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MEANS FOR SEPARATING PARTICLES FROM FLUIDS

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2 Sheets-Sheet 2

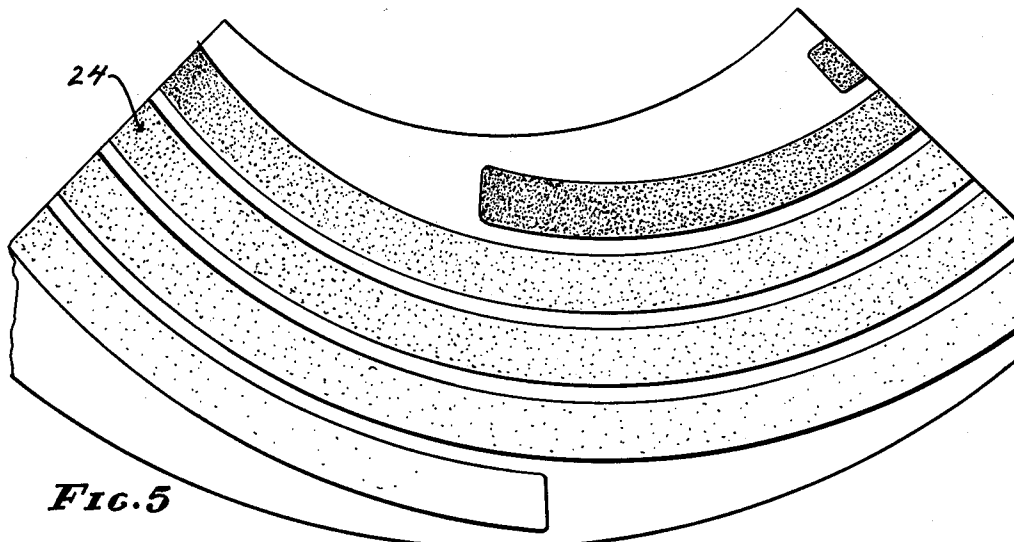


FIG. 5

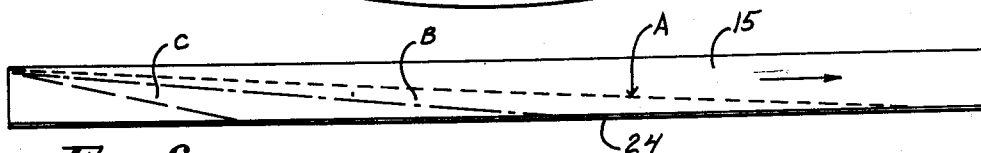


FIG. 6

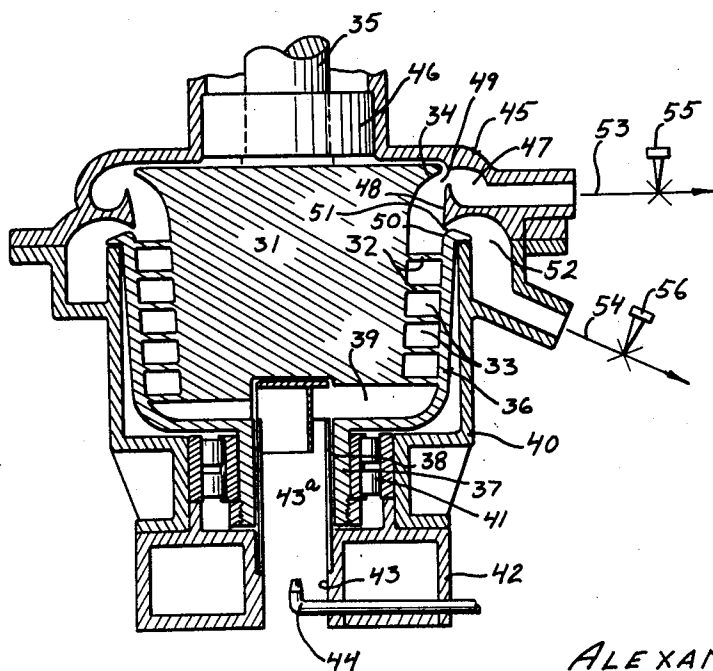


FIG. 7

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3,074,627 MEANS FOR SEPARATING PARTICLES FROM FLUIDS

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This invention relates to means for separating particles and is a continuation-in-part of my copending application Serial No. 603,677 filed August 13, 1956, now abandoned, for Means and Method of Separating Particles from Fluids. Included in the objects of this invention are:

First, to provide a means for separating particles from fluids wherein the fluid containing the particles to be separated is caused to flow substantially turbulence free in a channel under conditions wherein the fluid and the particles therein are subjected to centrifugal force for a controlled period calculated to drive all or a selected proportion, quantity or type of particle toward a surface of the channel for removal.

Second, to provide a means of this class wherein means defining a helical channel having an inlet and an outlet at its axial ends is caused to rotate at high velocities while the particle bearing fluid is fed therethrough at a controlled rate to establish a laminar flow while subjecting the fluid and its particles to the centrifugal force generated by the high speed rotation of the channel defining means.

Third, to provide a means of this class wherein the outer peripheral wall of said channel defining means may be removable and be prepared to adsorb or otherwise retain the particles forced into contact therewith for later study.

Fourth, to provide a means of this class wherein: a scavaging fluid of greater density than the fluid in which the particles are suspended may be caused to flow among the outer peripheral wall of the rotating helical channel and receive the particles driven to the outer peripheral wall by centrifugal force.

With the above and other objects in view as will appear hereinafter, reference is directed to the accompanying drawings in which:

FIGURE 1 is a side elevational view of one form of apparatus for separating particles from fluids wherein the apparatus is intended for laboratory use.

FIGURE 2 is an enlarged fragmentary longitudinal sectional view thereof taken through 2—2 of FIGURE 1.

FIGURE 3 is a transverse sectional view thereof taken through 3—3 of FIGURE 2, showing the entrance ends of the helical separation chambers.

FIGURE 4 is a transverse sectional view taken through 4—4 of FIGURE 2, showing the exit ends of the helical separation chambers.

FIGURE 5 is a developed view of a record sheet removed from the apparatus.

FIGURE 6 is a diagrammatical view representing a straightened length of a separation chamber indicating the rates at which different masses move to the collector surface.

FIGURE 7 is a fragmentary longitudinal sectional view of a modified form of apparatus wherein a scavaging fluid is introduced to effect continuous removal of particles driven to the walls of the separator chamber.

Reference is first directed to FIGURES 1 through 6. The construction here illustrated is intended primarily as a laboratory instrument for the study of particles contained in aerosols by causing the particles to be deposited on a record sheet such as the record sheet shown in FIGURE 5.

A suitable base 1 is provided on which is mounted a

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motor shell 2 containing a high speed electric motor not shown. The motor shell is cylindrical and is provided at its upper end with a partition retention ring 3 which secures within the upper end of the motor shell a partition 4. The retention ring 3 forms a mounting shoulder which receives the lower end of a cylindrical rotor shell 5 at the upper end of the rotor shell there being provided a bearing mounting ring 6.

A shaft 7 extends upwardly from the motor through the partition 4 and in to the bearing mounting ring 6. The upper portion of the shaft 7 is enlarged as indicated by 8 and is journaled within a ball or roller bearing 9 which is prefitted in a sleeve bearing 10 which in turn is journaled within a sleeve bushing 11 loosely received within the bearing mounting ring 6. The upper end of the sleeve bushing is provided with a flange 12.

The lower portion of the tubular extremity 8 receives a rotor core 13 which is in the form of a cone frustum and provided with helical ribs 14. In the construction illustrated, two such ribs are provided which define therebetween a pair of helical separation chambers 15 extending from the upper or smaller end of the cone to the lower or larger end thereof. The upper extremities of the chambers 15 are connected by radially extended inlet ports 16 with the interior of the tubular extremity 8 of the shaft 7.

The lower or larger end of the rotor core receives an annular base member 17 having a depending skirt 18. The base member forms in part the lower shoulder of the separation chambers 15 at their lower extremities, and is provided with downwardly directed outlet passages 19 in which are mounted orifice bushings 20. The skirt 18 fits within but clears the walls of an annular channel 21 formed in the partition 4. Below the skirt 18 the channel 21 forms an annular outlet chamber which communicates with an outlet port 22.

The rotor core receives a conical shell 23, the inner surface of which is adapted to rest on the peripheral portions of the ribs 14 so as to close the separation chambers 15. Positioned between the shell 23 and the ribs 14 is a record sheet 24. The shell 23 is connected at its upper or smaller end to a mounting ring 25 by means of a screw thread connection 26. The mounting ring is in turn connected to the tubular portion 8 of the shaft 7 by a screw thread connection 27. The screw thread connection 26 permits axial adjustment of the shell. Supported on the bearing mounting ring 6 is a supporting disc 28 in which is centered an entrance tube 29 having means at its outer portion for connection to a hose or the like. The entrance tube fits freely within the core of the tubular extremity 8 and extends to the inlet ports 16. At this end the entrance tube is provided with a triangular plug 29a having concave sides to form three ports 30 communicating with the bore of the tube and open radially to communicate with the inlet ports. The entrance tube 29 remains fixed during the operation of the apparatus, therefore, it is preferable to provide three lateral ports 30 communicating with the two inlet ports 16 in order to minimize any siren effect.

A cover member 28a having a central aperture overlies the upper end of the rotor shell 5.

Operation of the apparatus illustrated in FIGURES 1 through 6 is as follows:

Prior to conducting a test the apparatus is assembled with a record sheet 24 interposed between the shell 23 and rotor core 13. The outlet port 22 is connected to an exhaust line which may be a vacuum pressure line or may be arranged for discharge of air at atmospheric pressure.

Air or other fluid to be analyzed is introduced through the entrance tube 29. The air or fluid and the particles entrained therein move down the entrance tube 29, flow radially through the inlet ports 16 and then proceed to

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flow helically through the separation chambers 15. The fluid discharges through the orifice bushings 20, annular channel 21 and outlet port 22.

The rate of flow of the air or fluid is predetermined by the capacity of the orifice bushings 20. As these orifices are small, the rate of flow of air or fluid through the helical separation chambers 15 is relatively slow. In any case, the velocity of flow is such that laminar flow conditions are maintained. During the time interval between the entrance of a quantity of air or fluid in the inlet ports 16 and its discharge through the orifice bushings 20 the air or fluid and the particles contained therein are subjected to centrifugal force by rotation of the shaft 7 and rotor comprising the rotor core 13 and shell 23. The centrifugal force exerted may be many times the force of gravity; for example, ten thousand times greater than gravitational force. Due to the fact that the flow is laminar, the particles within the separation chamber behave much as if they were contained within a quiescent fluid, but due to the fact that their masses have been increased enormously, the rate at which they "settle" toward the radially outer surfaces of the separation chamber and on to the record sheet 24 is much more rapid than would be the case if only gravitational force were involved.

With reference to FIGURE 6 which represents diagrammatically a developed view of one of the separation chambers and assuming that all of the particles contained in the fluid are of equal mass and that the particles are randomly distributed at the entrance end of the separation chamber, it follows that all of these particles will move with substantially equal velocity toward the outer peripheral wall or record sheet so that the fluid above the line as indicated by A in FIGURE 3 will be free of such particles. If the particles are of greater mass, the line of demarcation between the particle-laden and particle-free fluid will be represented by B or if the mass is still greater, by C.

Reference is now directed to FIGURE 7. In the construction here illustrated the particles are not deposited so as to remain on a surface, but are forced toward the surface and then entrained in a denser fluid and discharged through a separate exit. The construction, however, may be in many respects similar to the construction of the first described apparatus. A mandrel 31 is provided on which is formed the helical fin 32 defining an annular channel or chamber 33. The upper end of the mandrel is provided with a deflector flange 34 and is joined or otherwise secured to a shaft 35. The mandrel fits within a cup-shaped shell 36 having a hollow stem 37 which forms an inlet passage 38. The bottom end of the mandrel and confronting wall of the shell 36 form a radial entrance duct 39 communicating with the helical channel or chamber 33. The shell 36 is incased in a lower housing 40 and journaled therein by means of a bearing 41. The lower housing may rest on a base structure 42, having a fixed inlet passage 43 communicating with the inlet passage 38. Extending upwardly from the inlet passage 43 is a fixed entrance tube 43a which fits freely within the passage 28 and is provided with radial ports communicating with the duct 39. Suitably disposed in the inlet passage 43 is a spray 44 which discharges a washing fluid in pre-determined proportions to the flow of the main fluid.

The upper portion of the mandrel 31 is covered by an upper housing 45 in which is provided a bearing 46 to journal the shaft 35. Formed in the upper housing and surrounding the deflector flange 34 of the mandrel 31 is an annular primary collector channel 47. The upper housing also forms an annular wall 48, the inner surface of which is a continuation of the inner wall of the shell 36. The axial upper extremities of the annular wall 48 constricts the primary channel to form an annular discharge slit 49 communicating between the annular space defined by the annular wall 48 and the mandrel 31 and the primary collector channel 47.

The upper extremity of the shell 36 is provided with a radially outwardly directed lip 50 which forms with the

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low axial extremity of the wall 48 a secondary discharge slit 51. Outwardly of the discharge slit 51 the upper and lower housings may form complementarily a secondary collector channel 52. The primary and secondary collector channels 47 and 52 communicate with discharge lines 53 and 54 having regulator valves 55 and 56 to permit regulation of the rate of flow through the helical separation channel or chamber 33.

Operation of the construction shown in FIGURE 7 is as follows:

A fluid to be cleaned of particles such as particle-laden air is introduced through the entrance tube 43a. Water or other scavaging fluid of suitable density is introduced through the spray nozzle 44. The water or cleaning fluid is driven by centrifugal force to the inner wall of the shell 36 that is, the peripherally or radially outer wall of the helical passage or chamber 33. The water or washing fluid forms a continuous film which travels to the discharge slit 51.

The particles in the particle-laden fluid are subject to high centrifugal forces and migrate toward the wall 36 of the shell and are entrapped in the washing fluid. The particle-laden washing fluid is discharged through the secondary discharge slit into the secondary discharge channel 52. The particle-free fluid passes to the main discharge slit 49 and to the collector channel 47.

The size and shape of the helical channel may vary according to the type of fluid intended to be cleaned of particles by the apparatus.

Reduction in the radial dimension of the passage reduces the number of convolutions or length of the channel. The greater the diameter of the rotor comprising the mandrel and the shell, the lower the rotational velocity for the same centrifugal force.

The term, "fluid," as herein used is intended to include a liquid as well as a gas. Also while the scavaging medium is preferably a liquid, it is conceivable that it, too, might be a gas, particularly if it had a unique affinity for the particle to be collected.

Also the term "particle" is not limited to solid particles but also includes liquid particles, and may, of course, be inorganic or organic in character.

Two factors contributing to separation of the particles from the fluid are the magnitude of the centrifugal force exerted and the period during which the centrifugal force is applied. Various geometrical configurations may be utilized depending on the volume of the fluid to be treated, the character of the particles to be removed and whether or not the separation must be complete or may be partial.

Thus, for example, a single pitch helical conduit provides a long path with a small axial dimension and therefore is most suitable for complete separation of particles from a relatively small volume of fluid. That is a single pitch helical conduit may provide maximum length to provide a maximum period of exposure to the centrifugal force.

However, multiple pitch helical conduits may be provided to increase the volumetric capacity. This, of course, requires proportionate increase in axial length of the rotor to effect a separation corresponding to a single helix rotor. Still further, the pitch of the path or paths may be increased to infinity, that is, the paths may be axial. Such construction becomes feasible where separation is easily affected or where partial separation is sufficient.

The method of separation of particles whether accomplished by the apparatus hereinbefore described or other apparatus consists essentially in:

(1) causing substantially turbulent free or laminar flow of a particle-laden fluid in a confined conduit wherein the boundary layer of the fluid approaches zero velocity relative to the conduit wall;

(2) simultaneously subjecting the fluid to centrifugal force so that particles in the fluid are driven by centrifugal force through the boundary layer into contact with wall

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for collection at the wall or in a scavaging fluid coating the wall.

(3) producing a sufficiently high centrifugal force for a sustained period of such duration that particles to be collected which are initially adjacent the wall remote or opposite from the collecting wall may be forced transversely of the fluid to the collecting wall.

Reference is directed to FIGURE 5. The stippled stripes represent the areas of the record sheet exposed to the separator channels 15, and the stippling represents the particles which have settled out. The individual particles are, of course, of much smaller magnitude, and may range from a small fraction of a micron μ to several microns μ .

Reference is made to the bearing structure which supports the upper end 8 of the shaft 7. The sleeve 11 is loosely retained in the mounting ring so that it tends to center itself. Movement is dampened by a washer 11a held by the supporting disc 28 which is secured by screws to the ring 6. Also a viscous material such as grease is interposed between the sleeve 11 and ring 6.

The ring 10 is rotatable in the sleeve and their confronting surfaces mate accurately to provide a minimum spacing therebetween. No lubricant is provided in this space; instead reliance is made on the thin body of air between these surfaces; that is, the ring 10 and sleeve 11 function as an aerodynamic bearing. This bearing under the conditions of high speed rotation develops far less friction than the so-called "anti-friction" bearing 9. As a consequence the bearing 9 normally does not function but rotates at a unit. The aerodynamic bearing is more fully described in my co-pending application Serial No. 785,280 filed January 6, 1959 and now patent number 3,012,827.

Having thus described certain embodiments and applications of my invention, I do not desire to be limited thereto, but intend to claim all novelty inherent in the appended claims.

I claim:

1. A means for separating particles from fluids comprising: a rotor defining a helical conduit extending essentially the length of said rotor and centered about the longitudinal axis thereof, said conduit having an inlet and an outlet at its opposite ends but being otherwise closed by radially inner and outer spaced walls and adjoining walls which are spaced axially of said rotor, said radially outer wall defining a straight line in the axial direction of the rotor and having an axial dimension at least as great as the distance between the walls of said conduit adjoining said radially outer wall, means for in-

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roducing a particle-laden fluid into the inlet end of said conduit, means for discharging particle-free fluid from the outlet end and means for maintaining the flow of fluid through said conduit at a velocity adequate to provide a stream having laminar flow, said last-named means comprising an adjustable flow restricting member in said outlet end; means for rotating said rotor at high speed to cause said conduit to rotate about the axis of said rotor, there being no relative velocity between said conduit and its radially outer wall, whereby said particles are driven in free paths between the adjoining walls of said conduit to the radially outer wall and out of said stream; and means for collecting the thus driven particles on said outer wall, said outer wall being removable without disturbing the particles collected thereon whereby said collected particles may be subsequently studied.

2. A means for separating solid particles from fluids as set forth in claim 1, wherein: said rotor includes a separable inner core and outer shell, the inner wall of said shell defining the radially outer wall of said helical conduit; and said collecting means is a removable collector sheet covering said radially outer wall.

3. A means for separating solid particles from fluids as set forth in claim 1, wherein: said radially outer wall defines a conical surface increasing in diameter toward said outlet.

4. A means for separating solid particles from fluids as set forth in claim 1, wherein: said rotor includes a separable inner core and outer shell having confronting surfaces defining a cone increasing in diameter toward said outlet; and said collector means is a removable sheet in the form of an axially slit cone covering and conforming to said radially outer wall.

References Cited in the file of this patent

UNITED STATES PATENTS

631,680	Staahlgren	Aug. 22, 1899
1,061,656	Black	May 13, 1913
2,004,011	Podbielniak	June 4, 1935
2,043,313	Wells	June 9, 1936
2,311,606	Bannister	Feb. 16, 1943
2,472,475	Hamilton	June 7, 1949
2,616,619	MacLeod	Nov. 4, 1952
2,688,437	Monnet	Sept. 7, 1954
2,730,299	Kelsey	Jan. 10, 1956

FOREIGN PATENTS

66,267	France	Mar. 26, 1956
	(Addition to No. 1,067,028)	