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(71) Applicant: **B.H.R. Group Limited**
Cranfield, Bedford MK43 0AJ (GB)

(72) Inventors:
• **Saunders, David Henry**
Olney, Bucks MK46 5HB (GB)

• **Arato, Emil Gygory**
Kempston, Bedford MK42 8BW (GB)
• **Davies, Owen Matthew**
Blakelands, Milton Keynes MK43 5BS (GB)

(74) Representative: **Foster, Mark Charles**
Edward Evans Barker
Clifford's Inn,
Fetter Lane
London EC4A 1BZ (GB)

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(54) **Cyclone separator**

(57) A vacuum cleaner is disclosed for separating particulate matter from air. The vacuum cleaner includes a container 1 comprising an outer container portion 12 and an inner container portion 14, a first separation stage for depositing particular matter in the outer container portion 12, and a plurality of further separation stages downstream of the first separation stage for depositing particulate matter in the inner container portion 14.

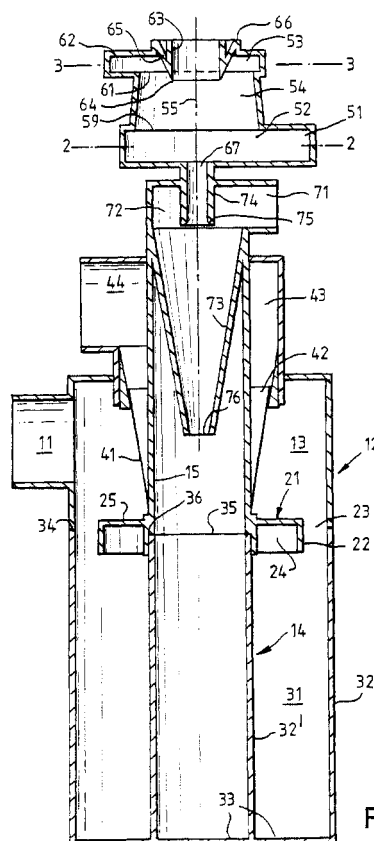


Fig. 1

Description

[0001] This invention relates to the separation of fluid phases, for example the separation of particulate matter from gases such as air.

[0002] Standard cyclone separators cause the incoming fluid mixture to swirl around a chamber so that phases separate radially due to the accelerations towards the axis, the separated phases being removed through separate outlets at different radii. Besides the chamber in which separation takes place, an inlet chamber may be provided in which linear motion of the fluid mixture is converted into swirling motion. This has normally been arranged by making the inlet chamber a cylinder with a linear inlet conduit entering the periphery of the cylinder along a tangent, so that the fluid from the inlet conduit then swirls about the cylinder axis.

[0003] The change from linear motion to motion around the inside of the cylinder involves an abrupt change of curvature of the path from zero to the curvature of the cylinder, which may cause turbulence in the flow. We have found a construction of separator in which the change is less abrupt, so that a free vortex is more likely to be found. Continuing increases of curvature enable the flow to be concentrated.

[0004] According to the invention there is provided a cyclone separator comprising an inlet chamber including means to introduce a fluid mixture to swirl about an axis within the chamber, an outlet chamber spaced along said axis from the inlet chamber and including a first outlet for heavier phases of the mixture and a second outlet for lighter phases of the mixture, and an intermediate chamber connecting the inlet and outlet chambers, the intermediate chamber being, at its junction with the inlet chamber, of not greater dimensions radially of said axis than the minimum such dimension of the inlet chamber.

[0005] Preferably the intermediate chamber is, at its junction with the outlet chamber, of not greater dimensions radially of said axis than the minimum such dimension of the outlet chamber.

[0006] In use the intermediate chamber preferably provides the only outlet for fluid mixture within the inlet chamber. A secondary axial inlet may be provided for the inlet chamber, the secondary inlet being connected to the first outlet. In this case, the secondary inlet is preferably connected to the first outlet through a further separator stage, said secondary inlet being connected to the outlet of the further stage for lighter phases of the mixture in said further stage. The further separator stage preferably comprises means for inducing the mixture within it to swirl about an axis, the axes of the two stages being parallel and preferably co-incident.

[0007] An example of the invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a diagram of a three-stage phase separator, and

Figures 2 and 3 are transverse sections on respective lines 2 and 3.

[0008] In an embodiment of the invention, the fluid mixture to be separated into phases is introduced into the apparatus illustrated in Figure 1 by a tangential conduit 11 leading to a cylindrical separation chamber 13 at the top of a cylindrical container 12. Within the container is a co-axial inner cylinder 14 extending through the full height of the container 12.

[0009] The separation chamber 13 is defined at its lower end by a baffle 21 extending outwards from the inner cylinder to a peripheral wall 22 which baffle defines with the wall of the container 12 an annular gap 23 whose (radial) width is slightly less than the (axial) length of the peripheral wall. In this particular example the width is just under 75% of the length. The baffle 21 is undercut at its lower side 24, but presents a continuous upper plane surface 25 and the wall 22 is a continuous outer cylindrical surface. Possible variations of the baffle are described in the simultaneously filed international application based on GB 9723341.5 and 9819071.5, and features from the statements of invention in that application may be combined with the separator of the present invention. Furthermore, features from the statements of invention in the simultaneously filed international application based on GB 9723345.6 and 9817073.1 may be combined with the separator of the present invention.

[0010] Below the baffle 21 the container 12 defines with the inner cylinder 14 an annular collection chamber 31 to which the only access in the assembled state of the apparatus is through the gap 23. The apparatus can be disassembled by removing the lower portions 32, 32' of the two cylinders which are formed as a single unit joined by a common base 33. The cylindrical container 12 splits at a level 34 just below the top of the baffle and the inner cylinder splits at a slightly lower level 35, still within the length of the baffle, and its upper end fits within a recess 36 in the upper part 15 of the inner cylinder 14 within the baffle. The split in the cylindrical container is shown as a butt join, but some means of making the join more fluid-tight may be provided. A bayonet fitting may be provided to join the cylinders at their split planes; external clamps are another suitable joining means. Annular closed cell foam seals (not shown) may be provided to make the joins fluid-tight.

[0011] Above the baffle 21 the central cylinder is surrounded by a frusto conical perforated shroud 41, tapering outwards towards the top of the container 12 and defining the inner boundary of the separation chamber. The volume between the shroud and the inner cylinder provides an outlet duct 42 which continues to taper outwards above the shroud and then becomes cylindrical at 43.

[0012] The apparatus so far described forms the first

stage of the separator. Fluid mixture flowing in the tangential conduit 11 is caused to swirl around the separation chamber 13 as it enters that chamber, the lighter phases tending to move to the smaller radii and heavier phases to the greater radii where they will diffuse and fall under gravity through the gap 23 to the collection chamber 31. As discussed in the co-pending application, the proportions and dimensions of the gap 23 are chosen so that sufficient heavier phase fluid passes through the gap and very little of the heavier phase fluid in the collection chamber 31 is drawn back through the gap. The provision of one or more annular co-axial baffles (not shown) on the base 33 assist the retention of heavier phases against re-entrainment. The lighter phases remaining in the separation chamber 13 pass through the shroud 41 and continue to swirl around the upper part 15 of the central cylinder 14 in the outlet duct 42, 43. This first stage of the separator is an initial stage, in which efficiency is not of prime importance. In a vacuum cleaner application, it serves to remove the fluff and heavier dirt particles from the flow. The shape of the separation chamber and the relationship of its inlet are not critical. The critical separation occurs in the later stages to those described below and it is these stages which embody the essential features of the invention.

[0013] The cylindrical part 43 of the outlet duct 42 of the first stage has a tangential outlet 44 leading by means not shown to the inlet conduit 51 of a second stage which has involute shaped inlet and outlet chambers 52, 53 with an intermediate chamber 54 which joins the inlet and outlet chambers along the common axis 55 of the three chambers. As can be seen from Figure 2, the curved wall of the inlet chamber decreases from a maximum radius at 56 to a minimum radius at 57 as it subtends the full 360 degrees around the axis 55. The downstream end of the inlet conduit 51 is defined on the outside 56 by the curved wall of maximum radius and on the inside 57 by the curved wall of minimum radius. For ease of manufacture, the radius decreases gradually, the curved wall having at least three, and in this embodiment four, sections of constant radius and subtending equal angles (90 degrees) at their respective centres, adjacent sections being centred about points on the common normal to the adjacent ends of those portions (thus making those common ends tangential), the radii of successive sections increasing from the minimum to the maximum. In this embodiment, the innermost section of the involute is centred on the normal 58 which passes through the axis 55. The radius of the inlet end 59 of the intermediate chamber 54 is not greater than the minimum radius of the inlet involute and in this embodiment is smaller than the smallest of the four radii.

[0014] The intermediate chamber 54 is frusto-conical, tapering inwardly to a smaller radius at its outlet end 61 which is not greater than and in this embodiment is smaller than the minimum radius of the outlet involute. The radius of the intermediate chamber 54 is of course smaller than the minimum radius of the inlet involute.

The curved wall of the outlet involute gradually increases in radius in subtending the full 360 degrees leading to an outlet conduit 62 for heavier phases in the opposite manner to that described for the inlet involute, the involutes being arranged to receive fluids swirling in the same sense about the stage axis 55 as the swirl induced in the inlet involute. There is an axial outlet from the second stage comprising a co-axial inner cylinder 63 extending through the outlet chamber and protruding at 64 slightly into the intermediate chamber 54. A frusto-conical wall 65 surrounds the inner cylinder, tapering outwards from the entry of the axial outlet to the far end 66 of the outlet involute. The inlet involute chamber 52 has an axial inlet 67 of radius small compared to all the radii of the chambers, in this example being one quarter of the minimum radius of the inlet involute.

[0015] The fluid mixture flowing in the inlet conduit 51 of the second stage follows the increasing curvature of the curved wall of the inlet involute and so swirls around the axis 55 with increasing velocity. As the swirling mixture travels along the axis 55, the heavier phases tend to move to the outer radii and the lighter phases tend to move towards the axis of the stage. The velocity of swirl is increased by the small entry radius of the intermediate chamber and further by its taper. The lighter phases near the axis will therefore leave the intermediate chamber through the axial outlet cylinder 63, whereas those phases at greater radii will be urged by the tapered shield 65 into the outlet involute around the curved wall of which they will swirl towards the outlet conduit 62. The swirling fluids in the inlet involute will create a low pressure point therein on the axis 55, so that fluids presented at the axial inlet 67 will tend to be drawn into this stage of the separator to move along the stage axis, as will be described later.

[0016] The outlet conduit 62 of the second stage is connected by means not shown to an inlet conduit 71 which is tangential to the cylindrical inlet chamber 72 of a third stage, which is itself of a conventional form. The inlet chamber opens on one side into a co-axial frusto-conical chamber 73 which tapers from a maximum radius equal to that of the inlet chamber 72 to a minimum at the other end where there is an axial outlet 76 for heavier phases, located within the upper part 15 of the inner cylinder of the first stage at a level within the shroud 41. A cylindrical duct 74 coaxial with the inlet chamber 72 has a mouth at the one side of the inlet chamber formed with a radiused inner rim 75 and extends therefrom through that chamber 72 to connect with the axial inlet 67 of the second stage, the axes of the three stages being in this embodiment coincident at 55 and vertical, the outlet 76 of the frusto-conical chamber 73 being at the lowest point of the third stage.

[0017] Fluid mixture flowing in the inlet conduit 71 of the third stage is caused to swirl around the chamber 72 as it is deflected around its curved wall, thus providing further separation of the phases. The lighter phases tend to move towards the axis 55 where they reverse

axial direction and enter the inner cylinder 74 and are drawn back into the axial inlet 67 of the second stage by the reduced pressure on the axis of the inlet chamber 52 of that second stage, thus being re-subjected to the separation processes of the second and third stages. The flow which is recirculated from outlet 62 back through the inlet 73 is about 5 to 30% of the flow which exits through the outlet 63. By recirculating this fraction, it is possible to form the third stage much smaller in volume than if the third stage had to deal with the whole flow through the second stage. The location of the inner cylinder 74 within the inlet chamber 72 provides a vortex finder as this third stage of the separator. The heavier phases in the chamber 72 tend to move to greater radii within the frusto conical chamber 73 as they continue to swirl, moving down the tapering wall towards the lower end of that chamber to leave by the outlet 76 at the lower end, to continue to the base 33 of the inner cylinder 14 of the first stage.

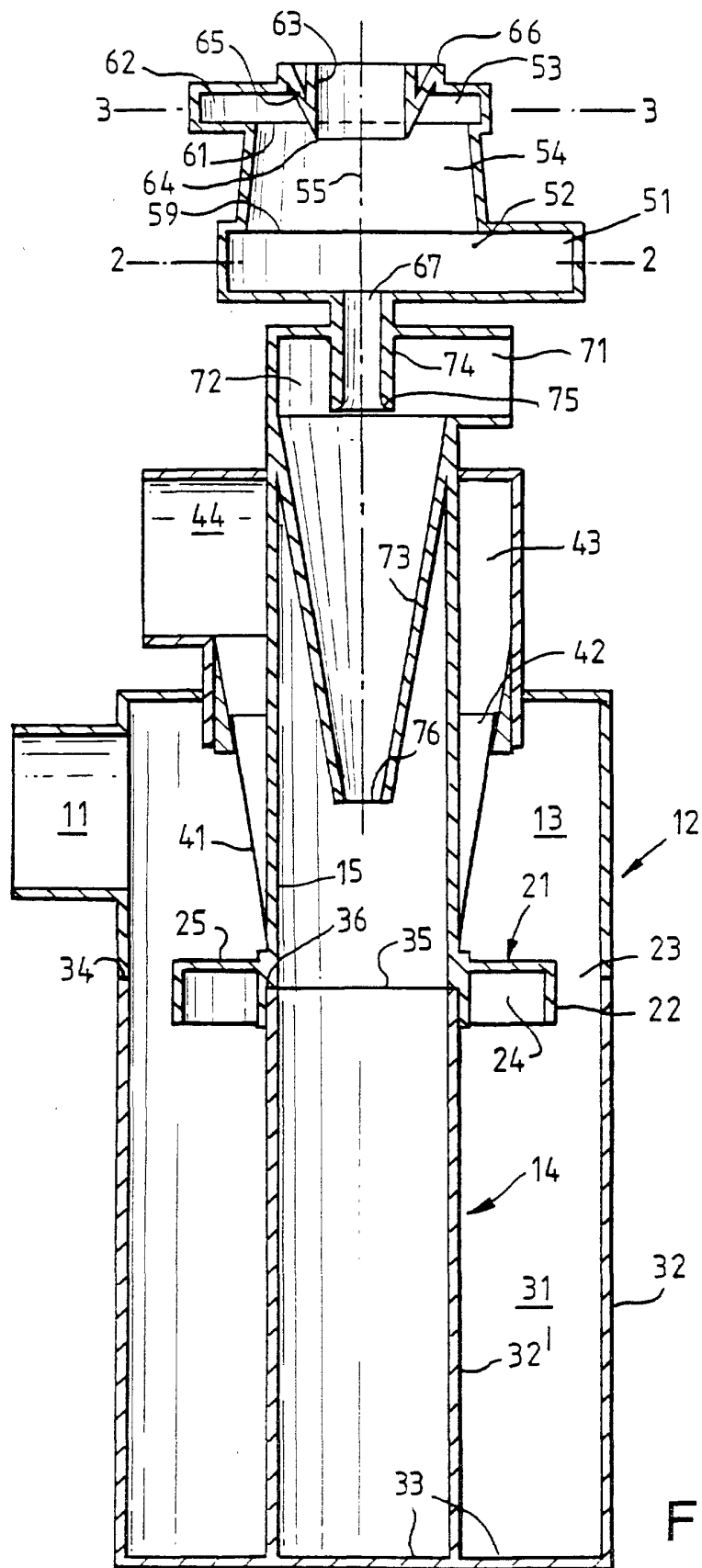
[0018] Heavier phases from the first and third stages therefore collect at the base 33 of the first stage container, those from the first stage within the annular chamber 31 and those from the third stage within the chamber within cylinder 32'. Both these chambers can be emptied by splitting the container as described above. Since there is only a small overlap between the portions of the container 12 across the split, the removal can be effected easily without knocking the upper portion which knocking might cause heavier phases such as dust to be dislodged, falling when the lower portion is no longer in place to collect them.

[0019] In the embodiments of the invention so far described, the apparatus is a vacuum cleaner and the mixture of fluid phases comprises dust particles entrained in air. Other mixtures which could be separated include silt entrained in a liquid or a mixture of oil and water. Gases, liquids or solids of different density, or any combinations thereof, or gas that is dissolved in liquid can be supplied to the inlet chamber.

3. A vacuum cleaner according to claim 2, wherein the portion of fluid flowing through the second of said plurality of stages is substantially 5 to 30% of the flow which exits from a lighter phase outlet of the first of said plurality of stages.
4. A vacuum cleaner according to claim 1, 2 or 3, wherein the most upstream separation stage is formed in an upper portion of the container (1) and deposits particulate matter in a lower portion of the container, the lower portion being splittable from the upper portion, there being only a small overlap between the upper and lower portions of the container, such that removal can be effected easily without knocking the upper portion which knocking might cause heavier phases such as dust to be dislodged, falling when the lower portion is no longer in place to collect them.
5. A vacuum cleaner according to any one of the preceding claims, wherein the axes of the separation stages are substantially parallel.
6. A vacuum cleaner according to any one of the preceding claims, wherein said plurality of separation stages comprise frusto-conical chambers.
7. A method of separating gasses, liquids or solids of different density, or combinations thereof, comprising introducing them as a swirling mixture to the vacuum cleaner as claimed in any one of claims 1 to 6.

Claims

1. A vacuum cleaner for separating particulate matter from air, including a container (1) comprising an outer container portion (12) and an inner container portion (14), a first separation stage for depositing particulate matter in the outer container portion (12), and a plurality of further separation stages downstream of said first separation stage for depositing particulate matter in the inner container portion (14).
2. A vacuum cleaner according to claim 1 wherein a portion of fluid from the first stage flows through a first of said plurality of further stages, and a portion of fluid from the first stage flows through a second of said plurality of further stages.



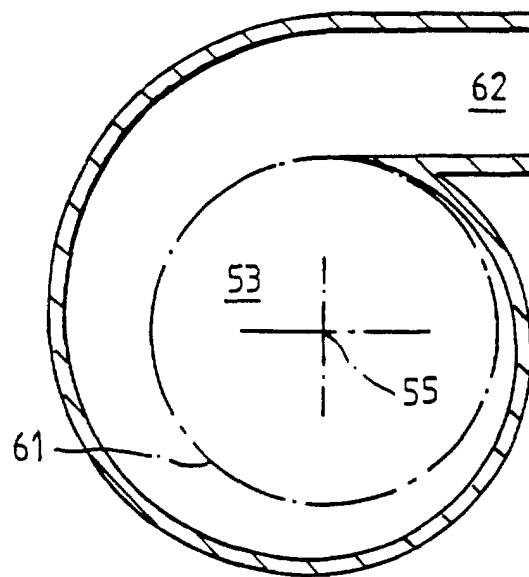


Fig. 2

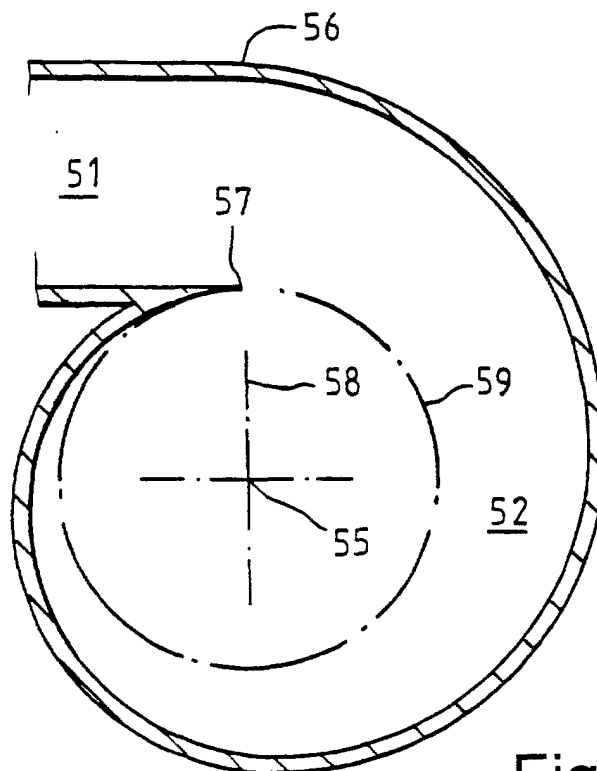


Fig. 3