

Apparatus and method for comminution of pulverulent material by fluid energy

Field of the invention

The present invention relates to the comminution of pulverulent material by fluid energy, and is directed particularly to an apparatus and method wherein the particulate or pulverulent material is directed into a recirculating flow of fluid carrier medium in a manner to reduce the particle size of the particulate material.

Background of the invention

Pulverulent material has been subjected to reduction of particle size in fluid energy mills for many years but the expense of such treatment has rendered it impractical for all except certain limited applications.

Fluid energy mills rely on the introduction of particulate material into a vessel having a high-velocity, normally sonic or supersonic velocity, fluid medium recirculating therein. The circulating flow of fluid medium is normally used to effect a centrifugal separation of the particulate material to permit a withdrawal of the finely-ground material while the coarse material continues its recirculation. The coarse material is reduced in size either by impingement against other particles in the recirculating flow or else by impingement against the vessel walls. In the former case, there is considerable loss of energy in the prior art ways of causing the inter-particle impingement, and in the latter case, there is substantial erosion of the vessel walls due to the high speed impact of the particles against the walls.

Prior to the present invention, the fluid energy mills incorporated one or more of three basic designs namely the "pancake", the opposed nozzle, and the tubular.

The "pancake" design consists of a short flat cylindrical vessel having tangential inlet nozzles for the fluid carrier medium and a central exhaust outlet. The inlet nozzles are designed to introduce jets of fluid medium into the chamber with an overlap between adjacent nozzles to impart a turbulent condition to the flow which assists the inter-particle impact within the flow. Commercially available mills of this character are normally designed for laboratory use and the flow from the jets carries the particulate material into abrading impact with the walls of the vessel not only causing rapid deterioration of the vessel walls, but also tending to cause the particles to rebound in towards the center of the vessel where the coarse particles may be entrained in the flow of finely ground particles being carried from the mill through the exhaust port.

Details of various mills of the "pancake" design can be taken from United States Patents 2032827, 2191095, 2339568, 2390678, 3726484 and 3840188.

In the opposed nozzle mills, the particulate material is introduced into the mill with a jet

oriented in one direction and the jet is impacted with a jet from an opposite direction to obtain maximum particle-to-particle impact at the junction of the jets. Although this type of mill avoids a substantial degradation of the vessel wall by the impact of particulate material, there is substantial energy loss through the use of the opposed jets. To assure maximum comminution of the particulate material in such apparatus, it frequently is combined with a "pancake" or a tubular mill.

Details of various mills of the "opposed nozzle" design can be taken from United States Patents 2704635, 2735626, 2914391 and 3229918.

In the tubular mill, the vessel is in the form of an upright annulus of a particular configuration and the circulation through the annulus is effected by jets disposed tangentially in the bottom portion of the annulus. A substantial part of the grinding effect is obtained in the zone where there is injection of additional jets into the recirculating flow of material, but heavy reliance upon the confinement of the flow by the vessel walls subjects the annular walls of the vessel to a substantial abrading action by the particle laden fluid medium. As with the pancake mills, the random impact of the heavier particles against the walls of the vessel permits rebounding of these particles into the central outlet of the vessel with the result that the fine particulate material being discharged with the carrier medium is contaminated by the coarser particles which rebound into the discharged flow.

Details of various tubular mills can be taken from United States Patents 2055385, 2219011, 2315083, 2550390, 2590220, 3491953, 3539294 and 3648936.

A modified tubular mill in which the particles to be ground flow downwardly from an upper horizontal annular zone, is disclosed in United States Patent 3565348, but again heavy reliance is placed on impacts with the vessel wall to produce the grinding effect.

Summary of the invention

In accordance with the present invention the pulverulent material is caused to be ground by impingement against other material within the fluid flow so as to avoid the energy loss which is inherent in prior art devices. In this fashion, a highly efficient and effective grinding action is obtained.

The present invention provides a method and apparatus for comminuting pulverulent material in which a highly efficient and effective grinding action is accomplished without substantial impingement of the particulate material against the walls of the vessel and in which the random entrainment of oversized particles into the discharge flow is minimized while enabling a

high capacity for the treatment of the pulverulent material, the capacity of the mill being sufficient to provide finely ground particulate pulverulent material in quantity suitable for commercial use.

More specifically, the present invention obtains an improved grinding action by the use of a carrier flow which is directed into a vortex within a cylindrical vessel, such as a hollow container, the vortex being controlled to operate within the central zone of the cylindrical vessel in a vertical fashion and wherein surrounding the central vortex a secondary return flow is established which permits repeated recirculation of the fluid carrier medium within the vessel.

Means is provided to generate the vertically-flowing vortex in a manner to provide differential flow velocities within the vortex and the recirculating secondary flow. As the particulate material is displaced from the lower velocity flow area to the higher velocity flow area, it is subjected to acceleration forces, and vice versa, when it is displaced from the higher velocity flow area to the lower velocity flow area it is subjected to deceleration forces. Where the particles are of different mass, the acceleration and deceleration forces affect the particles differently so as to cause varying acceleration and deceleration of the different particles. This variation in acceleration effects an impacting of the particles one upon the other so as to provide an effective grinding action upon the particulate material without impingement against the vessel walls, and without the energy loss inherent in mills which employ the impact of oppositely-directed jets.

Description of the drawings

The invention will now be further described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is a view in side elevation with a portion broken away of a fluid energy mill according to the present invention;

Figure 2 is a transverse sectional view taken on the line 2—2 of Figure 1;

Figure 3 is an enlarged fragmentary cross section of the lower part of the mill shown in Figure 1;

Figure 4 is an inverted fragmentary sectional view taken on the line 4—4 of Figure 1; and

Figure 5 is a transverse sectional view through a modified embodiment of a fluid energy mill in accordance with the present invention and incorporating additional feed and control means which may be used to facilitate the practice of the present invention.

Detailed description

Before discussing the structure and operation of the fluid energy mills shown in the drawings, it is useful to examine some of the principles involved in the particle size reduction, the consequences of flow development, and the prin-

ciples of centrifugal classification utilized in the present invention.

The discharge of a high velocity free jet as a primary flow into a low velocity gas secondary flow results in the establishment of a high shear field between the two flows in which violent turbulence is established due to the development of intense eddy currents. This shear field produces a rapid mixing of the two flows until all of the high velocity gas becomes mixed with the surrounding low velocity gas. Thereafter a mixed flow of intermediate velocity continues to penetrate the low velocity secondary flow with further mixing but at a much lower rate.

During the initial rapid mixing and the slower subsequent mixing phases, any particulate matter in the low velocity secondary flow will be swept into the shear field wherein it is subjected to turbulent and rapid acceleration. Small particles of low mass will achieve very high velocities quickly while larger high mass particles will achieve increased velocities over longer distances or time spans. Thus, in the initial phase, there is established a mixed flow wherein small particles are moving at velocities substantially greater than those of the larger particles. As the mixed flow continues to expand its field and the primary gas flow decelerates, the small particles in the primary flow will tend to decelerate rapidly due to their low mass and high viscous drag, but the larger particles of greater mass will tend to retain their high velocities so that during the subsequent decay portion of the mixed flow the large particles will be moving at velocities substantially greater than those of the small particles. Because of the differing acceleration and deceleration of the particles of different mass, there is substantial frequency of impacts between them.

Size reduction may be achieved by momentum interchange between large and small particles with the small particles overtaking and impacting the large ones in the initial phase of rapid mixing, and the large particles overtaking and impacting on the small ones during the subsequent decay phase. Thus, the particle-to-particle impact is achieved by introducing primary jets of fluid carrier medium into the secondary recirculating flow of the fluid carrier medium in such a fashion as to achieve the desired fluctuations in fluid velocities within the mixed flow. This is accomplished by introducing the primary jets into the secondary flows in substantially the same flow direction so as to minimize energy loss which is experienced in the opposed nozzle type of energy mill discussed above.

In accordance with the present invention, the design of the fluid energy mill is such as to provide a central vertical flow of the fluid medium within the vessel, the central upward flow being in the form of a vortex within a cylindrical core zone in the vessel. A secondary return flow in the annular zone surrounding the core zone is achieved so as to complete the

cycle. The energy for achieving the vertical flow in the central vortex is derived by a plurality of injector nozzles disposed circumferentially of the vessel at one end, these nozzles injecting a primary flow of carrier medium into the core zone of the vessel for generating the vertical vortex. A portion of the fluid medium injected at the one end of the vessel is withdrawn at the opposite end to assure flow lengthwise of the vessel. The jets generating the vortex comprise a high velocity flow which is mixed with the secondary recirculating flow which returns to the bottom of the vessel through the annular peripheral zone surrounding the central core.

The energy mill shown in Figure 1 accomplishes efficient and effective size reduction of particulate material with minimum impingement of the particles against the walls of the vessel. To this end, the structure in Figure 1 includes a generally upright cylindrical vessel 12. The vessel 12 is a pressure vessel having a domed top wall 13 and a bottom wall 14. Means is provided to inject a primary flow of carrier medium into the vessel at the bottom end and to this end, an inlet pipe 15 having a regulating means 16 connects through the wall of the vessel 12 to an internal manifold 17 encircling the interior of the vessel 12 adjacent to the bottom wall 14. The regulating means 16 controls the condition of the fluid carrier medium to enable control of the intensity of a vortex generated in the vessel. The regulator may control one or more of the pressure, temperature, mass flow, density, and composition of the fluid carrier medium introduced into the manifold 17.

The fluid medium is exhausted at the top end of the vessel through a discharge outlet 22. In the present instance the discharge outlet 22 has a flow regulating damper 23 and constitutes a tangential outlet to a discharge chamber 24 formed adjacent to the top wall 13 and separated from the rest of the vessel by a transverse partition 25 having an outlet opening 26 therein. The outlet 26 is defined by a downwardly-flared wall portion 27 projecting centrally within the cylindrical vessel 12. A disc-like deflector element 29 is positioned below the outlet opening 26 and a regulating shaft 30 supports the deflector element 29 at a selected position below the outlet to thereby regulate the flow area between the element 29 and the opening 26. Adjusting means is provided at 31 to alter the vertical position of the deflector element 29 and thereby regulate the effective flow area through the opening 26. By regulating either or both of the damper 23 and the element 29, the pressure within the vessel 12 may be adjusted to control the amount of particulate material which is recirculated with the fluid medium in the vessel. Restricting the exhaust of the fluid medium increases the pressure within the vessel and causes a recirculation of a larger proportion of the particulate material within the vessel as described more fully hereinafter.

When treating certain materials, the deflector element 29 may be eliminated and the control of the exhaust may be accomplished by regulation of the damper 23 or may be accomplished by a fixed discharge flow area calculated to be correct in the initial design of the equipment.

The work material, normally pulverulent material having a range of particle sizes, is introduced into the vessel 12 below the partition 25 by a feeder 35, in the present instance a feed auger having a drive shaft 36 which transmits the material from a feed hopper 37 through the feeder 35 into the pressure vessel 12.

In accordance with the invention, the flow of fluid carrier medium from the manifold 17 is controlled to effect a vertical flow in one direction within a central cylindrical core zone of the vessel 12 with a secondary recirculating flow in the opposite direction in the annular zone surrounding the central core zone. In the present instance, the vortex flow is upward in the core zone and downward in the peripheral zone. The upward flow is assured by the position of the outlet in the upper end of the vessel, and the intensity of the flow is enhanced by upwardly-directed jets of the carrier medium. To this end, the manifold 17 is provided with nozzle means 41 spaced circumferentially about the lower level of the vessel 12 to inject high-velocity jets of carrier medium into the vessel at an upwardly-inclined angle as indicated diagrammatically by the flow arrows 42 in Figure 3 and at an angle offset from the radial direction R as indicated by the arrows 43 in Figure 4. As a result of this dual inclination of the nozzles 41, the multiple jets of fluid medium issuing from the manifold 17 combine to generate an upwardly-flowing vortex 44 as indicated by the arrows in Figure 1. The shallow angular position indicated by the arrows 43 confines the upwardly-flowing vortex 44 to the central core zone of the chamber 12. The clockwise circular flow in the vortex 44 continues toward the top wall and in the present instance, the upward travel is arrested at the partition 25.

Upon nearing the partition, a first portion of the circulating flow is deflected outwardly into the annular peripheral zone surrounding the central core zone, causing a downward secondary flow 46 as indicated by the arrows in Figures 1 and 3, and a second portion is discharged through the outlet opening 26, as indicated by the arrows 47. The clockwise circular flow generated by the vortex 44 is not terminated by the flow separation occasioned by the partition 25 but for the purpose of illustration, the arrows 46 indicate a straight downward flow in Figure 1. As shown in Figure 1 the downward flow in the peripheral zone as indicated by the arrows 46 passes the feed device 35 and entrains the particulate matter which is fed into the vessel through the feeder 35. Thus, the secondary flow in the annular

peripheral zone is laden with the particulate matter fed into the vessel. The downward secondary flow with the particulate matter entrained therein surrounds the nozzles 41 and is introduced into the primary flow issuing from the nozzles 41 and is aspirated into the flow by the high velocity jet action of the nozzles. In this manner, the high velocity jets are effective to interface with the lower velocity secondary flow having the particulate matter entrained therein, and to provide an interchange of momentum therebetween.

As discussed above, the interchange effected by the mixture of the primary and secondary flows generates shear fields surrounding the high velocity core of the jets in which the particulate matter is comminuted and reduced in mass. This reduction is effected primarily in the grinding zone at the bottom of the vessel 12. The particles of smaller mass flow in an upward spiral in the vortex 44 whereas, as shown in Figure 3, the particles of larger mass may tend to follow the straight path of the high velocity flow as indicated by the arrows 48. These larger particles thereby are subjected to the subsequent secondary mixing discussed above and impact against the slower moving particulate material. As shown in Figure 3, these particles also intercept the secondary flow as indicated by the arrows 46 prior to impinging against the walls of the vessel 12 and the secondary flow at the remote end of the jets thereby deflects the particles from perpendicular impingement against the vessel walls. These large particles are thereby entrained in the secondary flow and are again injected into the primary flow issuing from the nozzles.

Preferably, the pipe 15 and means 16 inject the fluid medium through the nozzles at an intensity which generates a sonic flow within the jets. The efficiency of the mill is optimized when the flow in the issuing portion of the jet is at sonic velocity, but the mill is effective in both the subsonic and the supersonic range. The nozzles are adjustable either individually or in unison to determine the angularity relative both to the radius R and to the horizontal plane of the manifold 17, so that the intensity of the vortex generated by the combined jets issuing from the nozzles may be regulated to the desired degree. The intensity of the vortex and its height determine the size of those particles which are retained within the interior of the core zone and are discharged with that portion of the flow of the vortex which is exhausted through the central opening 26. The particles below a given mass will remain within the inner part of the upwardly-flowing vortex, whereas the larger particles will be centrifugally classified and deflected into the outer secondary flow in the peripheral zone. By increasing the angle of the nozzles relative to the radius R , the intensity of the vortex may be increased to reduce the particle size which is discharged through the central opening 26. Conversely, reducing the

angle of the jets relative to the radius R will reduce the vortex intensity and increase the particle size which is discharged through the central opening. In Figure 1, the height of the core zone is approximately 1.5 times the diameter of vessel 12, and the intensity of the vortex is such that the upward flow of the vortex embraces at least 90° circumferentially between the nozzles 41 and the partition 25.

In the present instance, the nozzles 41 generate a spray divergence angle of about 25° with the velocity decreasing in the spray at increasing distances from the issuing flow of the jets. As shown in Figure 3, the inclination of the jets is about 12.5° so that the lower limit of the spray angle is substantially horizontal, thereby conserving maximum flow energy in generating the upwardly-flowing vortex. In Figure 4, the angularity of the jets, as indicated by the arrow 43 relative to the radius, is also of the order of 12.5° so that the spray issuing from the nozzles does not intersect the radius R .

Thus, it is possible to state general conditions for the preferred arrangement of a fluid energy grinding system. First, the area of the shear field should be maximized, and this is done by maximizing the number of nozzles and minimizing the mass flow through each one. Second, the unimpeded length of the free jet is maximized in order that the shear field area is as great as possible and so that the maximum amount of momentum is transferred from the primary jet flow to the particles in the recirculating secondary flow before any interaction between the mixed flows reduces the velocity of the primary flow. Third, the mass of the particles in the recirculating secondary flow must be great enough to absorb the momentum of the free jets with the result that the velocity of the mixed flow is minimized within a reasonable size of vessel. Fourth, sufficient distance must be provided for reducing the momentum of large particles either by deceleration or by additional size reduction, and this feature also contributes to reducing high velocity impingements which cause destructive wear of the vessel. Fifth, enough space must be provided between the nozzles to permit the recirculating secondary flow to completely envelop the free jets issuing from the nozzles.

An array of nozzles can be provided using various geometric arrangements, but there remains the necessity of removing product and spent carrier fluid from the processor, and vortex flow of the two-phase system is very effective in centrifuging large particles from the inner portion thereof, the primary parameters being the strength of the vortex, the time available for the larger particles to be displaced outwardly to a sufficient distance to prevent their capture in the exhaust from a centrally located outlet, and the freedom of the large particles to traverse the vortex chordwise without encountering any obstruction. Lastly, the recirculation of the medium must be controlled for

the optimization of the grinding operation. The above requirements have been accommodated by the present invention and the operating parameters have been optimized in the preferred embodiment.

A practical example will now be given to demonstrate the design of a processor which embodies the foregoing preferred features.

A nozzle discharging 227 Kg (500 lb.) of superheated steam per hour into a two-phase mixture of coal dust and steam dissipates within 147 cms (58 inches) and produces no detectable wear on a mild steel plate after several hundred hours of operation. The same jet caused destructive wear when the plate is moved to within 45 cms (18 inches) of the nozzle. Based on this data, a hollow cylindrical vessel of 152 cms (60 inches) diameter is suitable for the flows created in accordance with the present invention using a plurality of nozzles each of which delivers 227 Kg (500 lb.) per hour of superheated steam.

A device which uses 60 nozzles with a throat diameter of 6.75 mm disposed around the base of the vessel at an angle of $12\frac{1}{2}^\circ$ from the radial direction provides sonic flow velocities at a rate of 13608 Kg (30,000 lbs.) per hour of superheated steam when the manifold steam conditions are 13 Kg/cm² (200 psig) and 370°C (700°F). A sonic velocity is in the range of 2140 Km/h (1950 ft./sec.) in this steam atmosphere. The vortex generated by this primary flow is of an intensity which retains particles above 20 microns mass within the vessel, whereas particles which have been comminuted to a mass of 20 microns or less are discharged through the outlet with the spent steam.

Figure 5 illustrates a mill in accordance with the present invention wherein the configuration of the mill incorporates modifications compared with that shown in Figures 1 to 4.

In the mill of Figure 5, the vessel has a hollow cylindrical shell 82 with frusto-conical top and bottom walls 83 and 84, respectively. A fluid carrier medium is introduced as a primary flow from a manifold 87, which is disposed at the lower end of the cylindrical shell 82 in circumscribing relation thereto. The manifold 87 is connected to a supply of pressure fluid in a conventional manner and has a plurality of nozzles 86 projecting through the shell into the interior thereof. The nozzles 86, in the present instance, are inclined to the vertical and to the radial direction by an angle of $12\frac{1}{2}^\circ$ similarly to the respective inclinations of the nozzles 41, so that the primary flow of pressure fluid medium intensifies the upwardly-flowing vortex within the central core zone of the shell 82. In Figure 5, the envelope of the vortex is indicated in dot-and-dash lines identified at 85.

The mill has two feeders 88 and 89 for introducing pulverulent material into the vessel. The feeder 88 is positioned in the cylindrical shell 82, whereas the feeder 89 is positioned in the bottom wall 84. Where the feeder 88 feeds into

the secondary flow above the grinding zone, the feeder 89 feeds directly into the grinding zone where it may be drawn vertically into the vortex generated by the nozzles 86. Either or both feeders may be operated to supply fresh pulverulent material to the grinding mill.

As in the embodiment of Figures 1—4, the jets from the nozzles 86 project a high velocity issuing flow indicated at 92 chord-wise across the cylindrical shell with an unobstructed flow path throughout. The combined effect of the several primary flows issuing from the nozzles 86 generates the vertical flow in the form of a vortex, as indicated by the arrows 94 in Figure 5. Centrally within the upper top wall 83, an outlet passageway is provided, as indicated at 97. The passageway is provided by a tubular duct 96 which is vertically adjustable in the top wall 83 to position its lower open end at varying levels within the central core zone of the shell 82. The particles of the material entrained in the upwardly-flowing vortex which are below the critical mass flow outwardly through the duct 96 with that portion of the carrier medium which is discharged therethrough as indicated by the arrows 99. The remainder of the carrier medium is recirculated radially outward and downwardly as indicated by the arrows 98 and is caused to merge with the primary medium flow issuing from the nozzles 86 at the lower end of the cylindrical shell 82. In the present instance, a guiding annulus 102 is positioned coaxially within the shell 82 having an inner diameter coincident with the envelope 85 of the vortex and having an outer diameter spaced inwardly from the shell 82 to provide an annular passageway for the secondary flow 98. It is noted that the feeder 88 opens into the vessel opposite the annulus 102, so that the fresh material introduced through the feeder 88 is isolated from the vortex 94 as it enters the secondary flow 98. It should also be noted that the lower end of the annulus 102 terminates above the grinding zone and is sufficiently above the nozzles 86 to avoid obstructing the flow paths from the nozzles 86.

In order to minimize eddy current flows within the central eye of the vortex 94, a plug element 104 depends downwardly through the passageway 97 into the eye of the vortex. The plug 104 is effective to eliminate eddy current flows in the eye of the vortex and thereby is effective to enhance the centrifugal classification of the particles in the upwardly-flowing vortex. As shown in Figure 5, the plug element extends downwardly through the vortex to a level above the grinding zone. In the present instance, the plug element 104 also cooperates with the adjustable tubular duct 96 to regulate the flow area of the outlet passageway 97 and thereby regulate the pressure within the shell 82. When the tubular duct 96 is elevated, the bottom thereof registers with a smaller diameter of a tapered portion 105 of the plug element 104 to thereby provide a larger flow

area for the discharge of carrier medium and the particles carried thereby. Conversely, when the tubular duct 96 is adjusted downwardly, its lower end registers with a larger diameter of the tapered portion 105 thereby reducing the flow area between the plug and the duct and increasing the pressure within the shell.

In operation, the embodiment of Figure 5 may function similarly to that of Figures 1—4 in that the particulate material is introduced through the feeder 88 into the recirculating secondary flow identified by the arrows 98 and this fresh particulate material flows downwardly for entrainment into the primary flow injected by the jets issuing from the nozzles 86. As in the embodiment of Figure 1, the downwardly-flowing particulate material impinges with any residual particles which are projected chord-wise across the shell without being entrained in the upwardly-flowing vortex to thereby impact with these particles and effect an interchange of flows to carry the particles downwardly into the jets at the bottom of the shell. In addition, or alternatively particulate material may be introduced directly into the grinding zone through the feeder 89.

The apparatus and method of the present invention can be used for reducing the mass of particles in a wide range of different particulate materials but have particular application in the grinding of fossil fuels. Reducing the particle size of fuel material can be of value not only in permitting more efficient use of the fuel but also in a reduction of environmental pollution consequent upon combustion of the fuel.

While particular embodiments of the present invention have been herein illustrated and described it is not intended to limit the invention to such disclosure and changes and modification may be made therein and thereto within the scope of the following claims.

Claims

1. A fluid energy mill for grinding pulverulent material comprising a vessel (12, 82) providing a grinding zone, feed means for introducing a fluid carrier medium and the pulverulent material into the vessel in such wise that the latter is ground in the grinding zone by inter-particle impacts, outlet means (26, 97) through which ground material is removed from the vessel and a generally cylindrical zone having an axis disposed generally centrally within said vessel between said grinding zone and said outlet means, characterised in that a plurality of circumferentially-spaced ejector nozzles (41, 86) is provided for injecting the fluid carrier medium into said grinding zone in a direction between a radius to said cylindrical zone axis and a direction perpendicular to said radius, all of said nozzles (41, 86) being disposed to inject a primary flow of the fluid carrier medium into said vessel through said grinding zone, said nozzles cooperating with a closed bottom (14,

84) of the vessel and said outlet means (26, 97) so as to generate an axially-flowing vortex (44, 94) within said cylindrical zone, said vessel having transverse wall means (25, 83) at the other end spaced from said grinding zone to intercept the axially-flowing vortex and deflect at least a first portion of the medium therein outwardly into an annular zone (46, 98) peripheral to the vortex, the fluid medium being deflected into said peripheral zone flowing in a direction opposite to the axial flow direction of the vortex as a secondary flow and being introduced into said primary flow issuing from said nozzles (41, 86) to thereby effect a recirculation of the fluid carrier medium within said vessel, the feed means (35, 88) introducing pulverulent material into the flow of fluid carrier medium so that the material so introduced is led into said primary flow for fluid energy grinding thereof, said outlet means (26, 97) at the remote end of said vortex being operable to withdraw a second portion of said fluid medium and with it a fraction of the pulverulent material which has been reduced in mass below a predetermined limit in said grinding zone.

2. Apparatus according to claim 1 characterised in that means (16) is provided to regulate the conditions of the fluid carrier medium supplied to said nozzles (41, 86) to ensure the intensity of the vortex in said cylindrical zone is sufficient to afford circumferential flow in said vortex through at least 90° between any nozzle and the outlet means.

3. Apparatus according to claim 1 or claim 2, characterised in that said nozzles (41, 86) have a divergent spray angle providing a high velocity issuing flow and a decreasing flow velocity at increasing distances from said issuing flow, said plurality of nozzles being spaced apart a distance sufficient to provide varying flow velocities at positions intermediate the high-velocity flows of adjacent nozzles, said grinding zone affording an unobstructed flow path for the issuing flow from each nozzle extending from the nozzle to the wall portion of said vessel (12, 82) opposite to said nozzle, said unobstructed flow path terminating at said opposite wall portion and being intercepted by said secondary flow from said peripheral zone adjacent said opposite wall portion.

4. Apparatus according to any preceding claim, characterised in that an annular guide means (102) is mounted within said vessel to separate part of said cylindrical zone from the surrounding part of said peripheral zone, said guide means extending beyond said grinding zone to a region spaced from said transverse wall means (83) at its other end whereby said fluid carrier medium has a primary flow axially toward said other end within said annular guide means and a secondary flow axially toward said one end outside of said annular guide means, said feed means (88) including an opening in said cylindrical shell (82) confronting said guide

area for the discharge of carrier medium and the particles carried thereby. Conversely, when the tubular duct 96 is adjusted downwardly, its lower end registers with a larger diameter of the tapered portion 105 thereby reducing the flow area between the plug and the duct and increasing the pressure within the shell.

In operation, the embodiment of Figure 5 may function similarly to that of Figures 1—4 in that the particulate material is introduced through the feeder 88 into the recirculating secondary flow identified by the arrows 98 and this fresh particulate material flows downwardly for entrainment into the primary flow injected by the jets issuing from the nozzles 86. As in the embodiment of Figure 1, the downwardly-flowing particulate material impinges with any residual particles which are projected chord-wise across the shell without being entrained in the upwardly-flowing vortex to thereby impact with these particles and effect an interchange of flows to carry the particles downwardly into the jets at the bottom of the shell. In addition, or alternatively particulate material may be introduced directly into the grinding zone through the feeder 89.

The apparatus and method of the present invention can be used for reducing the mass of particles in a wide range of different particulate materials but have particular application in the grinding of fossil fuels. Reducing the particle size of fuel material can be of value not only in permitting more efficient use of the fuel but also in a reduction of environmental pollution consequent upon combustion of the fuel.

While particular embodiments of the present invention have been herein illustrated and described it is not intended to limit the invention to such disclosure and changes and modification may be made therein and thereto within the scope of the following claims.

Claims

1. A fluid energy mill for grinding pulverulent material comprising a vessel (12, 82) providing a grinding zone, feed means for introducing a fluid carrier medium and the pulverulent material into the vessel in such wise that the latter is ground in the grinding zone by inter-particle impacts, outlet means (26, 97) through which ground material is removed from the vessel and a generally cylindrical zone having an axis disposed generally centrally within said vessel between said grinding zone and said outlet means, characterised in that a plurality of circumferentially-spaced ejector nozzles (41, 86) is provided for injecting the fluid carrier medium into said grinding zone in a direction between a radius to said cylindrical zone axis and a direction perpendicular to said radius, all of said nozzles (41, 86) being disposed to inject a primary flow of the fluid carrier medium into said vessel through said grinding zone, said nozzles cooperating with a closed bottom (14,

84) of the vessel and said outlet means (26, 97) so as to generate an axially-flowing vortex (44, 94) within said cylindrical zone, said vessel having transverse wall means (25, 83) at the other end spaced from said grinding zone to intercept the axially-flowing vortex and deflect at least a first portion of the medium therein outwardly into an annular zone (46, 98) peripheral to the vortex, the fluid medium being deflected into said peripheral zone flowing in a direction opposite to the axial flow direction of the vortex as a secondary flow and being introduced into said primary flow issuing from said nozzles (41, 86) to thereby effect a recirculation of the fluid carrier medium within said vessel, the feed means (35, 88) introducing pulverulent material into the flow of fluid carrier medium so that the material so introduced is led into said primary flow for fluid energy grinding thereof, said outlet means (26, 97) at the remote end of said vortex being operable to withdraw a second portion of said fluid medium and with it a fraction of the pulverulent material which has been reduced in mass below a predetermined limit in said grinding zone.

2. Apparatus according to claim 1 characterised in that means (16) is provided to regulate the conditions of the fluid carrier medium supplied to said nozzles (41, 86) to ensure the intensity of the vortex in said cylindrical zone is sufficient to afford circumferential flow in said vortex through at least 90° between any nozzle and the outlet means.

3. Apparatus according to claim 1 or claim 2, characterised in that said nozzles (41, 86) have a divergent spray angle providing a high velocity issuing flow and a decreasing flow velocity at increasing distances from said issuing flow, said plurality of nozzles being spaced apart a distance sufficient to provide varying flow velocities at positions intermediate the high-velocity flows of adjacent nozzles, said grinding zone affording an unobstructed flow path for the issuing flow from each nozzle extending from the nozzle to the wall portion of said vessel (12, 82) opposite to said nozzle, said unobstructed flow path terminating at said opposite wall portion and being intercepted by said secondary flow from said peripheral zone adjacent said opposite wall portion.

4. Apparatus according to any preceding claim, characterised in that an annular guide means (102) is mounted within said vessel to separate part of said cylindrical zone from the surrounding part of said peripheral zone, said guide means extending beyond said grinding zone to a region spaced from said transverse wall means (83) at its other end whereby said fluid carrier medium has a primary flow axially toward said other end within said annular guide means and a secondary flow axially toward said one end outside of said annular guide means, said feed means (88) including an opening in said cylindrical shell (82) confronting said guide



means, thereby introducing pulverulent material into the secondary flow of said carrier medium.

5. Apparatus according to any preceding claim characterised in that said feed means includes an opening (89) into said grinding zone to permit pulverulent material to be introduced directly into said grinding zone.

6. Apparatus according to claim 4 characterised in that an elongated plug means (104) is disposed axially in said cylindrical zone terminating at said one end beyond said grinding zone to prevent formation of eddy currents along the central axis of said vortex, said outlet means comprising a central circular opening (97) in said transverse wall, through which said plug means extends to define with said opening an annular discharge passageway for said second portion of the fluid medium and the fraction of pulverulent material entrained therein, and means is provided to regulate the flow area of said annular discharge passageway.

7. Apparatus according to any preceding claim characterised in that the axis of said cylindrical zone is vertical and the nozzles (41, 86) are inclined to the horizontal with an angle of inclination of at least $\frac{1}{2}$ the divergent spray angle of said nozzles, said nozzle direction being offset from the direction of a radius of said cylindrical zone axis by an angular distance at least $\frac{1}{2}$ the divergent spray angle.

8. A method of comminuting a pulverulent material having particles with varying mass, which comprises entraining the material in a flow of fluid medium within a vessel (12, 82), allowing inter-particle impacts during entrainment to reduce the mass of at least some of the particles, separating the entrained particles on the basis of mass to discharge those lighter than a given mass and recirculate those heavier than the said mass characterised in that a primary fluid flow fed to the vessel generates an axially-flowing vortex of said fluid medium in a core zone (44, 85) within said vessel, a first portion of the axially-flowing medium is deflected outwardly at a remote end of said core zone into a zone (46, 98) peripheral to said core zone, said first portion is directed in a secondary flow through said peripheral zone and introduced into said primary flow to effect recirculation of said fluid medium in the secondary flow back through the core zone, a second portion of said flow is discharged through an outlet at the remote end of said core zone and pulverulent material is introduced into the recirculating secondary flow, said comminuting being effected by supplying said fluid medium in a plurality of jets (42, 92) projected inwardly of said vessel (12, 82) from adjacent its circumference, each jet (41) providing a high-velocity issuing central flow and decreasing flow velocities at increasing transverse distances from said issuing central flow, said jets being spaced apart to provide varying flow velocities intermediate the issuing central flows of said jets, the pulverulent material being entrained in the

flows from said jets, whereby impacts are effected between said particles within the core zone, while said secondary flow (46, 98) prevents any substantial impingement of particles laterally from the core zone to the surrounding wall of the vessel.

9. A method according to claim 8 characterised in that said fluid medium provides an issuing flow velocity in said jets in the sonic range.

10. A method according to claim 8 or claim 9, characterised in that the axially-flowing vortex (44, 94) effects a centrifugal classification of the particles of the pulverulent material entrained in said vortex, the particles greater than a given mass being recirculated with the secondary flow (46, 98), and including the step of discharging the remaining particles with said second portion through a central discharge passage (26, 97) disposed axially beyond said vortex, the issuing flow from each nozzle (41, 86) providing an elongate obstruction-free path, said secondary flow being introduced into said path adjacent a nozzle and said path being intercepted by said secondary flow at the remote end of said path.

Patentansprüche

1. Fließmittelenergiemahlvorrichtung zum Zerkleinern körnigen Materials, bestehend aus einem Gefäß (12, 82) mit einer Mahlzone, einer Zufuhreinrichtung zum Zuführen eines Fließmittelträgermediums und des körnigen Materials in das Gefäß, derart dass das Material in der Mahlzone durch gegenseitigen Zusammenprall der Teilchen zerkleinert wird, einem Auslass (26, 97), durch welchen das zerkleinerte Material aus dem Gefäß abgezogen wird, und einer allgemein zylindrischen Zone mit einer allgemein zentral innerhalb dieses Gefäßes zwischen dieser Mahlzone und diesem Auslass angeordneten Achse, dadurch gekennzeichnet, dass eine Mehrzahl von auf dem Umfang in gegenseitigem Abstand angeordneten Ausstossdüsen (41, 86) zum Einspritzen von Fließmittelträgermedium in diese Mahlzone in einer Richtung zwischen einem Radius bezüglich jener Achse der zylindrischen Zone und einer zu diesem Radius senkrechten Richtung vorgesehen ist, wobei alle diese Düsen (41, 86) so angeordnet sind, dass sie einen Primärstrom von Fließmittelträgermedium durch jene Mahlzone hindurch in dieses Gefäß einspritzen wobei diese Düsen mit einem geschlossenen Boden (14, 84) des Gefäßes und jenem Auslass (26, 97) zwecks Erzeugung eines axial strömenden Wirbels (44, 94) innerhalb jener zylindrischen Zone zusammenwirken, wobei dieses Gefäß am anderen Ende im Abstand von jener Mahlzone Querwände (25, 83) zum Abfangen des axial strömenden Wirbels und zur Ablenkung mindestens eines ersten Teils des Mediums darin nach aussen in eine den Umfang des Wirbels umgebende Ringzone (46, 98) auf-



weist, wobei das Fließmittelmedium in einer der axialen Strömungsrichtung des Wirbels entgegengesetzten Richtung strömend als Sekundärstrom in diese Umfangszone abgelenkt und in den von jene Düsen (41, 86) ausgehenden Primärstrom eingeführt wird, um dadurch einen Kreislauf des Fließmittelträgermediums in diesem Gefäß zu bewirken, wobei die Zufuhreinrichtung (35, 88) körniges Material so in den Fließmittelträgermediumstrom einführt, dass das so eingeführte, Material zwecks dessen Mahlung durch Strömungsenergie in jenen Primärstrom gelangt, und wobei dieser Auslass (26, 97) am abseitigen Ende jenes Wirbels zum Abziehen eines zweiten Teils jenes Fließmittelmediums und damit eines Anteils des in seiner Masse unter eine vorbestimmte Grenze in jener Mahlzone zerkleinerten körnigen Materials betätigbar ist.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, dass eine Einrichtung (16) zum Regeln der Bedingungen des jenen Düsen (41, 86) zugeführten Fließmittelträgermediums vorgesehen ist, um sicherzustellen, dass die Intensität des Wirbels in jener zylindrischen Zone ausreicht, eine Umfangsströmung in diesem Wirbel über mindestens 90° zwischen jeder Düse und dem Auslass zu liefern.

3. Vorrichtung nach Anspruch 1 oder 2, dadurch gekennzeichnet, dass diese Düsen (41, 86) einen divergierenden Sprühwinkel besitzen, der eine mit hoher Geschwindigkeit austretende Strömung und eine mit zunehmendem Abstand vom austretenden Strom abnehmende Strömungsgeschwindigkeit liefert, wobei jene Mehrzahl von Düsen sich in ausreichendem Abstand voneinander befinden, um variierende Strömungsgeschwindigkeiten an Stellen zwischen den Strömungen mit hoher Geschwindigkeit aus benachbarten Düsen zu schaffen, wobei diese Mahlzone für die von jeder Düse ausgehende Strömung einen ungehinderten, sich von der Düse bis zu dem dieser gegenüberliegenden Wandungsteil jenes Gefäßes (12, 82) erstreckenden Strömungsweg bietet, der an diesem gegenüberliegenden Wandungsteil endet und durch jene Sekundärströmung aus der besagten Umfangszone neben diesem gegenüberliegenden Wandungsteil abgefangen wird.

4. Vorrichtung nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, dass eine ringförmige Führung (102) innerhalb dieses Gefäßes angebracht ist, um einen Teil jener zylindrischen Zone von dem umgebenden Teil jener Umfangszone zu trennen, wobei diese Führung sich über jene Mahlzone hinaus bis in einen Bereich im Abstand von jener Querwand (83) an deren anderem Ende erstreckt, wodurch dieses Fließmittelträgermedium innerhalb dieser ringförmigen Führung einen Primärstrom axial zu diesem anderen Ende hin und ausserhalb dieser ringförmigen Führung einen Sekundärstrom axial zu dem besagten ersten Ende hin besitzt, wobei diese Zufuhreinrichtung

(88) eine Öffnung in jener zylindrischen Hülle (82) gegenüber dieser Führung aufweist, wodurch körniges Material in den Sekundärstrom dieses Trägermediums eingeführt wird.

5. Vorrichtung nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, dass diese Zufuhreinrichtung eine Öffnung (89) in dieser Mahlzone zur direkten Einführung von körnigem Material in diese Mahlzone aufweist.

6. Vorrichtung nach Anspruch 4, dadurch gekennzeichnet, dass ein langgestreckter Stöpsel (104) axial in jener zylindrischen Zone angeordnet ist, der an jenem ersten Ende jenseits der besagten Mahlzone endet, um die Bildung von turbulenter Strömung entlang der zentralen Achse jenes Wirbels zu verhindern, wobei der besagte Auslass eine zentrale kreisförmige Öffnung (97) in jener Querwand aufweist, durch welche sich dieser Stöpsel hindurch erstreckt, um mit dieser Öffnung einen ringförmigen Entleerungsdurchgang für jenen zweiten Teil des Fließmittelmediums und den Anteil darin mitgerissenen pulverigen Materials zu definieren, und dass eine Einrichtung zum Regulieren des Strömungsquerschnitts dieses ringförmigen Entleerungsdurchgangs vorgesehen ist.

7. Vorrichtung nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, dass die Achse jener zylindrischen Zone vertikal ist und die Düsen (41, 86) zur Horizontalen mit einem Neigungswinkel von mindestens $\frac{1}{2}$ des divergierenden Sprühwinkels dieser Düsen geneigt sind, wobei die Düsenrichtung von der Richtung eines Radius dieser Achse der zylindrischen Zone um einen Winkelabstand von mindestens $\frac{1}{2}$ des divergierenden Sprühwinkels versetzt ist.

8. Verfahren zum Zerkleinern körnigen Materials mit Teilchen unterschiedlicher Masse, bei dem das Material in einer Fließmittelströmung innerhalb eines Gefäßes (12, 82) mitgerissen wird, um während des Mitreisens gegenseitigen Zusammenprall der Teilchen zur Verringerung der Masse mindestens einiger der Teilchen zu ermöglichen, um diejenigen mitgerissenen Teilchen, die leichter als eine gegebene Masse sind, auszutragen und die schwereren im Kreislauf zu führen, dadurch gekennzeichnet, dass ein dem Gefäß zugeführter Primärstrom von Fließmittel einen axial strömenden Wirbel dieses Fließmittelmediums in einer Kernzone (44, 85) innerhalb dieses Gefäßes erzeugt, ein erster Teil des axial strömenden Mediums am abseitigen Ende dieser Kernzone in eine zu dieser Kernzone periphere Zone (46, 98) nach aussen abgelenkt und in einer Sekundärströmung durch diese periphere Zone gerichtet und in jenen primären Strom eingeführt wird, um einen Kreislauf dieses Fließmittelmediums im Sekundärrückstrom durch die Kernzone zu bewirken, ein zweiter Teil dieser Strömung durch einen Auslass am abseitigen Ende dieser Kernzone ausgetragen und pulveriges Material in den umlaufenden Sekundärstrom eingeführt



wird, wobei diese Zerkleinerung dadurch erfolgt, dass dieses Fließmittelmedium in einer Mehrzahl von an Stellen am Umfang dieses Gefäßes (12, 82) nach innen in dieses projizierten Strahlen (42, 92) geliefert wird, wobei jeder Strahl eine zentrale Ausgangsströmung hoher Geschwindigkeit sowie mit zunehmenden Querabständen von dieser zentralen Ausgangsströmung abnehmende Strömungsgeschwindigkeiten ergibt, wobei diese Strahlen zur Schaffung unterschiedlicher Strömungsgeschwindigkeiten zwischen den zentralen Ausgangsströmungen dieser Strahlen im Abstand voneinander stehen, und wobei das körnige Material in den Strömungen dieser Strahlen mitgerissen wird, was ein Zusammenprallen dieser Teilchen innerhalb der Kernzone bewirkt, während jener Sekundärstrom (46, 98) im wesentlichen ein seitliches Aufprallen der Teilchen aus der Kernzone auf die umgebenden Gefäßwandung verhindert.

9. Verfahren nach Anspruch 8, dadurch gekennzeichnet, dass diese Fließmittelmedium eine Ausgangsströmungsgeschwindigkeit in diesen Strahlen im Schallgeschwindigkeitsbereich liefert.

10. Verfahren nach Anspruch 8 oder 9, dadurch gekennzeichnet, dass der axial strömende Wirbel (44, 94) eine zentrifugale Klassifizierung der Teilchen des in diesem Wirbel mitgerissenen körnigen Materials bewirkt, wobei Teilchen einer Größe über einer gegebenen Masse mit dem Sekundärstrom (46, 98) im Kreislauf geführt werden, und wobei ferner die verbleibenden Teilchen mit jenem zweiten Anteil durch einen zentralen, axial jenseits jenes Wirbels angeordneten Entleerungsdurchgang (26, 97) ausgetragen werden, wobei die Ausgangsströmung von jeder Düse (41, 86) einen länglichen ungehinderten Weg ergibt, in welchen die Sekundärströmung neben einer Düse eingeführt wird, und welcher an seinem abseitigen Ende von dieser Sekundärströmung abgefangen wird.

Revendications

1. Broyeur de substances pulvérulentes à énergie fluide comprenant une cuve (12, 82) formant une zone de broyage, un dispositif d'alimentation pour introduire un fluide transporteur et la matière pulvérulente dans la cuve d'une manière telle que cette matière soit broyée dans la zone de broyage par des impacts interparticules, un dispositif d'évacuation (26, 97) par lequel la matière broyée est évacuée de la cuve et une zone, dans l'ensemble cylindrique, dont l'axe est disposé en substance au centre dans la cuve entre la zone de broyage et le dispositif d'évacuation, caractérisé en ce que plusieurs ajutages d'éjection (41, 86) espacés circonférentiellement sont prévus pour injecter le fluide transporteur dans la zone de broyage dans une direction comprise entre un rayon passant par l'axe de la zone cylindrique et une

direction perpendiculaire à ce rayon, tous les ajutages (41, 86) étant disposés de manière à injecter un flux primaire de fluide transporteur dans la dite cuve à travers la zone de broyage, les ajutages coopérant avec un fond clos (14, 84) de la cuve et avec le dispositif d'évacuation (26, 97) de manière à produire un tourbillon (44, 94) à écoulement axial dans la zone cylindrique, la cuve comportant une cloison transversale (25, 83) située à l'autre extrémité et placée à distance de la dite zone de broyage pour intercepter le tourbillon à écoulement axial et dévier au moins une première partie du fluide de ce tourbillon vers l'extérieur dans une zone annulaire (46, 98) périphérique au tourbillon, le fluide dévié dans cette zone périphérique s'écoulant dans une direction opposée à la direction d'écoulement axial du tourbillon sous la forme d'un flux secondaire et étant introduit dans le flux primaire sortant des ajutages (41, 86) pour provoquer une remise en circulation du fluide transporteur à l'intérieur de la cuve, le dispositif d'alimentation (35, 88) introduisant de la matière pulvérulente dans le flux du fluide transporteur de telle sorte que la matière ainsi introduite soit amenée dans le flux primaire en vue de son broyage par énergie fluide, le dispositif d'évacuation (26, 97) situé à l'extrémité éloignée du tourbillon étant à même d'extraire une seconde partie du dit fluide et, avec celui-ci, une fraction de la substance pulvérulente dont la masse a été réduite au-dessous d'une limite prédéterminée dans la zone de broyage.

2. Broyeur suivant la revendication 1, caractérisé en ce qu'il comprend un dispositif (16) pour régler l'état du fluide transporteur fourni aux ajutages (41, 86) afin d'assurer que l'intensité du tourbillon dans la zone cylindrique soit suffisante pour provoquer une circulation rotationnelle dans le dit tourbillon sur au moins 90° entre l'un quelconque des ajutages et le dispositif d'évacuation.

3. Broyeur suivant la revendication 1 ou 2, caractérisé en ce que les ajutages (41, 86) ont un angle de divergence sous lequel ils projettent le fluide qui est à une vitesse élevée à leurs sorties et dont la vitesse décroît à mesure que l'on s'éloigne du lieu d'émergence du flux sortant des ces ajutages, les dits ajutages étant espacés les uns des autres d'une distance suffisante pour provoquer des variations de vitesse de circulation à des endroits situés entre le flux émergeant à vitesse élevée d'ajutages voisins, la zone de broyage autorisant des trajets de circulation suivant lesquels le flux émergeant de chacun des ajutages ne rencontre aucun obstacle entre les ajutages et la partie de paroi de la cuve (12, 82) opposée à chacun de ces ajutages, les trajets de circulation sans obstacle aboutissant sur la dite partie de paroi opposée et étant interceptés par le flux secondaire provenant de la zone périphérique près de la partie de paroi opposée.

4. Broyeur suivant l'une quelconque des revendications précédentes, caractérisé en ce



qu'un guide annulaire (102) est monté à l'intérieur de la cuve pour séparer une partie de la zone cylindrique de la partie environnante de la zone périphérique, le guide s'étendant au-delà de la zone de broyage vers une région espacée de la cloison transversale (83) à son autre extrémité, de sorte que le dit fluide transporteur forme un flux primaire se déplaçant axialement vers l'autre extrémité dans le dit guide annulaire, ainsi qu'un flux secondaire dirigé axialement vers la première extrémité à l'extérieur du guide annulaire, le dispositif d'alimentation (88) comprenant un orifice dans l'enveloppe cylindrique (82) en face du guide de telle sorte que la substance pulvérulente soit introduite dans le flux secondaire du fluide transporteur.

5. Broyeur suivant l'une quelconque des revendications précédentes, caractérisé en ce que le dispositif d'alimentation comprend un orifice (89) débouchant dans la zone de broyage de telle sorte que la substance pulvérulente puisse être introduite directement dans la zone de broyage.

6. Broyeur suivant la revendication 4, caractérisé en ce qu'un noyau allongé 104 est disposé axialement dans la dite zone cylindrique se terminant à la dite première extrémité au-delà de la zone de broyage afin d'empêcher la formation de courants parasites le long de l'axe central du tourbillon, le dispositif d'évacuation comprenant une ouverture circulaire centrale (97) dans la cloison transversale, par laquelle le noyau passe de manière à délimiter avec cette ouverture un passage annulaire de décharge de la dite seconde partie du fluide et de la fraction de la substance pulvérulente entraînée dans ce fluide, et un dispositif est prévu pour régler la section du passage de décharge annulaire.

7. Broyeur suivant l'une quelconque des revendications précédentes, caractérisé en ce que l'axe de la zone cylindrique est vertical et les ajutages (41, 86) sont inclinés sur l'horizontale d'un angle qui est égal au moins à la moitié de l'angle de divergence suivant lequel les ajutages projettent les jets, l'orientation des ajutages étant décalée de celle d'un rayon passant par l'axe de la zone cylindrique, l'écart angulaire étant au moins égal à la moitié de l'angle de divergence suivant lequel les ajutages projettent les jets.

8. Procédé de fractionnement d'une substance pulvérulente dont les particules ont des masses différentes, suivant lequel on entraîne la matière dans un flux de fluide dans une cuve (12, 82), on permet des chocs interparticules pendant l'entraînement pour réduire la masse d'au moins certaines particules, on sépare les particules entraînées sur base de leur

masse de manière à décharger les particules d'une masse inférieure à une masse donnée et à remettre en circulation les particules plus lourdes, caractérisé en ce qu'un flux de fluide primaire introduit dans la cuve produit un tourbillon axial du fluide dans une zone de veine centrale (44, 85) à l'intérieur de la dite cuve, une première partie du fluide s'écoulant axialement est déviée vers l'extérieur à l'extrémité éloignée de la zone de veine centrale dans une zone (46, 98) périphérique à la zone de veine centrale, la première partie du fluide est dirigée selon un flux secondaire à travers la zone périphérique et est introduite dans le flux primaire pour remettre ce fluide en circulation à contre-courant à travers la zone de veine centrale, une seconde partie du flux est déchargée par une sortie située à l'extrémité éloignée de la zone de veine centrale et de la matière pulvérulente est introduite dans le flux secondaire de recirculation, le dit fractionnement étant produit par création à l'aide du fluide de multiples jets (42, 92) projetés vers l'intérieur de la dite cuve (12, 82) à partir d'endroits adjacents à sa circonférence, chaque jet produisant un flux central à grande vitesse à sa sortie et des vitesses d'écoulement décroissantes à mesure que l'on s'écarte transversalement du flux central sortant, les jets étant espacés les uns des autres de manière à fournir des vitesses d'écoulement variables entre les flux centraux de ces jets, la matière pulvérulente étant entraînée dans les flux des jets, de sorte que des chocs se produisent entre les particules dans la zone de veine centrale, tandis que le flux secondaire (46, 98) empêche toute projection substantielle des particules latéralement par rapport à la zone de veine centrale vers la paroi environnante de la cuve.

9. Procédé suivant la revendication 8, caractérisé en ce que le fluide détermine une vitesse d'écoulement de sorte dans les jets situés dans la plage de la vitesse du son.

10. Procédé suivant la revendication 8 ou 9, caractérisé en ce que le tourbillon s'écoulant dans le sens axial (44, 94) provoque une classification par centrifugation des particules de la matière pulvérulente entraînée dans le tourbillon, les particules d'une masse supérieure à une valeur donnée étant remises en circulation avec le flux secondaire (46, 48) et on décharge les particules restantes avec la seconde partie du fluide par un passage d'évacuation central (26, 97) disposé dans l'axe au-delà du tourbillon, le flux sortant de chaque ajutage (41, 86) déterminant un long trajet dépourvu d'obstacle, le flux secondaire étant introduit dans le trajet près d'un ajutage et le trajet étant intercepté par le flux secondaire au niveau de son extrémité éloignée.

