

Aug. 10, 1965

55 KARL-HEINZ OEHLRICH 3,
APPARATUS FOR MIXING AND SEPARATING SUBSTANCES
OF DIFFERENT MASS-INERTIA
1961

3,199,270

Filed March 27, 1961

3 Sheets-Sheet 1

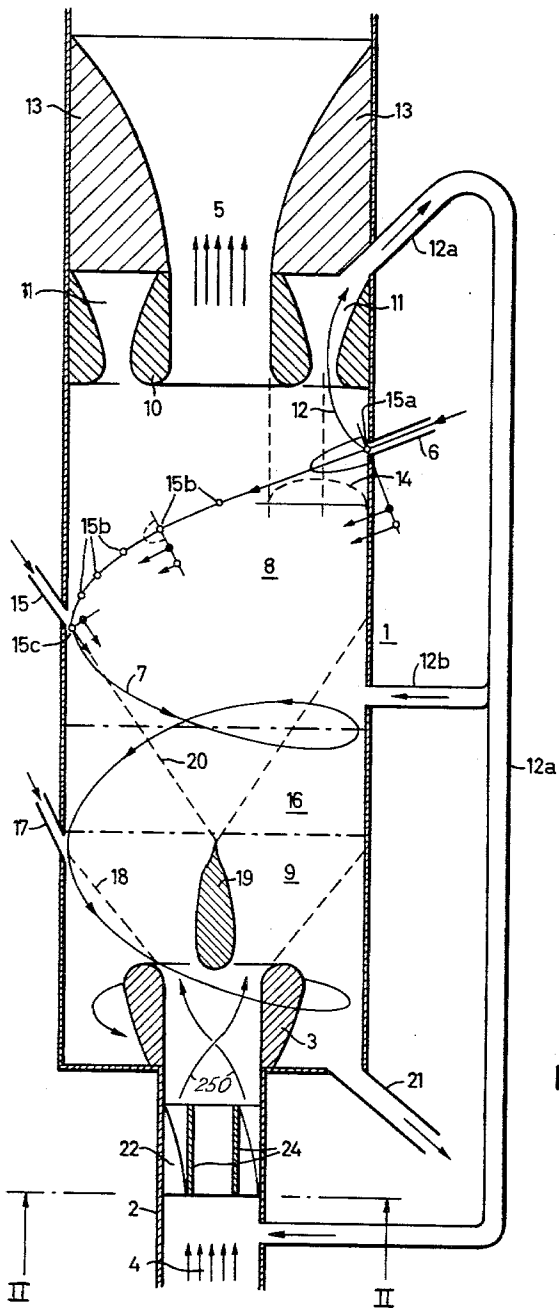


Fig. 1

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3 Sheets-Sheet 2

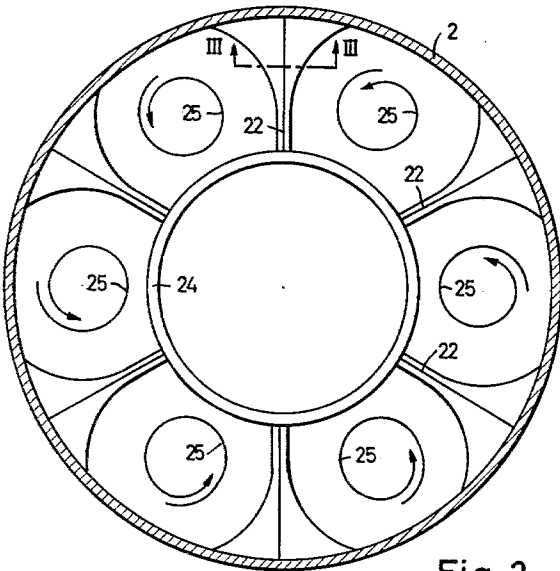


Fig. 2

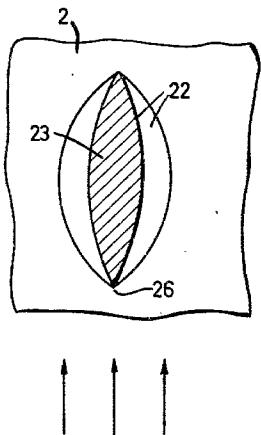


Fig. 3

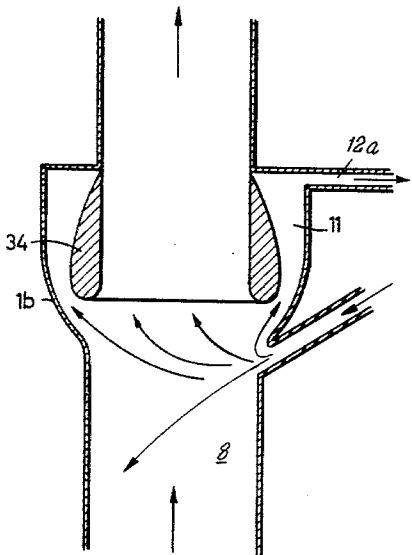


Fig. 5

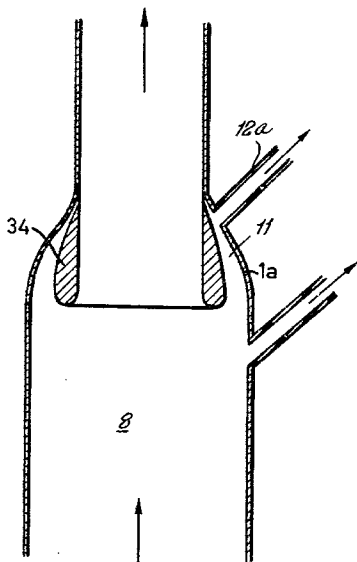


Fig. 6

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3 Sheets-Sheet 3

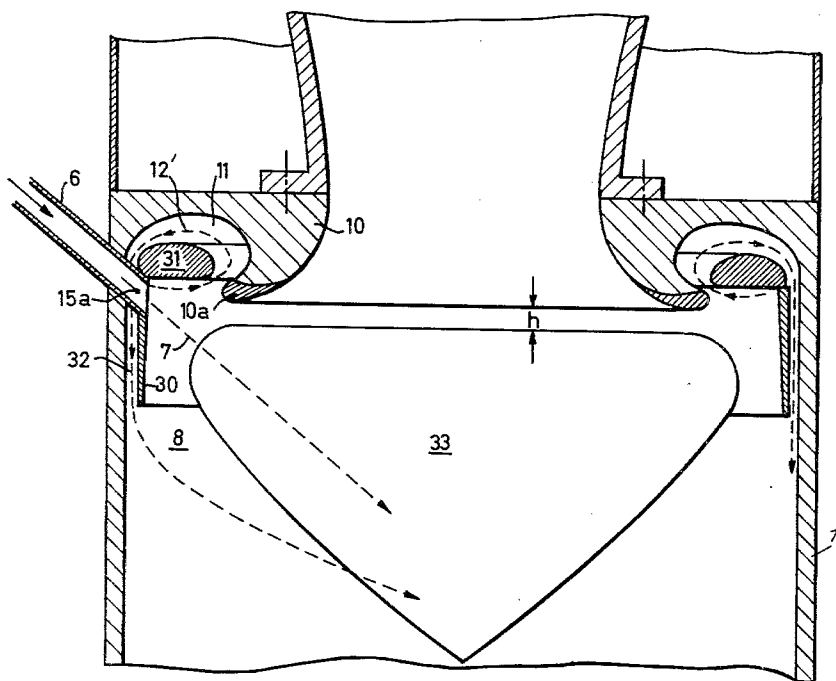


Fig. 4a

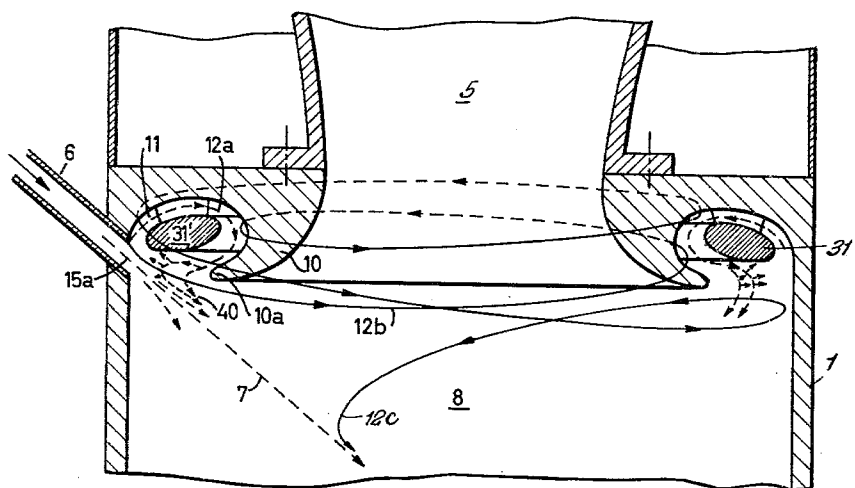


Fig. 4b

1

2

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APPARATUS FOR MIXING AND SEPARATING SUBSTANCES OF DIFFERENT MASS-INERTIA

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Filed Mar. 27, 1961, Ser. No. 93,604

Claims priority, application Germany, Mar. 25, 1960,

S 67,735

16 Claims. (Cl. 55-261)

My invention relates to apparatus for combining and separating substances according to the principle of utilizing differences in their mass-inertia with superimposed primary, secondary and tertiary flows and, more particularly, to dust-from-gas separating apparatus of this type.

Methods and devices involving the just-mentioned principle are described in the copending applications Serial No. 835,886, filed August 25, 1959, and Serial No. 862,570, filed December 29, 1959, and now abandoned, and Serial No. 24,391, filed April 25, 1960, all assigned to the assignee of the present invention. According to these methods, potential flow current and rotational flow currents are excited in the substances to be combined or separated, for example by means of injection nozzles or stirrer devices, in such a manner that both flow currents rotate in the same sense and coaxially, each as a rotary flow above a solid or rough ground with spatial vortex sources and vortex sinks and thereby produce Coriolis and so-called relative forces. A jet flow from a nozzle tangentially introducing secondary air entrains dust particles from an axial primary raw-gas flow. This secondary jet flow forms an outer potential flow. This potential flow is caught before it can flow into an annular back-pressure or quiescent zone, as manifested for example by a dust-enriched ring space, and is directed instead into a collector space from which the dust is discharged. The terms and phenomena involved in these flow principles will be further explained below.

According to one of the embodiments particularly for dust removal disclosed in the above-mentioned application Serial No. 835,886, dust-laden smoke-gas enters axially into a processing container through an inlet duct, and a circulating flow is excited by blowing a medium, such as air, into the container through respective tangential ducts or injection nozzles which are downwardly inclined. The resulting ring-shaped flow of gas constitutes a "rough ground" of the flow system, for separating dust from the raw smoke gas.

The performance of the method in accordance with the above-mentioned principles disclosed in copending application Serial No. 835,886, however, requires a relatively large amount of energy for the supply of secondary air through the above-mentioned injection nozzles or stirrer devices.

It is therefore an object of my invention to afford reducing the secondary-air energy to a correspondingly low value without impairing the degree of dust separation.

According to my invention, relating to an apparatus of the above-mentioned type, particularly for dust separation from a raw gas, I provide a series of secondary air injection nozzles, and a flow-line or stream-lined body located immediately beyond the last secondary-air injection nozzle of the nozzle series, considered in the flow direction of the raw gas. This stream-lined body is preferably of annular shape, and serves to build up the pressure at its location in an inward radial direction, and thus increases the peripheral component and width of the outer potential flow.

According to another feature of my invention, I provide one or more auxiliary secondary-air nozzles, each effecting an increase in speed of the main jet flow. The

auxiliary nozzles are positioned to inject air into a path which corresponds to the flow path of the main jet flow of secondary air, which preferably has a spiral or helical shape. I further provide additional nozzles at the height of, or ahead of, a stream-line body located at the raw-gas outlet, these additional nozzles serving to overcome the friction loss between the raw-gas flow and the nozzle main jet flow which attains a high dust concentration, e.g. about 500 grams/Nm.³ (Nm.³ representing one cubic meter of gas at 0° C. and 1 atm. pressure at sea level).

The invention will be further described with reference to the accompanying drawings showing various embodiments of the invention by way of example.

FIG. 1 is an axial sectional view of a dust separator according to the invention.

FIG. 2 is an enlarged horizontal cross section along the line II—II indicated in FIG. 1.

FIG. 3 is a section taken along the line III—III in FIG. 2.

FIG. 4a is an axial section through part of a modified dust separator otherwise similar to FIG. 1.

FIG. 4b is an axial section of another modification.

FIGS. 5 and 6 show two further modifications in a dust separator otherwise similar to that of FIG. 1.

The same reference numbers are used to designate the same or similar items in the various figures.

Before describing the illustrated embodiments, the fluid-flow phenomena will be explained, the effects involved described, and definitions given for various terms used.

(a) *Potential flow*.—Assuming a homogeneous and friction-free flow, this term denotes a flow in which the individual fluid particles do not rotate about their own axis.

(b) *Rotational flow*.—This denotes a flow in which the individual fluid particles rotate about their own axis.

(c) *Solid ground*.—This denotes, for example, a plate which extends transverse to the flow direction, upon which the flow impinges perpendicularly, and which deflects the flow. When this plate is given roughness a "rough ground" is involved.

(d) *Sources and sinks*.—If a fluid flows from a point between two parallel plates uniformly in all directions to the outside, then this form of flow is called a "source." However, if, conversely, the fluid arriving uniformly from all sides exits into one point, this point is called a "sink" or "vortex-sink."

(e) *Deformed plane* is a "spatial" plane, for example, the surface of a water eddy which narrows downwardly in conical shape.

Fluid flows in which no internal friction occurs, are called "potential flow." Due to the absence of internal friction, a potential flow is not subjected to internal energy losses so that the total energy initially inherent in the flow remains preserved. In flows of fluid occurring in nature, friction is essentially limited only to the zones of the boundary layer at those surfaces which limit the flow, whereas the friction within the flow itself is approximately zero. At the contacted boundary surfaces the occurring friction results in formation of sheering forces which withdraw energy from the flow. This energy is in part consumed for releasing a secondary flow. Hence a distinction must be made between the primary flow constituted by the energy dissipating flow, and the secondary flow which receives energy from the primary flow. In many cases, the secondary flow possesses greater technological importance than the primary flow causing the second flow.

When producing a flow within a containing vessel, the occurring secondary flow receives its energy from the sheering forces which the primary flow exerts upon any wall portions, for example upon the lateral walls, and on the so-called "ground." Without friction at boundary sur-

faces, no secondary flow can take place. With increased friction at the boundary surfaces, the shearing forces adjacent to the wall are increased and the resulting secondary flow is likewise increased. The original or impressed primary flow always becomes superimposed by a secondary flow as soon as any surfaces, for example the side walls or the ground, limiting the flowing medium produce an appreciable amount of friction. In practice, this is always the case to a greater or lesser extent. The secondary flow caused by the shearing forces at the friction-producing surfaces penetrates far into the original, primary flow because the secondary flow, which may again be looked upon as being the source of a tertiary flow, may likewise have no appreciable internal friction. It is possible, therefore, that a secondary flow, in turn, may dissipate energy at a rough surface to a tertiary flow, whereby of course the formation of the secondary flow is subjected to modification.

The foregoing explanation forms a basis for the understanding of fluid motions which in fluid mechanics are termed "circulatory flow above a solid ground" and which are of interest for the present invention. It will be understood that, when a liquid in a cylindrical or similarly shaped rotationally-symmetrical vessel is subjected to stirring motion about the vessel axis, the flow produced by the stirrer can be looked upon as being a primary flow. This primary flow releases a secondary flow, the possible formation of tertiary or further derivative flows being at first ignored. With such a stirring motion, the liquid is not only placed in circulating motion at the outer rim of the vessel but is also pressed downwardly. The flow lines directed downwardly at the external perimeter then run together on the bottom of the vessel near the vessel center, and the flow then moves upwardly in the center range. After reaching the surface zone, the flow lines again extend from the center radially outwardly.

This flow extending vertically downward and upward as well as toward the center at the bottom and toward the periphery at the top, superimposes itself upon the primary circulatory flow. Consequently, the liquid particles move on the periphery on a helical line downwardly but when they reach the vessel bottom, the motion converts to an approximately logarithmic spiral along which the particles reach the center whence they rise near the center axis. The ascending motion in the center takes place in form of a rotational motion along a helical line of relatively narrow diameter (vortex filament) depending upon the active range of the shearing forces. On the top surface, the course of the flow again corresponds to a spiral, now extending from the center outwardly.

The flow motion just described constitutes a simple form of the one usually designated in fluid mechanics as "circulatory flow above a solid ground" (coffee-cup flow).

The merging of all flow lines in the center of the ground is tantamount to the formation of a vortex sink from which a vortex filament, being a rotational flow, extends upwardly. At a certain height, inversely proportional to the square root of the angular velocity, a special vortex source forms itself. In the vortex source there occurs a surprising effect explained further below.

If different substances are present in the flow, or if with one and the same medium there are particles of respectively different phase or configuration, then the particles split off from the vortex source are flung outwardly and may reach the downwardly directed stirrer flow located outside of the vortex source and extending helically downward. This stirrer flow, representing the exciting or primary flow, conveys the flung-away particles to the outer rim zone of the vessel bottom. It is essential, however, that such particles are not driven against the vessel wall but are kept on a cylinder surface by virtue of non-centrifugal forces still to be explained. Consequently, the particles remain within the flow and, contrary to what is usually expected are not carried by centrifugal forces against the vessel wall. It is obvious, therefore, that

forces are active that are not identical with centrifugal force.

The distance of the vortex source from the solid bottom further depends upon the roughness of the bottom which, physically, constitutes the "solid ground." The excitation energy for the tertiary flow, taken from the secondary flow, increases with increasing roughness as will readily be understood from the foregoing explanations. Consequently the position and shape of the vortex source can be predetermined by the design of the rough ground. A concave ground imparts to the vortex source a shape contracted in the radial direction. A convex design of the ground results in deformation of the vortex source to a fuller shape radially expanded outwardly. In the latter case the vortex source closely approaches the external primary flow extending helically downward. Due to this short distance, there is a greater probability that a fluid particle flung out of such a vortex source will be carried out into the primary flow and will thus be separated. Consequently for each particle there is a certain separation probability which follows statistical laws and which, as a rule, is to be kept as high as possible in all cases where a separation, for example a dust separation, is desired. If the flow is to be utilized for reducing or eliminating noise or sound, then the boundary line or area, usually designated as "deformed plane" must extend as a closed area around the source of the sound. The foregoing examples will suffice for indicating the particular requirements that can be met by the circulatory flow, depending upon the particular purpose for which the invention is to be used.

The consideration of the resulting vortex sinks and vortex sources facilitate understanding the "relative forces" referred to in this disclosure. The vortex sink forming itself at the bottom of the processing vessel, is comparable with the vortex sink occurring when draining liquid through a drain pipe. The rotating velocity of the fluid particles increases when the particles approach the vortex filament, a phenomenon often observable when draining water from a bathtub. The peripheral velocity of the particles decreases gradually with increasing distance from the vortex source. The vortex filament extends between the vortex sink and the vortex source. While in a drainpipe there occurs a downwardly directed helical motion, the flow conditions here of interest have a vortex filament which, as explained, extends upwardly.

If one lays an imaginary cross section horizontally through the vortex filament beneath the vortex source, the resulting flow-field picture is such that the peripheral speed of the fluid particles at first increases with increasing distance from the center of the vortex filament of the circulatory flow.

However, a different flow-field picture is obtained if one extends an imaginary cross section horizontally through the vortex sink in the vicinity of the bottom. Now the particles travel approximately on a logarithmic spiral inwardly. An imaginary horizontal cross section in the vicinity of the upper surface, extending through the vortex source, would show a travel of the particles substantially along a logarithmic spiral in the outward direction.

While a horizontal section through the middle of the processing vessel does not offer further interesting flow configurations, the imaginary horizontal sections in the vicinity of the top surface offer information about the particle motion on inwardly and outwardly directed spiral paths upon which an acceleration on the one hand, and a deceleration on the other hand is obtained. For a particle that, within the vortex filament, moves upwardly, the peripheral velocity, therefore, must change spontaneously as the particle enters into the vortex source. The same applies to the angular velocity because the particle, as set forth above, passes from a rotational flow into a potential flow and vice versa. Due to the occurring change in velocity and angular velocity, the particle

is subjected to acceleration. Thus there occurs a force which is proportional to that acceleration and to the particle mass and which is directed toward the interior at the vortex sink and toward the outside at the vortex source. This force, having the character of a Coriolis force, is called "relative force."

Also effective, simultaneously with the relative force explained above, is a centrifugal force which has the same direction as the relative force in the vortex source but which is opposed to the relative force in the vortex sink. As a result, a virtually spontaneous spreading-apart of the particles comes about in the vortex source, whereas a corresponding phenomenon in the vortex sink takes place more slowly and in the opposite sense. It will be recognized that the relative force must be considerably stronger than the centrifugal force.

It may be added at this place that, due to the circulatory flow, there is also produced an additional, sinusoidal relative force. This sinusoidal force, in accordance with a further feature of the invention, can be taken advantage of by virtue of the fact that it manifests itself, for example in air flows, as infra-sonic action and causes a viscosity increase by orders of magnitude, as will be further explained hereinbelow. As a result, for example when applying this phenomenon in a suitable boiler firing system, the combustion is considerably promoted.

The described relative forces, as explained, originate in the transition zone between rotational flow and potential flow, and the rotational flow may occur above or below the potential flow as well as within or outside thereof or also conjointly with the potential flow or at a plurality of localities in alternating sequence.

As above mentioned, a considerable amount of energy has heretofore been required for introducing the secondary air through the injection nozzles which produce the stirring action. If one takes into account a pressure of 10,000 mm. WC (water column) just ahead of an injection nozzle for introducing secondary air, and a secondary-air quantity corresponding to ten percent of the raw-gas quantity, then the energy consumption for the supply of the secondary air is approximately 1000 mm. WC, relating to the entire flow of raw gas, plus an increase of about 100 mm. WC corresponding to the pressure drop in the raw gas. Thus the entire energy consumption for the secondary air is approximately 1100 mm. WC relating to the entire gas flow. This energy consumption, however, is too high, because for reasons of economy the total energy required for the injection of secondary air should not exceed a value of 300 to 500 mm. WC, relative to the entire raw-gas flow.

The dust separator vessel according to FIG. 1 is provided with a cylindrical jacket 1 of sheet metal which communicates with a raw-gas inlet conduit 2 at the bottom of the jacket. The exit opening from inlet conduit 2 into the jacket 1 is formed by a streamlined ring-shaped body 3 whose walls and outer diameter widen in the upward direction so as to make it tulip shaped. The raw-gas flow, or primary flow, schematically denoted at its inlet by a group of arrows 4, enters from below into the separator vessel, travels in an axial direction and leaves the top of the separator as a clean-gas flow at outlet conduit 5. A jet of secondary air is injected into the gas flow within the processing space of the jacket 1 by means of a nozzle 6. This nozzle 6 is downwardly inclined toward the jacket 1 and also extends tangentially to the main-gas flow. Consequently, the secondary-air jet issuing from nozzle 6 travels on a spiral or helical path schematically indicated at 7. This path extends through the separator space 8 into the collector space 9 of the separator. The air entering at 6 is heavily laden with dust particles, at a concentration of from 500 to 750 grams per cubic meter at normal conditions of temperature and pressure.

Located closely above the air nozzle 6 is a streamlined ring-shaped body 10 which has an inner and outer ring

portion defining a ring-shaped recess 11 which widens upwardly in diffuser fashion. This channel or recess 11 receives the waste portion of the secondary air issuing from the nozzle 6. The recess 11 is located at a place of maximum pressure, as is schematically indicated at 14 by a curved dotted line which denotes the varying pressure across the radial width of the ring body 10. With any nozzle injection a certain amount of ineffective or waste flow inevitably occurs to the side. In the present case, the jet from nozzle 6 entrains dust, and a portion of the waste flow therefrom is forced into the diffuser recess 11, which directs it into a conduit to recycle this dust-laden air flow back into the separator by reversing its flow direction 180° or more. For this purpose, the recess space 11 is connected with the raw-gas inlet duct 2 by the dust discharge pipe or conduit 12a, or alternately it is connected by a dust discharge pipe 12b with the separator space 8, or, as shown in FIG. 1, all the above-mentioned connections may be provided simultaneously. A catch nozzle may be provided between the dust lines 12a or 12b and the conduit 2 or the separator vessel 1. The ring body 10 can be given any suitable inner diameter, the separation between the clean gas at 5 and the dust laden gas at 11 being improved with smaller inner diameters of ring body 10. At its tail or outlet side relative to the direction of the gas flow, the ring body 10 is provided with a diffuser-like tail portion 13 for recovering or re-establishing the desired pressure of clean gas flow 5.

If the secondary-air injection nozzle 6 is substituted by several such nozzles, the product of the total secondary-air injection area $n \cdot F_D$ (wherein n is the number of nozzles and F_D is the injection area of each nozzle) times the applied pressure just ahead of the nozzles (Δp) remains constant for a predetermined quantity of secondary-air. This corresponds to the mathematical relation

$$n \cdot F_D \cdot \Delta p = \text{const.}$$

It follows from this relation that doubling the secondary air injection area F_D permits cutting the injection pressure to one-half. However, such an arrangement of a plurality of secondary-air nozzles 6 on a straight line behind each other, seen in the flow direction 4 to 5 of the raw gas, often permits accommodating only a limited number of nozzles for lack of space.

One or more auxiliary nozzles 15 are therefore provided at spaced locations along the helical course of the flow 7 from main nozzle 6. The velocity of the air entering with entrained dust from nozzle 6 normally would tend to decrease with increasing distance from nozzle 6, while the velocity of the dust, being heavier would not decrease as rapidly as the air velocity. The auxiliary nozzles 15 serve to again accelerate the specifically lighter medium, for example the main nozzle air back to the local speed of the specifically heavier and thus leading medium, such as the dust particles. Consequently, at each of the nozzles 15, of which the effect of only one is illustrated by velocity vector arrows of equal length at 15c, the speed of the specifically lighter particles or medium again corresponds to the speed of the specifically heavier particles.

The respectively different velocities of air and dust particles within the main nozzle flow path 7, laden with dust, are schematically indicated by arrows of respectively different lengths at the individual nozzle injection points 15a, 15b and 15c. The vector arrows indicating air velocity are attached to white dots and the vector arrows indicating dust particle velocity are attached to black dots. At the location 15a, immediately in front of the injection nozzle 6, the specifically lighter particles or medium still have the same speed as the specifically heavier particles. At the location 15b however, the latter have advanced in relative velocity. At the nozzle injection point 15c of nozzle 15 the heavier particles again have the same velocity as the specifically lighter air medium.

The provision of one or more auxiliary nozzles 15 on a spiral-shaped path corresponding to the travel path 7 of the nozzle main jet, causing a speed increase of the main jet flow from nozzle 6 affords a means for reducing the energy consumption down to a fraction of the value heretofore required for satisfactory separation. The auxiliary nozzles 15, arranged along the nozzle main jet 7 that extends spirally in opposition to the direction of the raw-gas flow, have the effect of stepwise increasing the speed of the nozzle main jet which normally would otherwise decrease in proportion to the distance from the main nozzle 6.

The following speed relations result with respect to the nozzle main jet 7:

The specifically heavier particles within the nozzle main jet 7 lead the specifically lighter air flow in velocity due to the greater inertia of the particles. Consequently these heavier particles, due to the retardation of the air current in the flow are, so to say, carried into a region of static overpressure. The auxiliary nozzles 15 mounted in a spiral arrangement impart to the air current of the jet flow 7 such an acceleration that, at each of the respective nozzle injection points 15a, 15b, 15c, the specifically lighter particles again attain the speed of the specifically heavier particles.

After the speed has been increased by the action of the last auxiliary nozzle at the location 15c, the path 7 of the injected main flow leaves the separator space 8 and enters into a quiescent region 16 before it passes into the collector space 9 of the separator. An additional nozzle 17 is provided, directed into space 9, for supplementing the energy loss consumed by friction between the raw-gas flow 4 to 5 and the injected main flow 7 which is enriched with dust in high concentration (500 to 750 g. Nm.³). The additional catch nozzle 17 is located between dust line 12a or 12b and conduit 2 and serves to advance the dust-enriched quantity into the collector space 9. Simultaneously, a first dust cone 18, promoting the separation, is formed within space 9 by the interacting flow currents. A streamlined body is positioned within the dust cone 18 and supported within the jacket 1 just beyond the opening of raw-gas inlet 3. On the downstream side of body 19 a second dust cone 20 forms itself. This streamlined body 19, also called a "Dobbas" has a tear drop or onion-shaped downstream tip so that the tip angle formed is as close as possible to zero, as in the known Joukowski type vane.

After the nozzle main flow 7 has passed by the first one of the mutually closely spaced nozzle injection points, as seen in the flow direction of the raw gas, it enters into the so-called quiescent region 16, mentioned above, in which no excitation of the flow takes place. At the height of the tear drop-shaped streamlined body (called "Dobbas") mounted at or ahead of the raw-gas outlet, the nozzle main flow is again amplified for overcoming the friction between the nozzle jet and the raw-gas flow, this amplification being effected by another nozzle, before the gas flow enters into the collector and discharge space.

The building up of pressure ahead of the ring-shaped body 10, mounted according to the invention at the pure-gas outlet 5, takes place in accordance with the mathematical relation

$$\frac{\partial p}{\partial r} = -\rho \cdot w^2 \cdot \Delta R \cdot 4$$

In this equation:

ΔR =radial width of the ring-shaped body

w =peripheral speed

ρ =density of the medium

The minus sign indicates the direction: radial toward the outside.

By virtue of the invention, the energy requirements are greatly reduced, not only with respect to the input pressure of the secondary air nozzles 6, 15 but also with

respect to the quantity of air passing through the nozzles.

Another advantage of the invention is the fact that the angle of inclination of the secondary-air nozzles 6, 15 produce the nozzle main jet flow 7, can be chosen shallower, i.e. less steep, than with the method according to the above-mentioned copending application Serial No. 835,886. This results in an increased peripheral speed. For example, the inclination angle α of the nozzles 6 may be 35 or even 30° in lieu of the 40° according to the prior application.

Located in the raw-gas inlet duct 2 are guide vanes 22 (FIGS. 1, 2) which pre-excite a potential flow in the raw gas. These guide vanes 22 constitute additional means for reducing the secondary-air energy. The structure and shape of the guide vanes 22 is shown in plan view in FIG. 2. A cylindrical tube 24 which interconnects the vanes is provided in the center of duct 2. The radial cross section of each of the guide vanes 22 increases toward the outer conduit wall 2. A good relative-vortex formation 25 is thus obtained between each of the guide vanes 22. These vortices 25 are the starting points of a dust-conveying flow 250, called the dust helix, which issues from exit opening 3 of conduit 2.

This pre-excitation by vanes 22, however, acts only upon part of the raw-gas flow and, since this excitation takes place without appreciable energy supply, constitutes the cheapest way of exciting a potential flow.

The upstream side of the guide vanes 22, as shown in FIG. 3, is given a sharp edge at 26 so that a lancet-shaped or double-edged curved cross section 23 will result. For safety reasons, to provide an unimpeded passage for sudden pressure developing in the eventuality of a possible explosion, the guide vanes 22 fill the tubular cross section only over the width of the annulus between 24 and 2, so as to always leave a portion of the cross section free for unimpeded passage of the gas flow.

By virtue of the structural shape of the cylindrical ring tube 24 and the guide vanes 22 with a sharp-edge 26 at the upstream side, the formation of a point of back-pressure flow at this upstream side is prevented, thus also preventing adherence of the specifically heavier dust particles. The "relative vortex" 25 mentioned above, comes about by the fact that normally the peripheral speed of particles tends to increase when they travel on a path toward a smaller periphery, e.g. when they travel from the periphery of conduit 2 toward the central axis of the raw-gas flow. These particles, however, are deflected during their travel by the guide vanes 22 and are forced to move on paths that are directed radially inward, and this is the cause of the vortex formation at 25.

FIGS. 4a and 4b show two modified embodiments of a particular construction of the hollow-ring recess 11 at the upstream side of the ring body 10 for guiding the waste-air flow 12 from the secondary-air nozzles 6 and 15. The same reference characters are used as in FIG. 1 for respectively corresponding components.

The ring-shaped recess 11 which has an undercut shape constitutes a trough which is open in a direction opposed to the flow direction of the raw gas. The ring body 10 is provided with a tulip-shaped edge portion 10a which tapers down radially inwardly and upwardly and is rounded for better guidance of the waste flow 12 from the jet coming from the side air nozzles 6.

According to FIG. 4a, a hollow cylindrical insert 30 is mounted in jacket 1 ahead of the ring body 10, seen in the direction of the raw-gas flow. The insert 30 has a bulging ring portion 31 of lentil-shaped cross section which protrudes into the recess 11. The secondary-air nozzle 6 is inserted at a location between the insert 30 and the bulge 31. While the main jet 7 from nozzle 6 moves, in opposition to the raw-gas flow, downwardly on its helical path (FIG. 1), a waste flow current 12' (FIG. 4a) from the jet of nozzle 6 travels on a logarithmic spiral at first radially inwardly relative to jacket 1, then turns in the recess 11 in a radially outward direc-

tion and passes down back into the separator space 8 through a ring space 32 between insert 30 and jacket 1. The ring space 32 widens in the flow direction to act as a diffuser. At the nozzle-outlet opening 15a there obtains a higher pressure than in the ring space 32 so that the flow path of the waste flow current 12 remains stable.

The above-mentioned ring-shaped flow-guiding body 10, which according to the invention especially with insert 30, 31 produces a widening of the outer potential flow radially inwardly and which thereby increases the peripheral component of the potential flow, has the result of augmenting the separating forces and the radial build-up in pressure ahead of the ring 10. This built-up pressure effects a stabilization of the nozzle main jet flow 7, an increase in pressure down to the lower portion of the dust collecting and discharging space, and thereby a better discharge of the separated medium.

A flow-guiding body 33 may be mounted at a distance h from the ring body 10. By means of this body 33 the radial component of the flow through jacket 1 around body 33 can be increased. As a result, the flow which extends spirally and radially in the inward direction converts within the annular gap between the ring body 10 and the guiding body 33 from a logarithmic to an arithmetic spiral so that a better separation of the particles from the carrier medium takes place. The pressure which is built up in the annular gap from the inner toward the outer side causes a deflection along path 12' of the jet waste flow in the radially upward direction and back through space 32 into the potential flow.

In the embodiment of FIG. 4b the hollow cylindrical insert 30 of FIG. 4a with its bulging portion is substituted by a ring 31' of generally oval cross section which is located in the recess 11. The secondary-air nozzle 6 is inserted into the wall of the separator in the same manner as in the embodiment according to FIG. 1. The current of waste air 12a, after being first deflected from the jet path 7 as it issues from the nozzle outlet at 15a, passes first in the radially outward direction, then along the inner side of the recess 11 and, after being again subjected to a directional change at the location 40, passes into the injected main flow 7. This causes an additional accumulation of dust in the waste flow, this dust being entrained by the main flow 7 and conveyed away therewith. In this case, too, as in the embodiment of FIG. 4a, the static pressure at the nozzle outlet opening 15a is high so that the waste flow current follows a stable path. Another portion 12b of the nozzle waste flow may also flow in multiple turns about the clean-gas outlet opening 5 through the recess 11 around the body 10, and can then be carried away together with the main flow 7, as shown at 12c.

FIGS. 5 and 6 show another structural embodiment and modification of the ring-shaped recess 11. In these embodiments the clean-gas outlet conduit 34, protruding into the separator space 8, is provided with a streamlined cross section, whereas the outer side of the diffuser-like recess space 11 is formed by the inwardly curved tapering wall 1a (FIG. 6) or the outwardly curved widening wall 1b (FIG. 5) of the dust separator vessel. Where the available energy is otherwise too small, to excite the potential flow an outlet opening 1a of the separator which tapers inwardly in the direction of the raw-gas flow, as shown in FIG. 6, additionally stabilizes the waste flow and is generally preferable to a device with a widening outlet opening such as 1b (FIG. 5).

It will be obvious to those skilled in the art, upon a study of this disclosure, that my invention permits of a variety of modifications with respect to the components, their design and arrangement in a dust separator or other apparatus according to the invention and hence that the invention may be given embodiments other than particularly illustrated and described herein, without departing

from the essential features of the invention and within the scope of the claims annexed hereto.

I claim:

1. A dust-from-gas separator apparatus for separating dust entrained in a raw gas, said apparatus comprising a conduit vessel defining a cylindrical vessel space having an inlet at one end and an outlet at the other end, said inlet and outlet defining therebetween a primary flow axis for fluid flow through said vessel space; duct means for introducing said raw gas containing said dust into said inlet along said primary flow axis, a plurality of nozzles disposed around said vessel and terminating at the inner wall surface thereof, said nozzles each having a direction generally tangential to the vessel wall and inclined relative to said primary flow axis for injecting gaseous fluid into said vessel along a main helical flow path in directions around said primary flow axis, said nozzle directions each having a component along said axis toward said inlet so that said main helical flow path superimposes upon the primary flow a rotational secondary flow coaxial with said primary flow axis and forms in said vessel space a vortex sink and a vortex source spaced from each other along said primary flow axis with fluid-entrained solid particles of said dust being caused to concentrate on helical travel paths having components along said primary flow axis due to fluid-internal relative forces, said vessel having means forming a collector space at the lower portion thereof for accumulation of the dust, discharge duct means extending outwardly from said collector space for discharge of the dust therefrom, means disposed near said outlet and forming an annular recess coaxial with said primary flow axis, said annular recess having curved surfaces widening in the flow direction of said primary flow axis.

2. Apparatus for handling solid particle material by entrainment in fluid and for separating said particle material from said fluid, comprising a cylindrical conduit vessel having an inlet at one end and an outlet at the other end, said inlet and outlet defining therebetween a primary flow axis for fluid flow through said vessel space; means for introducing fluid containing solid particle material into said inlet and along said primary flow axis, a plurality of nozzles mounted on said vessel and terminating at the inner wall surface thereof, said nozzles each having a direction generally tangential to the vessel wall and inclined relative to said primary flow axis so as to define a main helical flow path around said axis for injecting fluid into said vessel along said main helical flow path, said nozzle directions each having a component along said axis toward said inlet so that said main helical flow path superimposes upon said primary flow path a rotational secondary flow path coaxial with said primary flow path and forms in said space a vortex sink and a vortex source spaced from each other along said primary flow path with fluid-entrained solid particles being caused to concentrate on helical travel paths having components along said primary flow path due to fluid-internal relative forces, said vessel having means forming a collector space at the lower portion thereof for accumulation of the solid particle material, and discharge duct means extending from said collector space for discharge of the solid particle material therefrom, and teardrop shaped deflecting means disposed in said primary flow path and mounted in said vessel in said collector space adjacent said inlet, and means disposed near said outlet and forming an annular recess coaxial with said primary flow axis, said annular recess having curved surfaces widening in the flow direction of said primary flow axis.

3. A dust-from-gas separator apparatus for separating dust entrained in a raw gas, said apparatus comprising a conduit vessel defining a vessel space and having an inlet conduit for introducing dust-laden raw gas into the vessel and an outlet conduit for discharge of clean gas therefrom, said inlet and outlet conduits being coaxially arranged spaced from each other for passage of the gas

through the vessel space, said inlet and outlet conduits defining together a primary-flow axis extending through said vessel space, agitating means for imparting to the primary flow of the gas in said space a circulatory secondary flow, said agitating means comprising a plurality of nozzles mounted on said vessel and terminating at the inner wall surface thereof, said nozzles each having a direction generally tangential to the vessel wall and inclined relative to said primary flow axis so as to define a main helical flow path around said axis for injecting gaseous fluid along said main helical flow path into said vessel space, said nozzle directions each having a component along said axis toward said inlet conduit so that said agitating means superimposes upon said primary flow in said vessel space a rotational secondary flow coaxial with said primary flow and forming in said space a vortex sink and a vortex source spaced from each other along said primary flow axis, whereby gas-entrained dust particles are caused to concentrate in potential flow on helical travel paths having components along the primary flow direction due to fluid-internal relative forces, means for reducing the energy requirements of the nozzle injection along said main helical path comprising a streamlined ring-shaped body mounted in said vessel coaxial with said primary flow axis and beyond the last of said nozzles considered in the direction toward said outlet conduit for increasing toward said primary flow axis the pressure in the vicinity of said last nozzle while simultaneously increasing the peripheral component and width of said potential flow, said plurality of nozzles including at least one auxiliary nozzle arranged to inject gaseous fluid into said main helical flow path to increase the velocity of said secondary flow, said vessel having means forming a collector space at the lower portion thereof for accumulation of the dust, and discharge duct means extending outwardly from said collector space for discharge of the dust therefrom.

4. A dust-from-gas separator apparatus for separating dust entrained in a raw gas, said apparatus comprising a conduit vessel defining a vessel space and having an inlet conduit for introducing dust-laden raw gas into the vessel and an outlet conduit for discharge of clean gas therefrom, said inlet and outlet conduits being coaxially arranged spaced from each other for passage of the gas through the vessel space, said inlet and outlet conduits defining together a primary-flow axis extending through said vessel space, agitating means for imparting to the primary flow of the gas in said space a circulatory secondary flow, said agitating means comprising a plurality of nozzles mounted on said vessel and terminating at the inner wall surface thereof, said nozzles each having a direction generally tangential to the vessel wall and inclined relative to said primary flow axis so as to define a main helical flow path around said axis for injecting gaseous fluid along said main helical flow path into said vessel space, said nozzle directions each having a component along said axis toward said inlet conduit so that said agitating means superimpose upon said primary flow in said vessel space a rotational secondary flow coaxial with said primary flow and forming in said space a vortex sink and a vortex source spaced from each other along said primary flow axis, whereby gas-entrained dust particles are caused to concentrate in potential flow on helical travel paths having components along the primary flow direction due to fluid-internal relative forces, means for reducing the energy requirements of the nozzle injection along said main helical path comprising a streamlined ring-shaped body mounted in said vessel coaxial with said primary flow axis and beyond the last of said nozzles considered in the direction toward said outlet conduit for increasing toward said primary flow axis the pressure in the vicinity of said last nozzle while simultaneously increasing the peripheral component and width of said potential flow, said plurality of nozzles including auxiliary nozzles helically positioned on the vessel around said primary flow axis directed along a path correspond-

ing to the course of said main helical flow path to increase the velocity of said secondary flow, deflecting means having a teardrop streamlined shape narrowing in the direction of said primary flow and mounted within said collector space on said primary axis near the primary flow inlet conduit, said vessel having means forming a collector space at the lower portion thereof for accumulation of the dust, and discharge duct means extending outwardly from said collector space for discharge of the dust therefrom.

5. A dust-from-gas separator apparatus for separating dust entrained in a raw gas, said apparatus comprising a conduit vessel defining a vessel space and having an inlet conduit for introducing dust-laden raw gas into the vessel and an outlet conduit for discharge of clean gas therefrom, said inlet and outlet conduits being coaxially arranged spaced from each other for passage of the gas through the vessel space, said inlet and outlet conduits defining together a primary-flow axis extending through said vessel space, agitating means for imparting to the primary flow of the gas in said space a circulatory secondary flow, said agitating means comprising a plurality of nozzles mounted on said vessel and terminating at the inner wall surface thereof, said nozzles each having a direction generally tangential to the vessel wall and inclined relative to said primary flow axis so as to define a main helical flow path around said axis for injecting gaseous fluid along said main helical flow path into said vessel space in directions inclined relative to the primary flow axis, said nozzle directions each having a component along said axis toward said inlet conduit so that said agitating means superimpose upon said primary flow in said vessel space a rotational secondary flow coaxial with said primary flow and forming in said space a vortex sink and a vortex source spaced from each other along said primary flow axis, whereby gas-entrained dust particles are caused to concentrate in potential flow on helical travel paths having components along the primary flow direction due to fluid-internal relative forces, means for reducing the energy requirements of the nozzle injection along said main helical path comprising a streamlined ring-shaped body mounted in said vessel coaxial with said primary flow axis and beyond the last of said nozzles considered in the direction toward said outlet conduit for increasing toward said primary flow axis the pressure in the vicinity of said last nozzle while simultaneously increasing the peripheral component and width of said secondary flow, said plurality of nozzles including auxiliary nozzles helically positioned on the vessel around said primary flow axis directed along a path corresponding to the course of said main helical flow path to increase the velocity of said secondary flow, deflecting means having a teardrop streamlined shape narrowing in the direction of said primary flow and mounted in said vessel within said collector space along said primary axis near the primary flow inlet conduit, whereby said main helical flow becomes enriched with dust to a high concentration, said plurality of nozzles including at least one additional gaseous fluid nozzle directed into said collector space for overcoming the frictional energy loss of said secondary flow caused by contact with said primary flow, said additional nozzle being located between said primary flow inlet and a plane normal to said primary flow axis at the narrowest tip of said teardrop shaped deflecting means, said vessel having means forming a collector space at the lower portion thereof for accumulation of the dust, and discharge duct means extending outwardly from said collector space for discharge of the dust therefrom.

6. A dust-from-gas separator apparatus for separating dust entrained in a raw gas, said apparatus comprising a conduit vessel defining a vessel space and having an inlet conduit for introducing dust-laden raw gas into the vessel and an outlet conduit for discharge of clean gas therefrom, said inlet and outlet conduits being coaxially arranged spaced from each other for passage of the gas

through the vessel space, said inlet and outlet conduits defining together a primary-flow axis extending through said vessel space, agitating means for imparting to the primary flow of the gas in said space a circulatory secondary flow, said agitating means comprising a plurality of nozzles mounted on said vessel and terminating at the inner wall surface thereof, said nozzles each having a direction generally tangential to the vessel wall and inclined relative to said primary flow axis so as to define a main helical flow path around said axis for injecting gaseous fluid along said main helical flow path into said vessel space, said nozzle directions each having a component along said axis toward said inlet conduit in opposition to said primary flow so that said agitating means superimpose upon said primary flow in said vessel space a rotational secondary flow coaxial with said primary flow and forming in said space a vortex sink and a vortex source spaced from each other along said primary flow axis, whereby gas-entrained dust particles are caused to concentrate in potential flow on helical travel paths having components along the primary flow direction due to fluid-internal relative forces, means for reducing the energy requirements of the nozzle injection along said main helical path comprising a streamlined ring-shaped body mounted in said vessel coaxial with said primary flow axis and beyond the last of said nozzles considered in the direction toward said outlet conduit for increasing toward said primary flow axis the pressure in the vicinity of said last nozzle while simultaneously increasing the peripheral component and width of said potential flow, said body having an internal surface flaring outwardly toward the downstream direction of said primary flow in a diffuser-like manner, said plurality of nozzles including auxiliary nozzles helically positioned around said primary flow axis on a path corresponding to the course of said main helical flow path to increase the velocity of said secondary flow, said vessel having means forming a collector space at the lower portion thereof for accumulation of the dust, and discharge duct means extending outwardly from said collector space for discharge of the dust therefrom.

7. A dust-from-gas separator apparatus for separating dust entrained in a raw gas, said apparatus comprising a conduit vessel defining a vessel space and having an inlet conduit for introducing dust-laden raw gas into the vessel and an outlet conduit for discharge of clean gas therefrom, said inlet and outlet conduits being coaxially arranged spaced from each other for passage of the gas through the vessel space, said inlet and outlet conduits defining together a primary-flow axis extending through said vessel space, agitating means for imparting to the primary flow of the gas in said space a circulatory secondary flow, said agitating means comprising a plurality of nozzles mounted on said vessel and terminating at the inner wall surface thereof, said nozzles each having a direction generally tangential to the vessel wall and inclined relative to said primary flow axis so as to define a main helical flow path around said axis for injecting gaseous fluid along said main helical flow path into said vessel space, said nozzle directions each having a component along said axis toward said inlet conduit so that said agitating means superimpose upon said primary flow in said vessel space a rotational secondary flow coaxial with said primary flow and forming in said space a vortex sink and a vortex source spaced from each other along said primary flow axis, whereby gas-entrained dust particles are caused to concentrate in potential flow on helical travel paths having components along the primary flow direction due to fluid-internal relative forces, means for reducing the energy requirements of the nozzle injection along said main helical path comprising a streamlined ring-shaped body mounted in said vessel coaxial with said primary flow axis and beyond the last of said nozzles considered in the direction toward said outlet conduit for increasing toward said primary flow axis the

pressure in the vicinity of said last nozzle while simultaneously increasing the peripheral component and width of said potential flow, said body having an internal surface flaring outwardly toward the downstream direction of said primary flow in a diffuser-like manner, said body being provided around its entire upstream circumference with a ring-shaped recess flaring outwardly in said downstream direction in a diffuser-like manner, said plurality of nozzles including auxiliary nozzles helically positioned on the vessel around said primary flow axis directed along a path corresponding to the course of said main helical flow path to increase the velocity of said secondary flow, said vessel having means forming a collector space at the lower portion thereof for accumulation of the dust, and discharge duct means extending outwardly from said collector space for discharge of the dust therefrom.

8. Apparatus according to claim 7, and including a waste gas discharge line extending outwardly from said recess and connected for introducing dust-laden gas from said recess back into said vessel.

9. Apparatus according to claim 8, said waste gas discharge line connecting said recess with said raw gas inlet duct for introducing dust-laden gas from said recess back into said vessel.

10. Apparatus according to claim 7, and including a waste gas discharge line connecting said recess with said vessel and joined to the latter to form an entry location for injecting dust-laden gas from said recess back into said primary flow in a direction radial to said primary flow axis, and an entraining nozzle located between said entry location of said waste gas line and said vessel space for injecting a stream of air to precipitate the dust from the waste flow.

11. Apparatus according to claim 8, further defined in that said body is provided with an outwardly curved tulip-shaped edge at said recess for improved guidance of the waste stray flow from said nozzles into said recess.

12. A dust-from-gas separator apparatus for separating dust entrained in a raw gas, said apparatus comprising a conduit vessel defining a vessel space and having an inlet conduit for introducing dust-laden raw gas into the vessel and an outlet conduit for discharge of clean gas therefrom, said inlet and outlet conduits being coaxially arranged spaced from each other for passage of the gas through the vessel space, said inlet and outlet conduits defining together a primary-flow axis extending through said vessel space, agitating means for imparting to the primary flow of the gas in said space a circulatory secondary flow, said agitating means comprising a plurality of nozzles mounted on said vessel and terminating at the inner wall surface thereof, said nozzles each having a direction generally tangential to the vessel wall and inclined relative to said primary flow axis so as to define a main helical flow path around said axis for injecting gaseous fluid along said main helical flow path into said vessel space, said nozzle directions each having a component along said axis toward said inlet conduit in opposition to said primary flow so that said agitating means superimpose upon said primary flow in said vessel space a rotational secondary flow coaxial with said primary flow and forming in said space a vortex sink and a vortex source spaced from each other along said primary flow axis, whereby gas-entrained dust particles are caused to concentrate in potential flow on helical travel paths having components along the primary flow direction due to fluid-internal relative forces, means for reducing the energy requirements of the nozzle injection along said main helical path comprising a streamlined ring-shaped body mounted in said vessel coaxial with said primary flow axis and beyond the last of said nozzles considered in the direction toward said outlet conduit for increasing toward said primary flow axis the pressure in the vicinity of said last nozzle while simultaneously increasing the peripheral component and width of said potential flow, said body having an internal surface flaring out-

wardly toward the downstream direction of said primary flow in a diffuser-like manner, said body being provided around its entire upstream circumference with a ring-shaped recess flaring outwardly in said downstream direction in a diffuser-like manner, said plurality of nozzles including auxiliary nozzles helically positioned on the vessel around said primary flow axis directed along a path corresponding to the course of said main helical flow path to increase the velocity of said secondary flow, a hollow cylindrical insert mounted ahead of said streamlined ring-shaped body relative to said primary flow direction of the raw gas current, said insert having a bulging ring portion protruding into said recess, deflecting means having a teardrop streamlined shape narrowing in the direction of said primary flow and mounted within said collector space on said primary axis near the primary flow inlet conduit, said vessel having means forming a collector space at the lower portion thereof for accumulation of the dust, and discharge duct means extending outwardly from said collector space for discharge of the dust therefrom.

13. A dust-from-gas separator apparatus for separating dust entrained in a raw gas, said apparatus comprising a conduit vessel defining a vessel space and having an inlet conduit for introducing dust-laden raw gas into the vessel and an outlet conduit for discharge of clean gas therefrom, said inlet and outlet conduits being coaxially arranged spaced from each other for passage of the gas through the vessel space, said inlet and outlet conduits defining together a primary-flow axis extending through said vessel space, agitating means for imparting to the primary flow of the gas in said space a circulatory secondary flow, said agitating means comprising a plurality of nozzles mounted on said vessel and terminating at the inner wall surface thereof, said nozzles each having a direction generally tangential to the vessel wall and inclined relative to said primary flow axis so as to define a main helical flow path around said axis for injecting gaseous fluid along said main helical flow path into said vessel space, said nozzle directions each having a component along said axis toward said inlet conduit in opposition to said primary flow so that said agitating means superimpose upon said primary flow in said vessel space a rotational secondary flow coaxial with said primary flow and forming in said space a vortex sink and a vortex source spaced from each other along said primary flow axis, whereby gas-entrained dust particles are caused to concentrate in potential flow on helical travel paths having components along the primary flow direction due to fluid-internal relative forces, means for reducing the energy requirements of the nozzle injection along said main helical path comprising a streamlined ring-shaped body mounted in said vessel coaxial with said primary flow axis and beyond the last of said nozzles considered in the direction toward said outlet conduit for increasing toward said primary flow axis the pressure in the vicinity of said last nozzle while simultaneously increasing the peripheral component and width of said potential flow, said streamlined ring-shaped body having an internal surface flaring outwardly toward the downstream direction of said primary flow in a diffuser-like manner, said streamlined ring-shaped body being provided around its entire upstream circumference with a ring-shaped recess flaring outwardly in said downstream direction in a diffuser-like manner, said plurality of nozzles including auxiliary nozzles, helically positioned on the vessel around said primary flow axis directed along a path corresponding to the course of said main helical flow path to increase the velocity of said secondary flow, a torus-shaped member having an elliptical cross section mounted within said recess for guiding waste stray flow from at least one of said nozzles around the wall of said recess and back into said main helical path, deflecting means having a teardrop streamlined shape narrowing in the direction of said primary flow and mounted within said collector

space on said primary axis near the primary flow inlet conduit, said vessel having means forming a collector space at the lower portion thereof for accumulation of the dust, and discharge duct means extending outwardly from said collector space for discharge of the dust therefrom.

14. A dust-from-gas separator apparatus for separating dust entrained in a raw gas, said apparatus comprising a conduit vessel defining a vessel space and having an inlet conduit for introducing dust-laden raw gas into the vessel and an outlet conduit for discharge of clean gas therefrom, said inlet and outlet conduits being coaxially arranged spaced from each other for passage of the gas through the vessel space, said inlet and outlet conduits defining together a primary-flow axis extending through said vessel space, agitating means for imparting to the primary flow of the gas in said space a circulatory secondary flow, said agitating means comprising a plurality of nozzles mounted on said vessel and terminating at the inner wall surface thereof, said nozzles each having a direction generally tangential to the vessel wall and inclined relative to said primary flow axis so as to define a main helical flow path around said axis for injecting gaseous fluid along said main helical flow path into said vessel space, said nozzle directions each having a component along said axis toward said inlet conduit in opposition to said primary flow so that said agitating means superimpose upon said primary flow in said vessel space a rotational secondary flow coaxial with said primary flow and forming in said space a vortex sink and vortex source spaced from each other along said primary flow axis, whereby gas-entrained dust particles are caused to concentrate in potential flow on helical travel paths having components along the primary flow direction due to fluid-internal relative forces, means for reducing the energy requirements of the nozzle injection along said main helical path comprising a streamlined ring-shaped body mounted in said vessel coaxial with said primary flow axis and beyond the last of said nozzles considered in the direction toward said outlet conduit for increasing toward said primary flow axis the pressure in the vicinity of said last nozzle while simultaneously increasing the peripheral component and width of said potential flow, said plurality of nozzles including auxiliary nozzles helically positioned on the vessel around said primary flow axis directly along a path corresponding to the course of said main helical flow path to increase the velocity of said second flow, deflecting means having a teardrop streamlined shape narrowing in the direction of said primary flow and mounted in said vessel within said collector space along said primary axis near the primary flow inlet conduit, whereby said main helical flow becomes enriched with dust to a relatively high concentration said streamlined ring-shaped body forming together with the wall of said vessel an annular duct for discharge of waste gas, said annular duct becoming wider in the flow direction of waste gas there-through, said vessel having means forming a collector space at the lower portion thereof for accumulation of the dust, and discharge duct means extending outwardly from the collector space for discharge of the dust therefrom.

15. A dust-from-gas separator apparatus for separating dust entrained in a raw gas, said apparatus comprising a conduit vessel defining a vessel space and having an inlet conduit for introducing dust-laden raw gas into the vessel and an outlet conduit for discharge of clean gas therefrom, said inlet and outlet conduits being coaxially arranged spaced from each other for passage of the gas through the vessel space, said inlet and outlet conduits defining together a primary-flow axis extending through said vessel space, agitating means for imparting to the primary flow of the gas in said space a circulatory secondary flow, said agitating means comprising a plurality of nozzles mounted on said vessel and terminating at the inner wall surface thereof, said nozzles each

having a direction generally tangential to the vessel wall and inclined relative to said primary flow axis so as to define a main helical flow path around said axis for injecting gaseous fluid along said main helical flow path into said vessel space, said nozzle directions each having a component along said axis toward said inlet conduit in opposition to said primary flow so that said agitating means superimpose upon said primary flow in said vessel space a rotational secondary flow coaxial with said primary flow and forming in said space a vortex sink and a vortex source spaced from each other along said primary flow axis, whereby gas-entrained dust particles are caused to concentrate in potential flow on helical travel paths having components along the primary flow direction due to fluid-internal relative forces, means for reducing the energy requirements of the nozzle injection along said main helical path comprising a streamlined ring-shaped body mounted in said vessel coaxial with said primary flow axis and beyond the last of said nozzles considered in the direction toward said outlet conduit for increasing toward said primary flow axis the pressure in the vicinity of said last nozzle while simultaneously increasing the peripheral component and width of said potential flow, said plurality of nozzles including auxiliary nozzles helically positioned on the vessel around said primary flow axis directed along a path corresponding to the course of said main helical flow path to increase the velocity of said secondary flow, deflecting means having a teardrop streamlined shaped narrowing in the direction of said primary flow and mounted within said collector space on said primary axis near the primary flow inlet conduit, whereby said main helical flow becomes enriched with dust to a relatively high concentration, said ring-shaped streamlined body forming together with the wall of said vessel an annular duct for discharge of waste gas, said annular duct becoming narrower in the flow direction of waste gas, therethrough, said vessel having means forming a collector space at the lower portion thereof for accumulation of the dust, and discharge duct means extending outwardly from said collector space for discharge of the dust therefrom.

16. A dust-from-gas separator apparatus for separating dust entrained in a raw gas, said apparatus comprising a conduit vessel defining a vessel space and having an inlet conduit for introducing dust-laden raw gas into the vessel and an outlet conduit for discharge of clean gas therefrom, said inlet and outlet conduits being coaxially arranged spaced from each other for passage of the gas through the vessel space, said inlet and outlet conduits defining together a primary-flow axis extending through said vessel space, agitating means for imparting to the primary flow of the gas in said space a circulatory secondary flow, said agitating means comprising a plurality of nozzles mounted on said vessel and terminating at the inner wall surface thereof, said nozzles each having a direction generally tangential to the vessel wall and inclined relative to said primary-flow axis so as to define a main helical flow path for injecting gaseous fluid along said main helical flow path into said vessel space,

said nozzle directions each having a component along said axis toward said inlet conduit in opposition to said primary flow so that said agitating means superimpose upon said primary flow in said vessel space a rotational secondary flow coaxial with said primary flow and forming in said space a vortex sink and a vortex source spaced from each other along said primary flow axis, whereby gas-entrained dust particles are caused to concentrate in potential flow on helical travel paths having components along the primary flow direction due to fluid-internal relative forces, means for reducing the energy requirements of the nozzle injection along said main helical path comprising a streamlined ring-shaped body mounted in said vessel coaxial with said primary flow axis and beyond the last of said nozzles considered in the direction toward said outlet conduit for increasing toward said primary flow axis the pressure in the vicinity of said last nozzle while simultaneously increasing the peripheral component and width of said potential flow, said plurality of nozzles including auxiliary nozzles helically positioned on the vessel around said primary flow axis directed along a path corresponding to the course of said main helical flow path to increase the velocity of said secondary flow, at least one additional gaseous fluid nozzle directed into said collector space for overcoming the frictional energy loss of said secondary flow caused by contact with said primary flow, deflecting means having a teardrop streamlined shape narrowing in the direction of said primary flow and mounted within said collector space on said primary axis near the primary flow inlet conduit, said additional nozzle opening into said vessel at a location between said primary flow inlet and a plane normal to said primary flow axis at the narrowest tip of said teardrop shaped deflecting means, said agitating means further comprising guiding vane means positioned within said raw gas inlet conduit to assist in imparting said circulatory motion to the raw gas, said guiding vane means having a sharp edge at their upstream side and an outwardly widening lancet-shaped cross section relative to the radial direction of said vessel, said vessel having means forming a collector space at the lower portion thereof for accumulation of the dust, and discharge duct means extending outwardly from said collector space for discharge of the dust therefrom.

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