Aug. 10, 1965 K. R. SCHMIDT ETAL 3,199,271

APPARATUS FOR SEPARATING FLOWING MEDIA OF RESPECTIVELY DIFFERENT MASS INERTIA

Filed Aug. 18, 1961 2 Sheets-Sheet 1

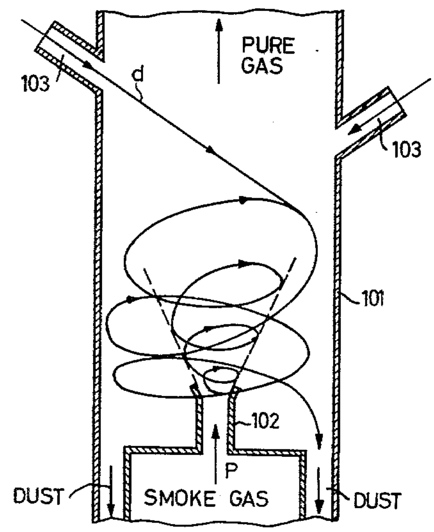


FIG. 1

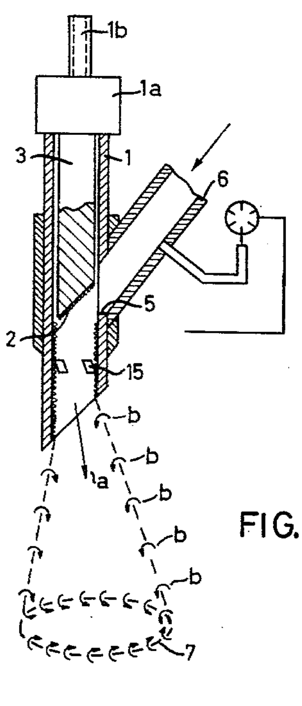


FIG. 2

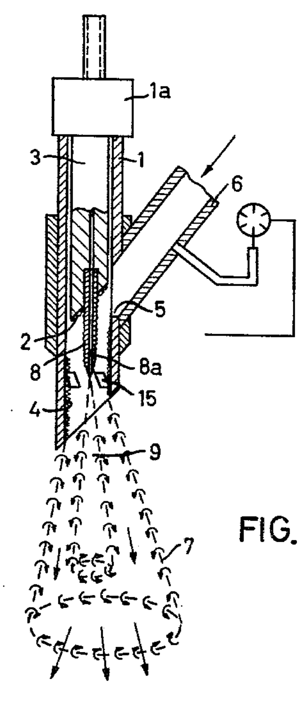


FIG. 3

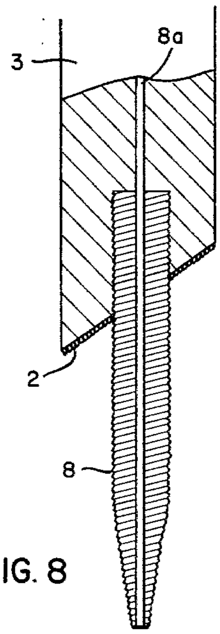


FIG. 8

HOLLOW TUBULAR THORN

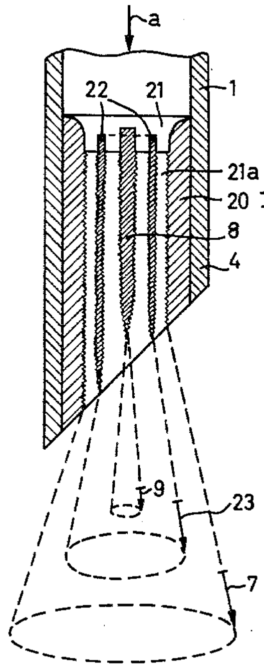
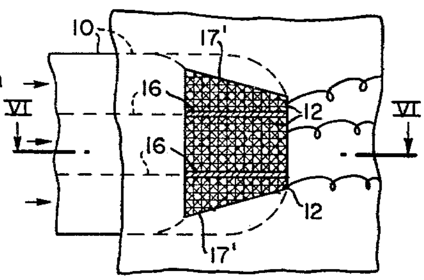


FIG. 4

FIG. 7



NOZZLE WITH PRISMATIC CROSS-SECTION

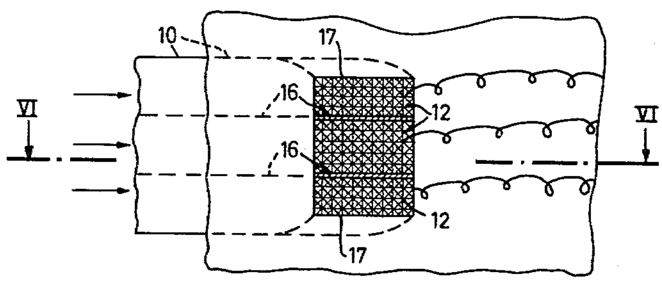


FIG. 5

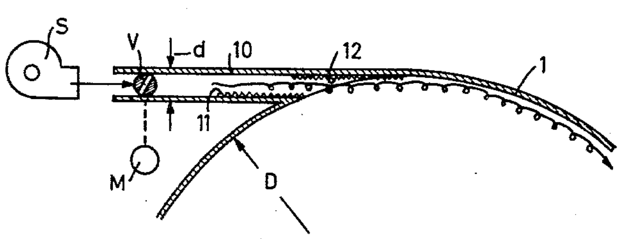


FIG. 6

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APPARATUS FOR SEPARATING FLOWING MEDIA OF RESPECTIVELY DIFFERENT MASS INERTIA

Karl Rudolf Schmidt and Karl-Heinz Oehlrich, both of Erlangen, Germany, assignors to Siemens-Schuckertwerke Aktiengesellschaft, Berlin-Siemensstadt, Germany, a corporation of Germany

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9 Claims. (Cl. 55—261)

Our invention relates to apparatus that are predicated upon the production of relative forces, particularly Coriolis forces, in a flow of media of respectively different mass inertia, particularly for the purpose of separating dust from gas, but also for other purposes such as mixing pulverulent substances with gaseous substances. In a more particular aspect, our invention relates to apparatus based upon the fluid-flow principles set forth in the copending application Serial No. 835,886 of Oehlrich et al., filed August 25, 1959 and assigned to the assignee of the present invention.

For a further understanding of the principles of fluid mechanics involved and various ways in which they may be applied, reference may also be had to copending applications Serial No. 24,391 of Oehlrich et al., filed April 25, 1960, Serial No. 862,570 of Oehlrich et al., filed December 29, 1959, and Serial No. 98,604 of Oehlrich, filed March 27, 1961, all assigned to the assignee of the present invention. Reference may also be had to the "Explanatory Appendix" portion of the specification of application Serial No. 128,431, filed August 1, 1961 of Karl Rudolf Schmidt and Karl-Heinz Oehlrich, entitled "Nuclear Reactor and Method of Processing, Entraining, Handling and Moving Fissionable Material," and assigned to the assignee of the present invention.

According to these principles and apparatus, a potential flow is excited in a fluid medium, and this potential flow is converted into a secondary rotational flow that circulates in coaxial relation to and in the same sense as the primary flow, the conversion being effected with the aid of a flow profile which acts as a solid or rough ground and whose symmetry axis extends in the flow direction of the media. Such a primary, potential flow may be excited by stirrer or guiding devices which rotate in a plane perpendicular to the flow direction of the media, or it may be excited by an auxiliary medium, particularly "secondary air" which is blown into the main flow in an inclined tangential direction and opposed to the primary flow direction of the media. The present invention particularly relates to the last-mentioned excitation of the primary flow by means of secondary air injected into the potential flow. For the purpose of dust separation, the dust-laden jet of the potential flow, located outside of the rotational flow, is caught and guided out of the processing space prior to being converted into a ring-shaped mixing or baffle zone such as represented by a dust ring.

As disclosed in the above-mentioned earlier copending applications, the desired rotational flow can be excited by injecting the secondary air with the aid of slots, channels or other nozzle means which, for distinction from those that supply the primary flow of dust-laden air or gas, are hereinafter called "secondary-air nozzles." The present invention concerns itself particularly with the design and operation of the secondary-air nozzles for exciting the circulating flow that comprises a component potential flow and a component rotational flow, and has for its object to greatly improve the efficacy of these secondary-air nozzles.

It is, therefore, an object of the present invention to provide means for producing turbulence in jet streams

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ejected from nozzles, and particularly for producing conical flow patterns with marginal turbulence zones.

It is another object of the invention to provide an apparatus for the purposes of handling, combining or separating pulverulent materials in a carrier fluid by injecting a secondary fluid flow tangential to and having a component in opposition to a primary flow path, and to make the secondary flow effective for these purposes independent of the angular position of the secondary injection.

It is a further object of the invention to provide adjustable throttling means for controlling the flow of secondary gases introduced tangentially into a primary gas flow path.

It is another object of the invention to create turbulence in injected gaseous flow by providing a rough surface on which the gaseous flow impinges.

The invention will be further described with reference to the embodiments of apparatus according to the invention illustrated by way of example on the accompanying drawings in which:

FIG. 1 is a schematic illustration of an apparatus for separating dust from smoke-gas.

FIGS. 2, 3 and 4 illustrate schematically and in axial section three respective secondary-air nozzles provided with roughness means according to the invention, and also symbolically indicate the effect of such means.

FIG. 5 shows partially a side elevation of a vessel wall with a rectangular, slit-type nozzle according to the invention.

FIG. 6 is a sectional view of the same nozzle, the view being taken along the line VI—VI in FIG. 5.

FIG. 7 is a top view of a slit nozzle having a cross section of trapezoidal shape; and

FIG. 8 shows an enlarged view of a thorn according to FIG. 3 with a bore therethrough.

FIG. 1 illustrates schematically an apparatus for removal of dust from smoke gas. Dust-laden smoke-gas enters as a "primary flow" P into the processing container 101 through an inlet duct 102. A circulating flow is excited by blowing medium as a "secondary flow" into the container through respective tangential ducts 103 which are downwardly inclined. The resulting ring-shaped flow of gas constitutes a "rough ground" of the flow system, and the dust may be separated out from the primary flow at the bottom of the vessel as shown (FIG. 1). By controlling the primary and secondary flow, the same general principles may be used not only for dust-separation, as shown in FIG. 1, but also for mixing, demixing, combining, de-combining and handling of various media, as further described in the above-mentioned copending applications.

The devices illustrated in FIGS. 2–6 may be inserted, for example, at 103 in FIG. 1 for a more effective "secondary flow."

The secondary-air nozzles for injection at 103 as heretofore proposed are smooth in their interior. As explained in the above-mentioned copending application Serial No. 835,886, the effect of the secondary-air flow can be greatly augmented if the secondary air possesses a high circulatory turbulence. For that reason, the injection of the secondary air is preferably effected over a sharp edge or through a rotating-vane device or by means of a combination of such devices.

A turbulence in the injected secondary air produces fluctuation pulses transverse to the main flow direction P of the gas and thereby produces also an energy transmission perpendicular to this main flow direction. Since the main travel direction a of the secondary-air current, being injected in an inclined-tangential direction, is opposed and inclined to the raw-gas current P, the fluctuation velocities in the intermediate boundary layer between these two currents, i.e. in the so-called "boundary zone" or "mixing zone," produce additional "virtual shearing tensions" which are approximately proportional to the fluctuations in speed.

Such a turbulent flow is of essential significance to the effectiveness of the secondary air because the entire efficiency of excitation and, in the case of dust separation the overall degree of the dust separation, are nearly independent of the angular position of the secondary-air nozzles if the secondary-air flow is given marginal turbulences, this having been ascertained by comprehensive tests.

According to our invention, therefore, these phenomena are taken advantage of by providing the secondary-air nozzles, for excitation of the potential flow, with turbulence-producing means, preferably protuberances, serrations, teeth or other roughness. Such a nozzle injects the secondary air in the form of a conical current into the main gas flow P which, in the case of dust separation, is laden with the dust to be separated. The injected secondary air then exhibits marginal turbulence zones and form individual jet streams at the conical peripheral surface zone of the flow. In the case of dust separation, the lower, turbulent edge or end portion of such a turbulence cone suffices at a slight positive pressure of the secondary current to remove the dust downwardly.

By a particular design of the secondary-air nozzle, several such marginal turbulence zones can be produced simultaneously in one and the same nozzle. Furthermore, the eddies or vortexes that form themselves at the roughness of the nozzle contribute essentially to stabilizing the main jet of the secondary air and thus to reducing the secondary-air energy for a given degree of effectiveness or dust separation.

The turbulence-producing means according to the invention may be arranged in nozzles of round and/or prismatic or rectangular cross section. Rectangular nozzles, when given a slit-type design or with a particular sub-division, afford a favorable arrangement of the turbulence-producing means while simultaneously maintaining a high injection pressure. Such a rectangular nozzle, also called "slit nozzle" may be sub-divided by guide sheets for parallel guidance of the air. The narrow sides of the slit nozzle may be curved toward each other in order to obtain a contraction of the jet.

Roughness may be provided at the inner side of the nozzle exit portion, on the face impinged by the air being supplied. The roughness of the surface may be teeth, serrations, screw threads or grating having raised patterns. If the nozzle possesses an adjustably mounted throttle body whose displacement permits adjusting the quantity of secondary air and the nozzle pressure, then the upstream side of this body may be roughened. If a plurality of marginal turbulence zones are to be produced simultaneously with one and the same nozzle, then a thorn designed approximately as a flow-guiding or air-foil body is preferably inserted into the nozzle, this thorn being roughened on its surface. The thorn itself may also be provided with a central bore to act as an additional nozzle.

According to another feature of our invention, vane bodies are arranged within the nozzle at a location ahead of the air-outlet opening which effect a pre-excitation of the secondary air flow in such a manner as to impress a potential flow upon the injected secondary air and placing the air in the rotary-turbulence nozzle in rotation. This further improves the desired turbulent action. These features will be described below in greater detail, with reference to FIGS. 2–6.

The nozzle illustrated in FIG. 2 (nozzle 1) comprises a tubular nozzle member 1 mounted on a carrier or support **1***a* with a threaded stud **1***b* serving for attachment of the nozzle to a suitable mounting structure or to the vessel **101**. Also secured to the carrier **1***a* is a piston 3 in coaxial relation to the tubular structure 1. The secondary air is supplied through a lateral tube 6 in an inclined direction with respect to the nozzle tube 1. The piston 3 has an inclined front surface 2 provided with numerous protuberances or grooves to provide for roughness relative to the flow of secondary air. Similar roughness is provided at 4 on the inner side walls of the tubular member 1. For further increasing the turbulence-producing action, a projection 5 with a sharp edge is located inside the nozzle within the path of the secondary air from 6.

The rough front surface 2 of the adjustable throttle piston 3 and the roughness at 4 on the inner side of the nozzle outlet effect the formation of a conical jet 7 with a multitude of turbulence zones at the boundaries thereof. That is, the particles of the secondary-air current, aside from flowing in the main (secondary flow) direction indicated in FIGS. 1, 2 and 4 by an arrow *a*, also rotate in the plane of illustration, as schematically indicated by the arrows *b* (FIG. 2). The particles are subjected to a braking action at the roughened surfaces of the nozzle so that the particle speed becomes reduced at these places, whereas the speed at the particle side facing the inner core of the current becomes increased. This results in stabilization of the secondary-air jet flow stream as to direction and shape.

According to a further feature, illustrated in FIG. 2 and also in the embodiment shown in FIG. 3, a potential flow is impressed upon the secondary air by vane bodies 15. In this manner, the resulting rotational motion further increases the turbulence of the flow. In all other respects, the nozzle according to FIG. 3 corresponds to that of FIG. 2, the same components being designed by the same reference numerals, respectively.

The nozzle shown in FIG. 3 is provided with an axially displaceable throttle piston 3 with a rough front surface 2 impinged upon by the incoming gases from 6, the tubular nozzle member 1 being also provided with roughness at 4 near the nozzle outlet. Also provided is a sharp edge at 5 for increasing the turbulence-producing action.

The secondary air injected through the angular tube 6 passes out of the nozzle in form of a turbulence cone 7, the turbulence being due to the roughness 2 at the piston 3 and the roughness 4 at the nozzle outlet. Inserted into the displaceable throttle piston 3 is a thorn 8 which has a roughened outer surface and which forms in the air flow an internal turbulence cone 9 within the cone 7. The thorn 8 may be given a bore 8*a* (FIG. 8) to make it hollow and to thus produce a third turbulence cone within cones 7 and 9. The provision of such additional marginal turbulence zones greatly increases the degree of separation, particularly with respect to the finest fractions or grain sizes of dust.

An angular injection of the secondary air by means of the angularly mounted tube 6 as in FIGS. 2 and 3 is preferably provided if the nozzle is to simultaneously act as a throttle member. However, as shown in FIG. 4, the air can also be injected in the direction of the main jet *a* through the nozzle tube 1 which in the above-described embodiments of FIGS. 2 and 3 is substantially filled by the piston 3. The thorn 8, according to FIG. 4, can then be fastened in the nozzle tube 1 by spacer structures or bridging members such as 21 or 21*a*.

Turbulence nozzles of greater diameter can be provided with an additional tubular insert 20, as further shown in FIG. 4. The inner surface of the insert 20 is roughened in the above-described manner. Fastened to a bridge or spacer member 21 extending across the insert 20 are the thorn 8 and another tubular insert 22. The thorn 8 has a roughened surface, and both the inner and outer surfaces of the tubular insert 22 are roughened. In this manner, a further cone 23 is formed in addition to the turbulence cones 7 and 9.

FIGS. 5 and 6 illustrate a rectangular nozzle (slit nozzle) in the side of a vessel 1 of diameter D. FIG. 7

is a modification of the structure of FIG. 5 but with the sides **17'** inclined instead of parallel. The nozzle conduit **10** is provided on its longitudinal inner sides with turbulence-producing means **11** and **12**. These turbulence-producing means **11** and **12** are rough surfaces, such as grating patterns, and are spaced from each other a relatively small distance *d*, so that, with a high injection pressure, a great multiplicity of turbulence zones will result because of the numerous variously-oriented members of each pattern **11**, **12**. The slit nozzle is provided with transverse guide sheets **16** within the conduit **10**, and the narrow sides **17** at the outlet of the slit nozzle are bent so as to curve toward each other.

An additional augmentation of the turbulence can also be obtained by injection of a pulsating or intermittent air current from a blower or other source S (FIG. 6) and a valve V rotated by motor M to open periodically.

The invention is applicable to advantage not only for separation of dust or other fine-granular substances from gaseous media, but also in other cases where turbulent fluid flows are to be produced, for example for fuel injection in cyclone-firing systems, and in the corner-type firing systems of combustion chambers.

It will be obvious to those skilled in the art, upon a study of this disclosure, that our invention in amendable to various other modifications and hence can be given embodiments other than particularly illustrated and described herein, without departing from the essential features of our invention and within the scope of the claims annexed hereto.

We claim:

1. Apparatus for handling materials entrainable in a carrier fluid for the purpose of separating out said materials from said fluid, comprising a vessel having a wall, means defining an inlet and an outlet for the passage of fluid through the vessel and defining a primary-flow axis for the carrier fluid in which said materials are entrained, agitating means for imparting to the primary flow in said vessel a circulatory motion, said agitating means comprising nozzle means for injecting fluid along respective helical flow paths into said vessel in a direction substantially tangential to the primary flow and inclined toward the primary flow axis and having a component in opposition to said primary flow so that said agitating means superimpose upon said primary flow in said vessel a circulatory secondary flow coaxial with said primary flow and forming in said vessel a vortex sink and a vortex source spaced from each other along said primary flow axis; said nozzle means terminating flush with the wall of the vessel and being provided with means defining protuberances for producing turbulence in the fluid injected into said vessel from said nozzle means, and means for collecting the separated materials in the lower part of the vessel.

2. In an apparatus according to claim **1**, said means for producing turbulence comprising a rough surface within said nozzle means and placed along the path of the fluid passing through said nozzle means.

3. In an apparatus according to claim **1**, said nozzle means having a prismatic cross section.

4. In an apparatus according to claim **1**, said means for producing turbulence comprising a rough surface having a serrated cross section and disposed within said nozzle means along the path of the fluid passing through said nozzle means.

5. In an apparatus according to claim **1**, said nozzle means being provided with guide means on the inner surface of the outlet thereof for guiding the fluid injected into said vessel space in said circulatory secondary flow coaxial with said primary flow.

6. In an apparatus according to claim **1**, said means for producing turbulence comprising projections having sharp edges and disposed within said nozzle means.

7. In an apparatus according to claim **1**, a throttle piston adjustably mounted within said nozzle means and having a front face arranged in the path of and to be impinged upon by the fluid passing through said nozzle means, said front face having a rough surface to form at least part of said means for producing turbulence in the fluid injected into said vessel space from said nozzle means.

8. In an apparatus according to claim **1**, said means for producing turbulence comprising a thorn member having a rough surface disposed within said nozzle means.

9. In an apparatus according to claim **8**, said thorn member comprising a hollow tubular body.

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HARRY B. THORNTON, *Primary Examiner.*

HERBERT L. MARTIN, *Examiner.*