quench means located in the first conduit.

23. The separator of claim 22 wherein the preferred quench means is a spray nozzle for injection of quench fluid.

24. The separator of claim 21 wherein the chamber has a solids removal outlet the first section of which is co-linear with the flow path and the second section normal to the first section, and aligned for downflow of solids by gravity, said first section being stepped away from the wall of the chamber opposite the inlet.

25. The separator of claim 21, wherein the preferred secondary separation is a cyclone.

26. The separator of claim 21 wherein the pressure balance means is a check valve at the outlet and of the second conduit.

27. The separator of claim 21 wherein the pressure balance means is a pressure control valve on the solids discharge vessel.

28. A method for separating by centrifugal force particulate solids from a dilute mixed phase stream of gas and solids, the method comprising the steps of adding the mixed phase stream to a chamber having a flowpath of essentially rectangular cross section from an inlet of inside diameter D_i disposed normal to the flow path, said flow path having a height H equal to D_i or 4 inches (10.16 cm) whichever is greater, and a width W greater than or equal to $0.75 D_i$ but less than or equal to $1.25 D_i$, disengaging solids from gas by centrifugal force within said chamber along a bed of solids found at a wall opposite to the inlet as the gas flows through said flow path, the gas changing direction 180° , and the solids being projected 90° toward a solids outlet, withdrawing the gaseous portion of the inlet stream from a gas outlet disposed 180° from the inlet, said gas outlet located between the solids outlet and inlet, the gas outlet being at a distance no greater than $4 D_i$ from the inlet as measured between respective centerlines, and withdrawing the solids by gravity through the solids outlet.

29. The method of claim 28 further comprising the step of further separating residual solids from the gaseous portion of the inlet stream removed via the gas outlet in a secondary separator.

30. The method of claim 28, wherein the preferred secondary operation is a cyclone.

31. The method of claim 28, 29 or 30, further comprising the step of stripping solids withdrawn from the solids outlet with inert gas or steam.

32. The method of claim 31 further comprising the step of withdrawing bleed gas with the solids, said bleed gas amounting to no more than 10% of the inlet gas.

Patentansprüche

1. Ein Feststoff-Gas-Ausscheider zum schnellen Abtrennen von Feststoffteilchen aus einem verdünnten Feststoff-Gas-Strom in der Mischphase; der Abscheider enthält eine Kammer zum Abtrennen von Feststoff aus dem einfließenden Mischenphasenstrom; die besagte Kammer besitzt einen Mischphaseneinlaß (14), einen Gasphasenabzug (15) sowie einen Feststoffphasenauslaß (16), wobei sich der Einlaß (14) an einem Ende der Kammer und der Feststoffauslaß (16) am anderen Ende der Kammer befindet; der besagte Feststoffauslaß (16) eignet sich zum Abfließen des abgetrennten Feststoffs mittels Schwerkraft, während der Gasabzug (15) so eingestellt werden kann, daß ein Richtungswechsel des Gases von 180° in Bezug auf den Kammerzufluß erzielt wird; dies wird dadurch charakterisiert, daß die besagte Kammer geradlinige oder leicht gewölbte Längswände besitzt, die einen Strömungsweg zwischen dem Einlaß (14) und dem Feststoffauslaß (16) bilden, mit einem im wesentlichen rechteckigen Querschnitt, wobei der besagte Einlaß (14) und die Auslässe (15, 16) senkrecht zum besagten Strömungsweg angebracht sind.

2. Der Abscheider laut Patentanspruch 1, worin der besagte Strömungsweg eine Höhe H hat, die dem Innendurchmesser D_i des Einlasses zum mindesten gleich ist und, zusätzlich, nicht weniger als 10,16 cm (4 engl. Zoll) mißt.

3. Der Abscheider laut Patentanspruch 2 besitzt einen Mischphaseneinlaß mit einem Innendurchmesser D_i und der außerdem durch einen Strömungsweg mit einer Breite W , die zwischen 0,75 und 1,25 D_i liegt, charakterisiert wird; er hat einen Gasabzug, der sich zwischen dem Mischenphaseneinlaß und dem Feststoffauslaß befindet, mit einem Abstand vom Einlaß, der, gemessen zwischen den beiden Mittellinien, nicht mehr als $4.0 D_i$ beträgt.

4. Der Abscheider laut Patentanspruch 3, worin der Abstand zwischen den Mittellinien des Einlasses und des Gasabzugs nicht weniger als $1.5 D_i$, aber auch nicht mehr als $2.5 D_i$ beträgt.

5. Der Abscheider laut Patentanspruch 3 oder 4, worin die Höhe H des Strömungswegs doppelt so groß wie D_i ist.

6. Der Abscheider laut Patentanspruch 5, worin die Breite S des Strömungswegs nicht weniger als $0.9 D_i$, aber auch nicht mehr als $1.10 D_i$ beträgt.

7. Der Abscheider laut Patentanspruch 3 besitzt einen Feststofftrennauslaß, dessen erster Abschnitt kollinear zum Strömungsweg und dessen zweiter Abschnitt sich senkrecht zum ersten Abschnitt befindet und zum Abfließen des Feststoffs mittels Schwerkraft eingestellt ist.

8. Der Abscheider laut Patentanspruch 7 ent-



hält außerdem eine Strömungseinschränkung innerhalb des kollinearen Abschnitts des Abfuhrauslasses für Feststoffe.

9. Der Abscheider laut Patentanspruch 8, worin die Strömungseinschränkung aus einer Auslaßöffnung besteht.

10. Der Abscheider laut Patentanspruch 8, worin die Strömungseinschränkung aus einem Venturirohr besteht.

11. Der Abscheider laut Patentanspruch 1, 2 oder 3, der außerdem noch aus einem Wehr über dem Strömungsweg hinter oder beim Gasabzug aber vor dem Feststoffauslaß besteht.

12. Der Abscheider laut Patentanspruch 1, 2 oder 3, besitzt eine aus runden Querschnittsflächen hergestellte Kammer; der besagte Abscheider enthält außerdem eine Vorrichtung zur Formung des Strömungswegs, wobei die Form des Strömungswegs im wesentlichen rechteckig ist.

13. Der Abscheider laut Patentanspruch 12, worin die Formungsmittel aus der Auskleidung der Kammerwände mit Keramikwerkstoff besteht.

14. Der Abscheider laut Patentanspruch 12, worin die Formungsmittel aus Ablenkplatten die in die Trennkammer eingesetzt sind, besteht.

15. Der Abscheider laut Patentanspruch 1, 2 oder 3, dessen Kammerwände mit erosionsbeständiger Auskleidung ausgefüttert sind.

16. Der Abscheider laut Patentanspruch 1, 2, 3, 6 oder 7, dessen Kammerwände mit Wärmeschutzauskleidung ausgefüttert sind.

17. Der Abscheider laut Patentanspruch 15 enthält außerdem eine Wärmeschutzauskleidung zwischen den Kammerwänden und der erosionsbeständigen Auskleidung.

18. Der Abscheider laut Patentanspruch 1, 2, 3, 7 oder 8 hat eine Kammer, deren Längenmessung um die Länge L bis über den Gasabzug hinaus erweitert ist.

19. Der Abscheider laut Patentanspruch 18, dessen Kammerweiterung um die Länge L gleich $5 D_i$ oder kleiner ist.

20. Der Abscheider laut Patentanspruch 1, 2, 3 oder 7 enthält außerdem eine Mannluke zum Reinigen an einem oder beiden Enden der Trennkammer.

21. Der Abscheider laut Patentanspruch 3 enthält außerdem einen Feststoff-Gas-Sekundärabscheider der hauptsächlich zur Abfuhr aller restlichen Feststoffe dient; eine erste Rohrleitung, die den Gasabzug von der Kammer zum Sekundärabscheider verbindet, einen Behälter für die Abtrennung von Feststoffen, eine zweite Rohrleitung, die den besagten Behälter und die Kammer verbindet, sowie eine Druckregelvorrichtung zur Aufrechterhaltung einer Feststoffhöhe in der besagten zweiten Rohrleitung um eine Positivdichtung zwischen der Kammer und dem Behälter herzustellen.

22. Der Abscheider laut Patentanspruch 21 enthält außerdem eine Abschreckvorrichtung in der ersten Rohrleitung.

23. Der Abscheider laut Patentanspruch 22,

worin die Vorzugsabschreckvorrichtung aus einer Spritzdüse zum Einspritzen der Abschreckflüssigkeit besteht.

24. Der Abscheider laut Patentanspruch 21, worin die Kammer einen Feststofftrennauslaß besitzt, dessen erster Abschnitt mit dem Strömungsweg kollinear ist und dessen zweiter Abschnitt senkrecht zum ersten Abschnitt liegt und zum Abfließen von Feststoffen mittels Schwerkraft eingerichtet ist; der besagte erste Abschnitt ist von der dem Einlaß gegenüberliegenden Kammerwand abgesetzt.

25. Der Abscheider laut Patentanspruch 21, worin die Vorzugssekundärabtrennung aus einem Zyklon besteht.

26. Der Abscheider laut Patentanspruch 21, worin ein Rückschlagventil am Auslaß und an der zweiten Rohrleitung die Druckausgleichsvorrichtung darstellt.

27. Der Abscheider laut Patentanspruch 21, worin das Druckregelventil am Feststofftrennbehälter die Druckausgleichsvorrichtung darstellt.

28. Eine Zentrifugalkraftmethode zum Abtrennen von Feststoffteilchen aus einem verdünnten Feststoff-Gas-Strom in der Mischphase; die Methode besteht aus Maßnahmen, die nötig sind um einen Mischphasenstrom in eine Kammer zu leiten, die einen Strömungsweg mit einem im wesentlichen rechteckigen Querschnitt besitzt und zwar von einem Einlaß mit einem Innendurchmesser D_i , der senkrecht zum Strömungsweg eingerichtet ist; der besagte Strömungsweg hat eine Höhe H gleich D_i oder 4 englische Zoll (10,16 cm), je nachdem welche größer ist, sowie eine Breite W, größer als oder gleich $0,75 D_i$, aber kleiner als oder gleich $1,25 D_i$, zum Abtrennen von Feststoffen von Gas durch Zentrifugalkraft innerhalb der besagten Kammer längs einer Feststoffablagerung an der Wand, die dem Einlaß gegenüberliegt, so wie das Gas durch den besagten Strömungsweg fließt; das Gas ändert seine Richtung um 180° und der Feststoff wird um 90° gegen den Feststoffauslaß geschleudert.

29. Verfahren nach Anspruch 28, welches als weitere Stufe eine weitere Feststoffabtrennung vom Gasanteil des Eingangsstromes, der durch den Gasauslaß in einen sekundären Separator abgeführt wird, umfaßt.

30. Verfahren nach Anspruch 28, bei dem die bevorzugte sekundäre Operation eine Zyklonabtrennung ist.

31. Verfahren nach Anspruch 28, 29 oder 30, welches als weitere Stufe ein Abstreifen der vom Feststoffauslaß abgeführten Feststoffe mit Inertgas oder Dampf umfaßt.

32. Verfahren nach Anspruch 31, welches als weitere Stufe ein Abziehen eines Leckgasanteiles mit den Feststoffen umfaßt, wobei der Leckgasanteil nicht größer als 10% des Einlaßgases ist.

Revendications

1. Un séparateur de mélange gaz-solides



destiné à procéder à l'élimination rapide des particules solides d'un courant de mélange gaz-solides en phase mixte diluée, le séparateur comportant une chambre dans laquelle s'opère la séparation des particules solides du courant de mélange en phase mixte arrivant dans la chambre. Ladite chambre comprend une entrée en phase mixte (14), une sortie en phase gazeuse (15) et une sortie en phase solide (16), l'entrée en phase mixte (14) et la sortie en phase solide (16), étant chacune à une extrémité opposée de la chambre. La sortie en phase solide (16) assure l'écoulement gravitaire des solides rejetés et la sortie en phase gazeuse (15), située entre l'entrée et la sortie précitées est orientée de manière à faire effectuer aux gaz un virage de 180° par rapport à l'entrée de la chambre. La chambre se caractérise par des parois longitudinales rectilignes ou légèrement arquées formant un passage de section essentiellement rectangulaire entre l'entrée (14) et la sortie de solides (16), l'entrée (14) et les sorties (15, 16) étant disposées perpendiculairement audit passage.

2. Le séparateur du Point 1, dans lequel la hauteur, H, du passage d'écoulement est au moins égale au diamètre interne, D_i , de l'entrée, ou à 10,16 cm (4 pouces).

3. Le séparateur cité au Point 2 comporte une entrée en phase mixte d'un diamètre interne D_i , un passage d'écoulement d'une largeur W comprise entre 0,75 et 1,25 D_i et une sortie de gaz située entre l'entrée en phase mixte et la sortie de solides, la distance d'axe en axe séparant la sortie de gaz de l'entrée ne dépassant pas 4,0 D_i .

4. Le séparateur cité au Point 3 où la distance d'axe en axe séparant l'entrée de la sortie de gaz n'est ni inférieure à 1,5 D_i , ni supérieure à 2,5 D_i .

5. Le séparateur du Point 3 ou 4, dans lequel la hauteur H du passage d'écoulement est le double de D_i .

6. Le séparateur du Point 5, dans lequel la largeur S du passage d'écoulement n'est ni inférieure à 0,9 D_i , ni supérieure à 1,10 D_i .

7. Le séparateur du Point 3 comporte un canal de sortie d'évacuation de solides dont la première partie est colinéaire par rapport au passage d'écoulement et la deuxième partie est perpendiculaire à la première partie et alignée pour permettre l'écoulement gravitaire des solides.

8. Le séparateur du Point 7 comporte d'autre part un rétrécissement dans la partie colinéaire du canal de sortie des solides.

9. Le séparateur du Point 8 où le rétrécissement est constitué par un orifice.

10. Le séparateur du Point 8 où le rétrécissement est constitué par un venturi.

11. Le séparateur du Point 1, 2 ou 3 comprend par ailleurs un déversoir en travers du passage d'écoulement en amont ou au droit de la sortie de gaz et en aval de la sortie de solides.

12. Le séparateur du Point 1, 2 ou 3 com-

porte d'une part une chambre préfabriquée de section circulaire et d'autre part un passage d'écoulement profilé de forme essentiellement rectangulaire.

13. Le séparateur du Point 12 où le profilage du passage d'écoulement est un revêtement interne en céramique placé sur les parois de la chambre.

14. Le séparateur du Point 12 dans lequel le profilage du passage d'écoulement est constitué par des écrans introduits dans la chambre du séparateur.

15. Le séparateur du Point 1, 2 ou 3 dans lequel les parois de la chambre sont recouvertes d'un revêtement interne anti-usure.

16. Le séparateur du Point 1, 2, 3, 6 ou 7 dans lequel les parois de la chambre sont recouvertes d'un revêtement interne calorifuge.

17. Le séparateur du Point 15 comporte de plus un revêtement interne calorifuge placé entre les parois de la chambre et le revêtement interne anti-usure.

18. Le séparateur du Point 1, 2, 3, 7 ou 8 comporte une chambre qui se prolonge longitudinalement au-delà de la sortie de gaz sur une distance L.

19. Le séparateur du Point 18 dont la longueur de prolongement L de la chambre est inférieure ou égale à 5 D_i .

20. Le séparateur 1, 2, 3 ou 7 comprend un trou d'homme à usage d'entretien à une ou chaque extrémité de la chambre du séparateur.

21. Le séparateur du Point 3 comporte d'autre part un séparateur secondaire, dont l'objet essentiel est d'éliminer toutes les particules solides résiduelles du mélange; celui-ci comprend: un premier canal reliant la sortie de gaz de la chambre au séparateur secondaire, un collecteur recueillant les solides évacués, un deuxième canal reliant ledit collecteur à la chambre et enfin un dispositif de régulation de pression qui permet de maintenir dans le second canal une hauteur de solides suffisante pour assurer une étanchéité positive entre la chambre et le collecteur.

22. Le séparateur du Point 21 comporte un dispositif de refroidissement dans le premier canal.

23. Le séparateur du point 22 où le dispositif de refroidissement consiste de préférence en une buse de pulvérisation injectant le fluide de refroidissement.

24. Le séparateur du point 21 dont la chambre comporte une sortie d'évacuation de solides; la première partie de ce canal de sortie étant colinéaire par rapport au passage d'écoulement, et la deuxième partie étant perpendiculaire à la première partie et alignée pour permettre l'écoulement gravitaire des solides. La première partie est en retrait par rapport à la paroi de chambre opposée à l'entrée.

25. Le séparateur du Point 21 où le dispositif de séparation secondaire est de préférence un séparateur à cyclone.

26. Le séparateur du Point 21 où le disposi-



tif de régulation de pression est constitué par un clapet de retenue positionné à la sortie du second canal.

27. Le séparateur du Point 21 où le dispositif de régulation de pression est constitué par une vanne régulatrice positionnée sur le collecteur de solides.

28. Un procédé permettant la séparation par force centrifuge des particules solides d'un courant de mélange gaz-solides en phase mixte. Ce procédé fait intervenir le passage d'un courant en phase mixte dans une chambre. Cette chambre comporte un passage d'écoulement de section essentiellement rectangulaire auquel mène une entrée perpendiculaire d'un diamètre interne D_i , ledit passage a une hauteur H égale à D_i ou 10,16 cm (4 pouces), selon la valeur la plus grande, et une largeur W égale ou supérieure à $0,75 D_i$ et égale ou inférieure à $1,25 D_i$. La séparation des solides et des gaz s'opère dans la chambre par force centrifuge, le long d'un lit de particules solides qui s'accu-

mulent sur la paroi opposée à l'entrée à mesure de l'écoulement des gaz dans ledit passage, les gaz effectuant un virage de 180° et les solides étant projetés à 90° vers une sortie d'évacuation.

29. Un procédé selon la revendication 28 comprenant en outre la phase de séparation ultérieure des solides restants de la portion gazeuse du courant d'entrée retirée par la sortie de gaz vers un séparateur secondaire.

30. Un procédé selon la revendication 29 dans lequel l'opération secondaire se fait dans un cyclone.

31. Un procédé selon l'une des revendications 28, 29 ou 30 dans lequel en outre on enlève les solides, retirés à la sortie des solides, au moyen d'un gaz inerte ou de vapeur.

32. Un procédé selon la revendication 31 dans lequel en outre on enlève le gaz de fuite avec les solides, la proportion de ce gaz ne dépassant pas 10% du gaz admis.

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