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US 5244479 A **US 3234716 A** **US 2425410 A**

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(54) Abstract Title
A boundary layer separator

(57) A disc for a boundary layer separator (21) of the type having a plurality of closely spaced plates (11) mounted so as to be rotatable together about a common axis substantially perpendicular to the plane of the plates, with a flow path extending radially inwardly between adjacent pairs of plates (11) from the perimeter thereof towards a radially inner region (14, 15 and 16) defining a void forming part of an exit route of the flow path has a central disc portion (13) for connection to a drive shaft and openings (14, 15, 16) between the central portion (13) and a radially outer perimeter portion (12). The separator finds particular use in vacuum cleaners.

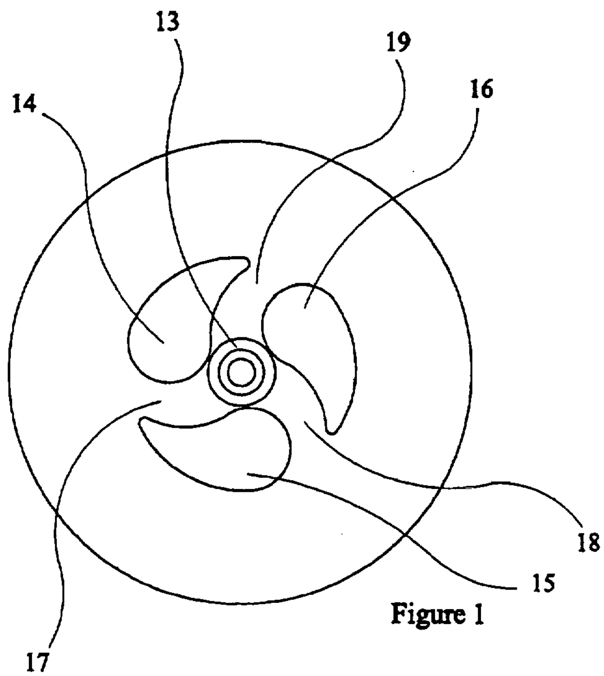

Figure 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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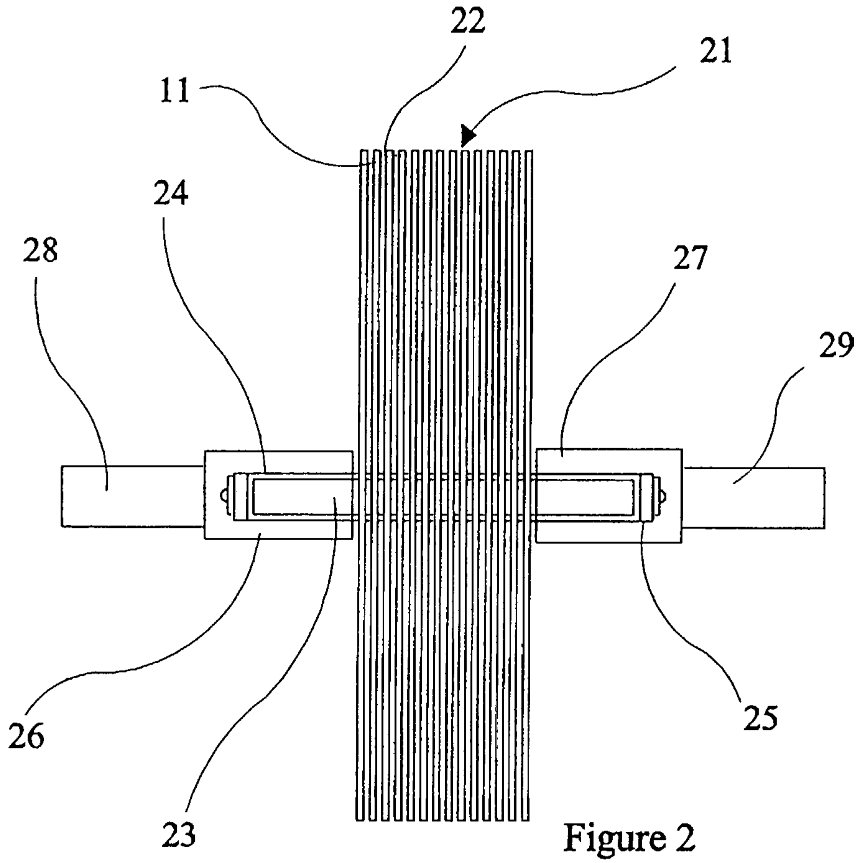

Figure 2

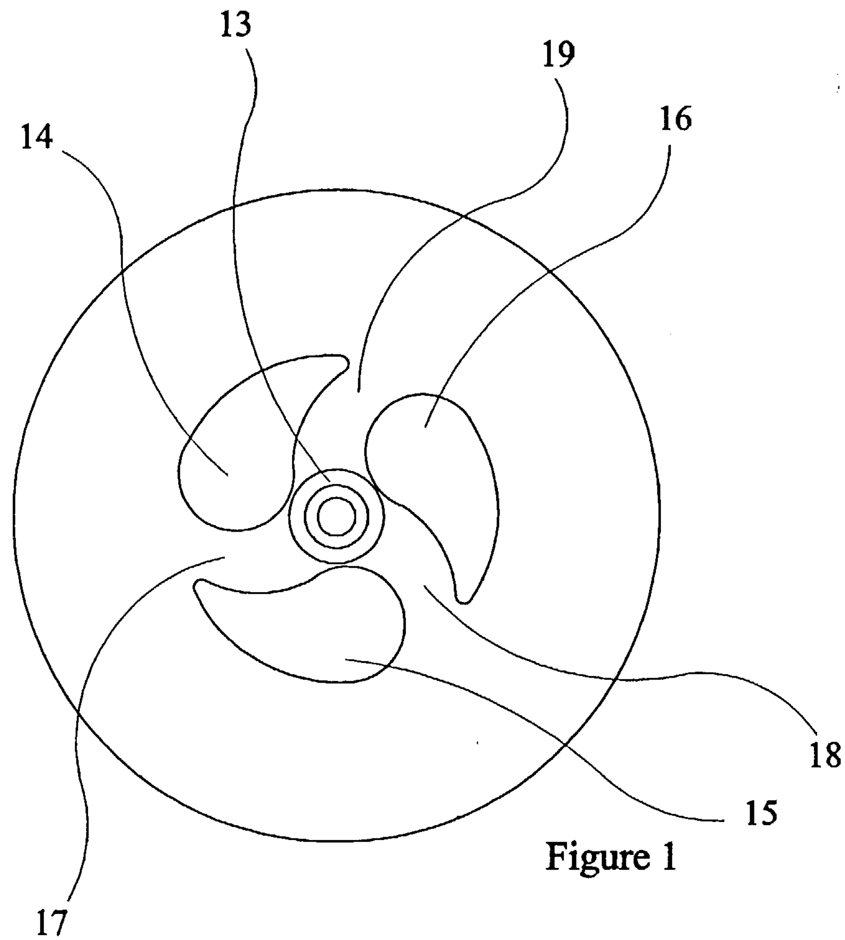

Figure 1

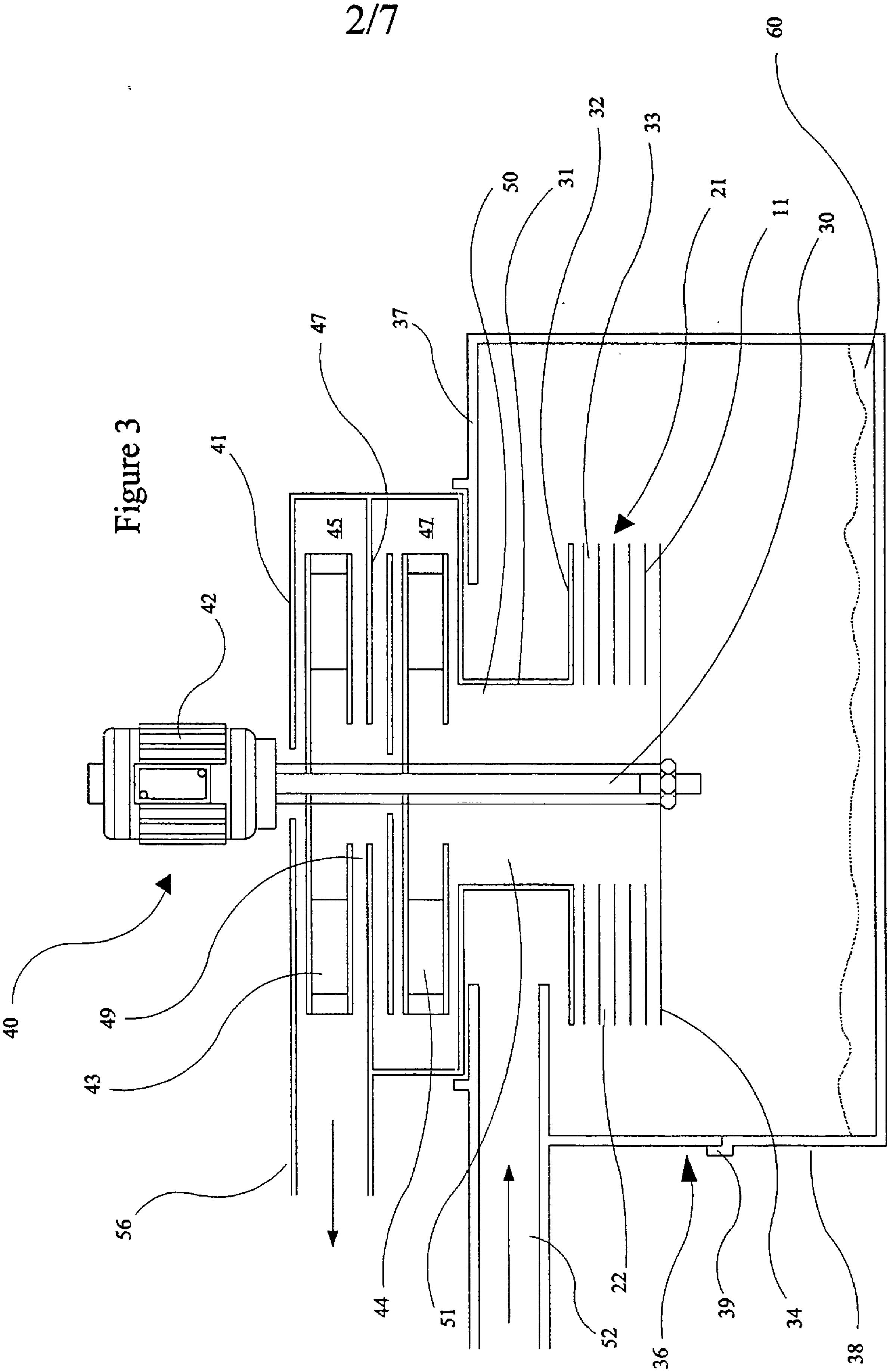
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Figure 3

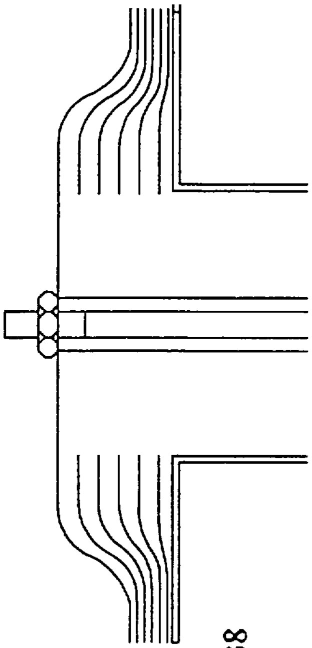

Figure 4a

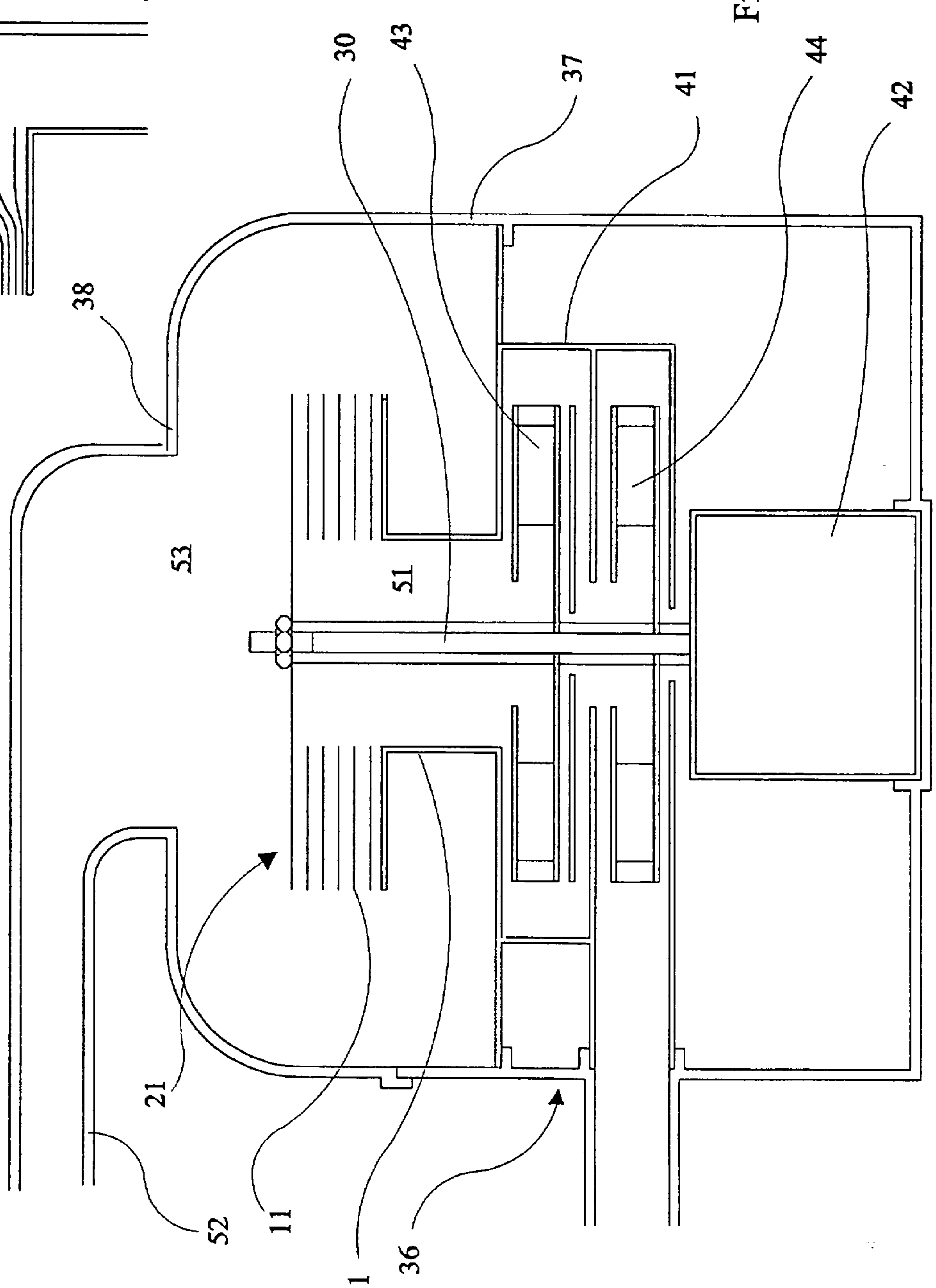

Figure 4

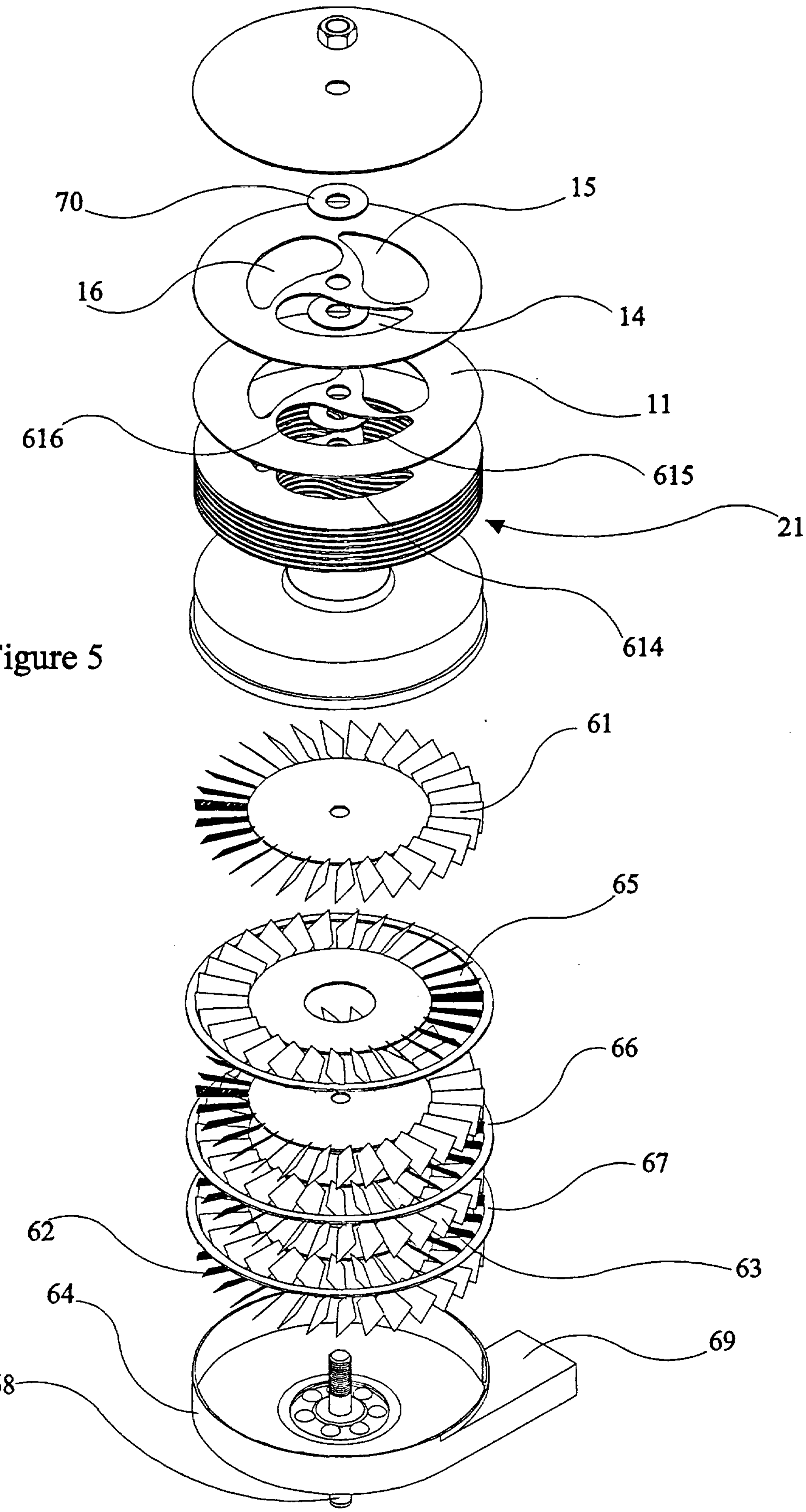

Figure 5

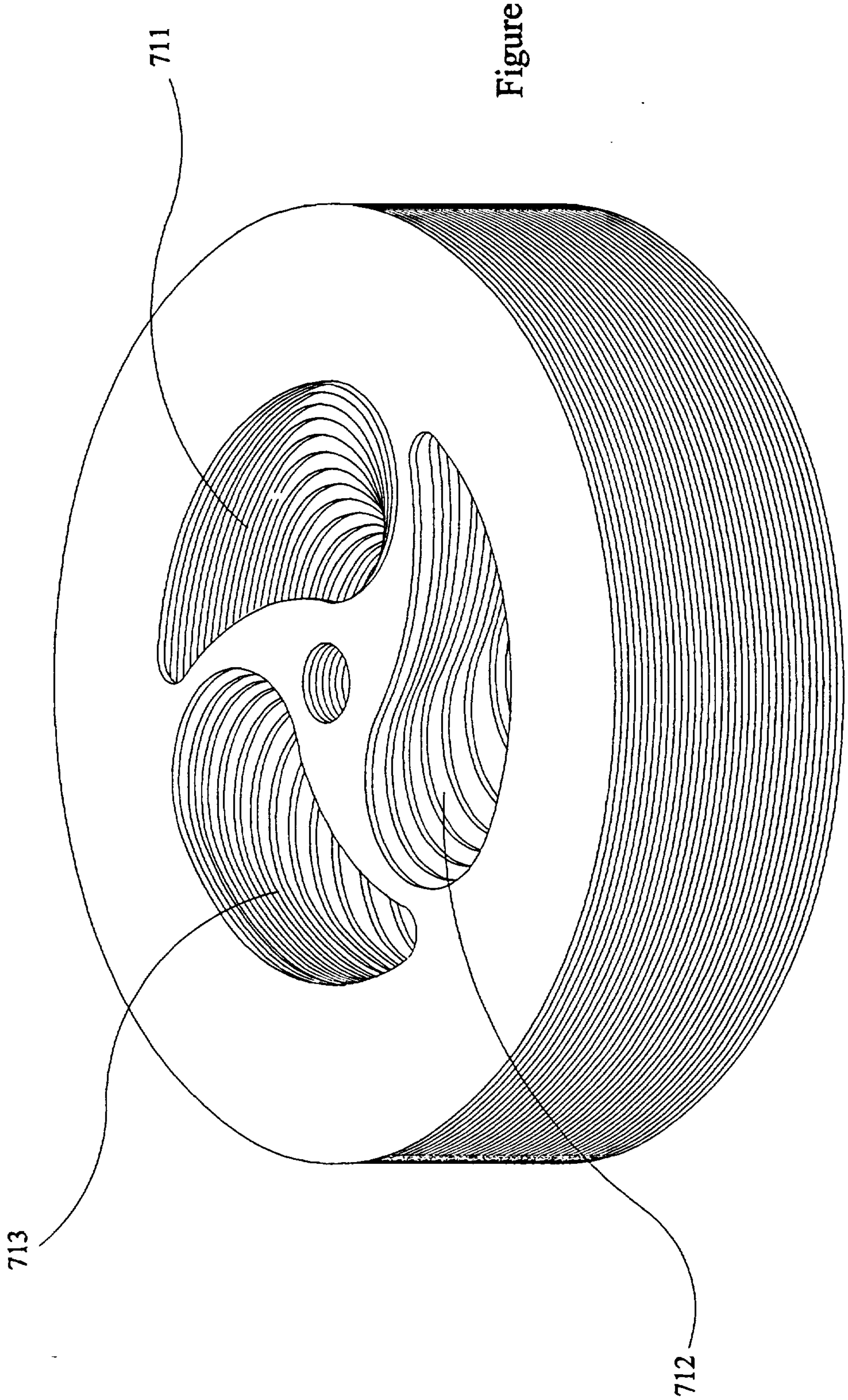

Figure 6

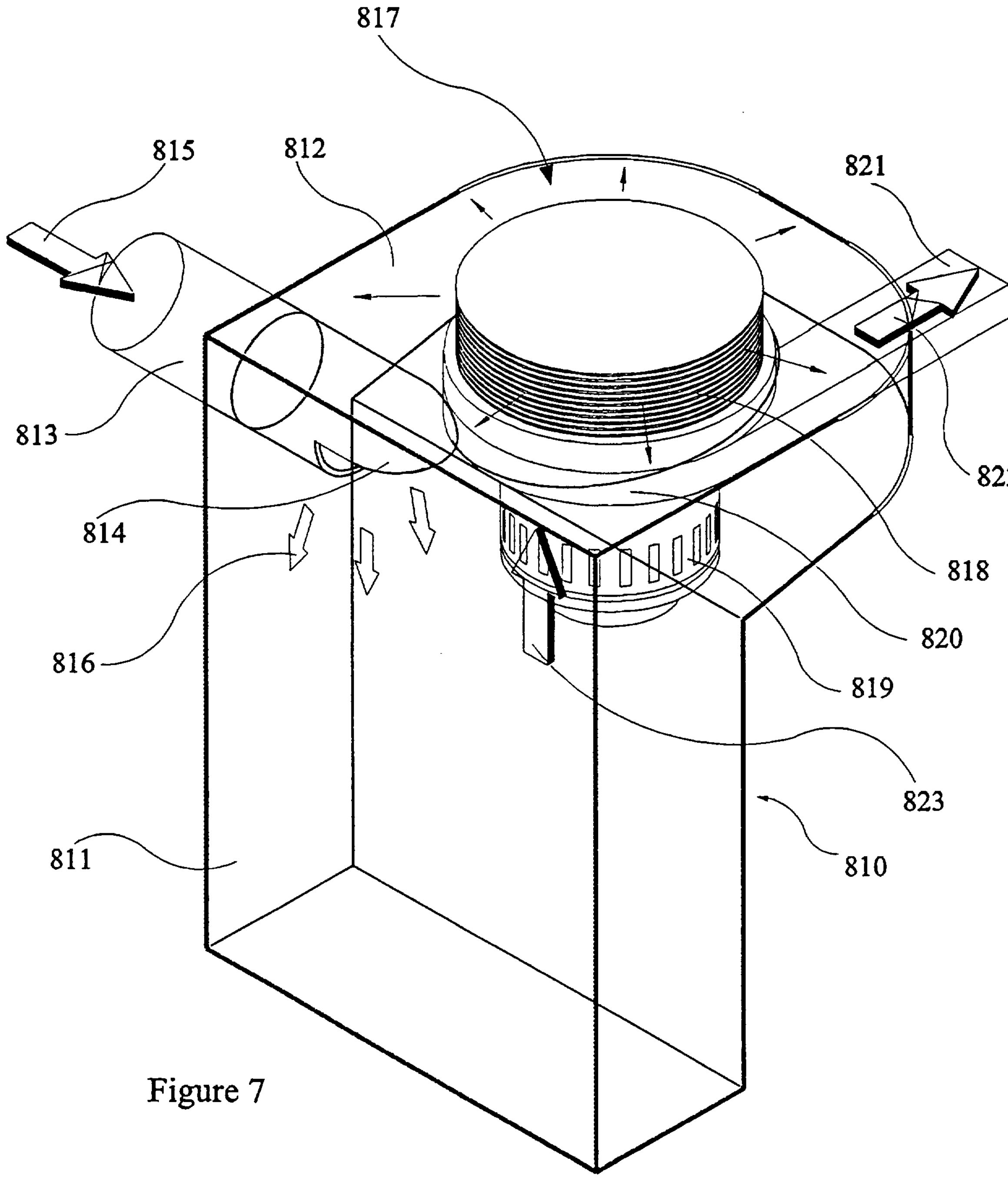

Figure 7

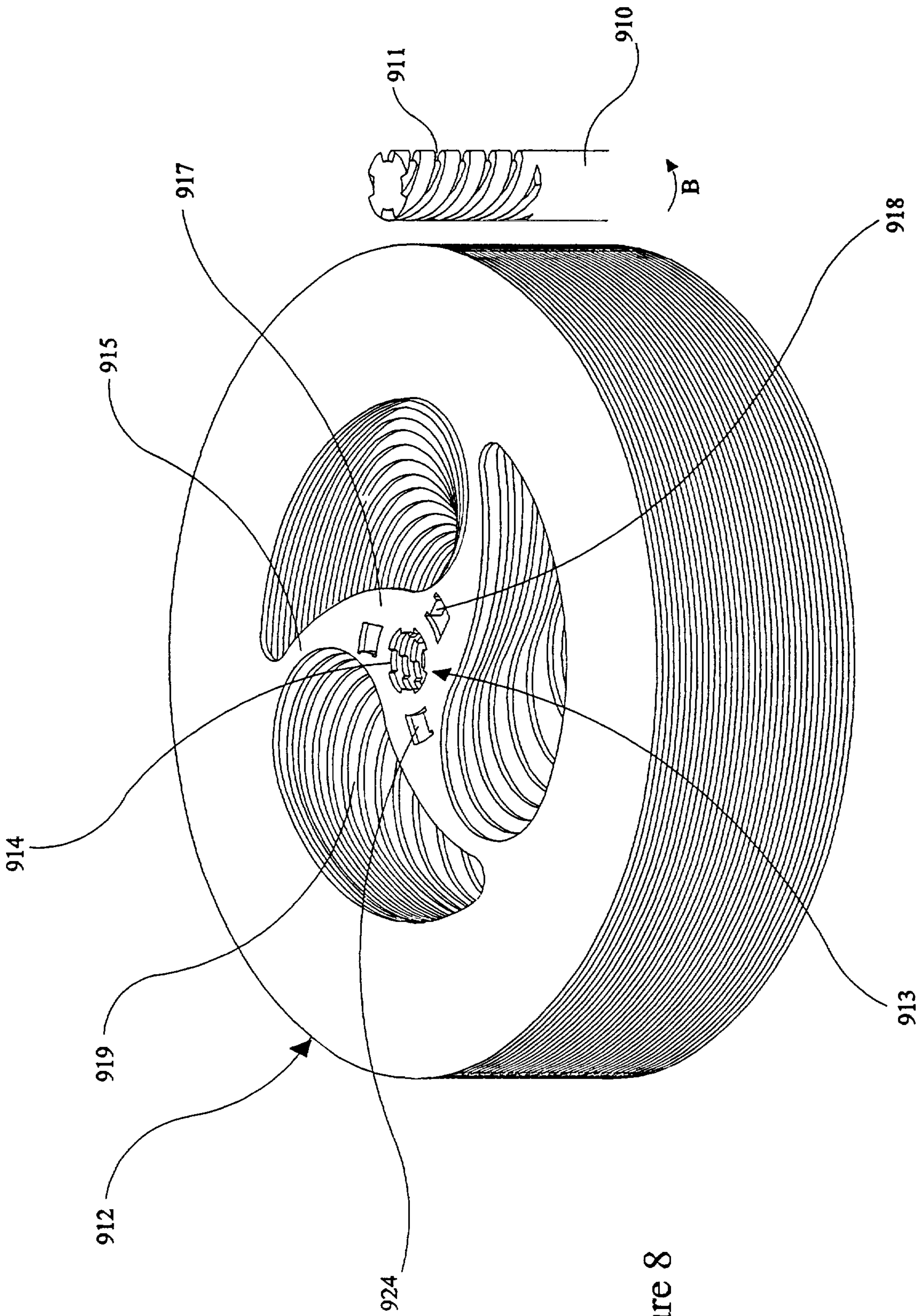

Figure 8

A BOUNDARY LAYER SEPARATOR

The present invention relates generally to a boundary layer separator.

The need to separate solid particulate material from a fluid in which it is entrained arises in a wide variety of industrial and other circumstances. Several different types of apparatus have been developed for achieving this object with differing degrees of success. The most obvious way of separating particulate material from a fluid is to pass the fluid through a filter medium, that is a material having apertures or openings the size of which is less than the average size of the particles to be separated from the fluid. In flowing through media filters the fluid is thus separated from the particulate material as the individual particles are obstructed from passing through the apertures or openings in the filter medium. This means, however, that the filter medium gradually builds up a load of particulate material filling the apertures, which progressively reduces the ability of the filter medium to allow the fluid to pass through it.

When using apparatus having a filter medium it is necessary periodically to replace or renew the filter medium, which is achieved by physically withdrawing the medium from its location in the apparatus and replacing it with fresh medium, or by so-called "back-washing" techniques which involve a reverse flow under pressure which are employed in an attempt to dislodge particles trapped in the filter medium. This is not always entirely successful so that, even after back-washing, filter media are frequently partially clogged resulting in a reduction in efficiency and an increase in the pressure drop across them.

It is also known to use cyclones, cascade separators, baffles, cavity filters and the like to effect separation between particulate material entrained with a fluid, but each of these has its own characteristic limitations. PCT publication WO97/19739 describes apparatus for separating particulates from a fluid stream in the form of a radial in-flow centrifugal filter device comprising a plurality of parallel discs mounted in spaced relationship and attached via spacers to a hollow drive tube which is in flow communication with the interior of the discs via a plurality of holes in the tube.

In fact the tube is provided with a relatively large number of apertures which communicate with the spaces between adjacent discs when these are stacked on the tube. In use the tube, and therefore the disc, is rotated at high speed and a pressure difference is created between the region surrounding the perimeter of the discs and the interior of the tube such as to urge a fluid to flow in the spaces between the discs.

As the fluid and entrained particulate material enters the space between the discs they experience a change in momentum due to the boundary layers established on each face of each disc and this causes the particulates to be expelled from the perimeter of the device whilst the fluid continues its motion between the discs towards the central chamber defined by the hollow tube. Such apparatus functions to separate particulate material from a fluid due to the interaction between the boundary layers on the faces of the discs and the particulate materials, and requires that the discs be rotated at a sufficiently high speed for the kinetic energy imparted to the particulate materials by the motion to be greater than the potential energy of the particulate material due to the pressure difference across the discs. Provided this relationship is maintained the particulate material will not enter the central chamber and the fluid will thus be cleaned of particulate material down to a size beyond which the interaction between the material and the boundary layers no longer imparts sufficient kinetic energy to the particulate material.

The apparatus described in WO97/19739 has a number of disadvantages in structural terms, in particular the need to provide a large number of apertures in the tube which drives the disc in order to communicate between the interior chamber and the spaces between the discs. This both weakens the tube through which the discs are driven in rotation and limits the flow cross section for the fluid.

The present invention seeks to provide an improved boundary layer separator in which the disadvantages of the known such separator are overcome.

The present invention also seeks to provide a wider range of applications for such boundary layer separators and, in particular, to provide a vacuum cleaner employing a boundary layer separator.

According to one aspect of the present invention, therefore, there is provided a disc for a radial flow parallel plate disc separator of the type having a plurality of closely spaced plates mounted so as to be rotatable together about a common axis substantially perpendicular to the plane of the plates, with a flow path extending radially inwardly between adjacent pairs of plates from the perimeter thereof towards a radially inner region in which there is a void forming part of an exit route of the said flow path, in which at least one opening in the disc is located between a central portion of the disc and a radially outer part thereof, which opening, together with other such openings in adjacent discs, define the said void.

In a preferred embodiment of the invention there are a plurality of said openings in the said disc.

The said openings may be separated by generally radially extending arms of the disc joining a central region thereof with the peripheral region thereof.

The present invention also comprehends a separator device including a plurality of discs as defined hereinabove, in which a limited relative movement between at least part of at least some of adjacent discs can take place whereby to tend to dislodge any particulates trapped between them.

This addresses one of the foreseen problems of closely spaced parallel plate boundary layer disc separators, namely that larger particulates entrained in the fluid may be driven, by the potential energy in the pressure difference across the discs, which in turn is influenced by the viscosity of the fluid and any local kinetic energy in the particles, to a position where they physically contact the opposite faces of the disc. This could also occur if a number of smaller particles were present between the discs at the same time, in which case a minor degree of coagulation or compaction may result in the build up of a composite particle which, because the frictional contact between those particles actually touching the surface of the discs will be greater than the forces exerted on the particles by their interengagement with the boundary layer, may result in such particles becoming trapped between the discs and constituting a trigger point for further coagulation which may result in partial clogging of the separator. By allowing the adjacent plates or discs to undertake a limited relative movement such potential clogging can be prevented by allowing the particles in contact with the discs to be displaced by such relative movement to reduce the frictional forces in play and allow the interengagement between the boundary layers of fluid between the adjacent plates to cause the particles to be ejected tangentially from the perimeter of the discs as these are brought up to the high speed of rotation which is the normal speed of operation of the separator.

For this purpose, at least alternate discs may have at least a part thereof which is resilient whereby to provide the said relative movement between at least some adjacent discs. In this respect at least alternate discs may comprise a radially inner part and a radially outer part joined by relatively narrow connecting arms which between them define respective said apertures of the disc.

These arms may be substantially rectilinear or curved, and in any event may be sufficiently resilient as to allow the radially inner and outer parts of the disc to experience relative angular displacement when subject to angular acceleration or deceleration about the axis of the disc. Such movement will contain a circumferential and a radial component, acting at different times, and the motion of adjacent faces of adjacent discs thus acts to "roll" any particles trapped between the adjacent discs thereby allowing them to adopt an orientation at which they may be affected by the boundary layers and ejected from the perimeter of the discs.

In one embodiment of the invention the said adjacent discs are spaced apart by spacers located on the said drive shaft between adjacent said discs. Alternatively, however, the radially inner part of the discs may be thicker than the radially outer parts such that the necessary separation between the perimetral regions of the discs is achieved immediately upon stacking of such discs onto the drive shaft. In order to encourage axial movement of the fluid in the region surrounding the drive shaft, that is the central chamber defined by the apertures in the discs, the said arms of adjacent discs may be angularly offset from one another. The chamber defined by adjacent openings in adjacent discs will thus have a helical form which, if appropriately oriented with respect to the intended direction of rotation of the discs, can act to limit the angular motion imparted to the fluid as it flows axially through the stack of discs parallel to the drive shaft.

The arms of adjacent discs are, therefore, preferably offset from one another in the same direction in order to define such a generally helical void in the array of discs so as to minimise any swirl of the fluid passing axially therethrough.

In a separator device as described hereinabove, in which each disc has a radially inner part and a radially outer part joined by arms which between them define the said apertures in each disc, the radially inner part of each disc may be thicker than the radially outer part as mentioned above, such that the radially outer part of the adjacent discs are spaced from one another when the radially inner parts of the discs are in contact with one another.

In a separator device incorporating such discs, or, indeed, incorporating discs separated by spacers, the said generally radially extending arms may be inclined to the general plane of the disc and/or may have an aerofoil section such as to exert an axial displacement on fluid in the said void when the discs are rotated.

At least some of the said discs may be flexible. The degree of flexibility of said flexible discs may be such that adjacent discs touch one another when the discs are not in rotation. This, too, assists in separating any clogged or jammed particles as the discs will flex to their relaxed state under the action of gravity when the shaft is allowed to stop rotating, and will adopt a straightened substantially parallel configuration when the disc is rotated at high speed. The rubbing of adjacent faces of the discs in the conversion from the stationary, curved or flexed configuration, to the straight configuration which is adopted when the shaft is rotated at high speed, allows the particles effectively to be "rolled" between adjacent faces and effectively dislodged thereby. This effect can be increased if at least some of the said discs have surface features in the form of asperities or recesses thereon.

A separator formed as an embodiment of the present invention, therefore, includes means for securing a plurality of discs to a common shaft for rotation therewith, and means for driving the said shaft to rotate in operation of the device. The said means for driving the said shaft to rotate are preferably a motor, and more preferably an electric motor. Other means for driving the shaft may, of course, be utilised, and in particular the said means for driving the said common shaft to rotate may be a turbine driven by a fluid. Such turbine may be driven by fluid flowing between the discs and into the said void. The separator device of the invention may be adapted to separate particles from a liquid stream or a gas stream, with variations in the structure to make it more robust if intended to be used with a liquid.

In embodiments in which some or all of the said discs are flexible the arrangement may be such that when the discs are not driven to rotate they lie in contact with one another at least substantially to close the flow path through the device. In this sense the separator may also be considered to act as a valve which automatically closes when not energised. The closure movement may be effected by axial displacement of rigid discs between contacting stationary positions and spaced operating positions, or may be effected by the use of flexible discs which flex into a contacting position when stationary and are held out radially by the centrifugal force when the discs are spinning especially at high speed.

Although embodiments of the invention in which each disc has only a single aperture may be envisaged, it is preferred that there are a plurality of apertures in the discs and it is likewise preferred that those parts of the disc separating the apertures be formed in such a way that when the discs are rotated they impart energy to the fluid in which the disc is located, with at least a component thereof directed axially of the discs.

Such a separator as is described herein may be utilised in many forms of industrial apparatus. One particularly suitable application for the separator device of the invention is in a vacuum cleaner in which it is desired to separate particles entrained in a stream of air from the airstream itself. In this respect the present invention also comprehends a vacuum cleaner including a separator device as defined herein. Preferably such separator device is housed in a chamber or casing of the vacuum cleaner. The discs may be carried in a stack at or adjacent one end of a driven shaft, and at a height (or position along the shaft) within a chamber or casing of the vacuum cleaner such as to allow particulate material separated from the airstream to collect in a region below the separator and within the chamber.

An air inlet to the said chamber or casing may be located at a position between the said discs and the said means for causing the air to flow through the spaces between the discs, the flow passage being defined by a sheath surrounding the said common drive shaft.

The present invention may also be considered, in another aspect, to comprise a device for separating solid particles from a fluid with which the particles are entrained, comprising a chamber with an inlet through which the said fluid may enter into the chamber, and an outlet through which fluid separated from the entrained particles may exit from the chamber, a separator device being located in the chamber in the flow path from the said inlet to the said outlet and comprising a plurality of parallel discs or plates mounted for rotation together about a common axis perpendicular to the plane of the plates, and arranged on a central drive shaft which passes through the said exit opening, each said plate having one or a plurality of apertures therein which together define a part of the exit route to the said outlet opening for fluid leaving the chamber.

The relative separation of the discs may vary along the stack. In particular because as has been found, the pressure drop across the active part of a pair of adjacent discs, that is from the periphery to a radially inner position at which the said opening is located, varies along the stack, being higher closer to the source of the pressure difference, it may be appropriate for the spacing to be closer in the region of the stack nearer to the source of the pressure difference that is the inlet if the separator is downstream for the source and the outlet if the source is downstream from the separator.

Various embodiments of the present invention will now be more particularly described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a view of a disc formed as an embodiment of the present invention;

Figure 2 is a schematic elevation view of a stack of discs such as that illustrated in Figure 1 mounted on a drive shaft;

Figure 3 is a schematic sectional view of a vacuum cleaner incorporating a disc separator formed using the discs of Figure 1;

Figure 4 is an alternative vacuum cleaner incorporating a disc separator;

Figure 5 is an exploded perspective view of a disc separator incorporating a fluid flow drive device;

Figure 6 is a schematic perspective view of a stack of discs orientated with a helical central channel;

Figure 7 is an alternative form of separator apparatus incorporating the separator device of Figures 5 and 6; and

Figure 8 is a perspective view of a stack of discs and co-operating shaft with means for varying the separation of the discs between a closed, stationary position and space, operating position.

Referring now to the drawings, and particularly to Figures 1 and 2, there is shown a disc generally indicated 11 which may be a self-supporting rigid material such as steel or other metal, or may be a flexible material such as a polymer or other plastics or composite material. The disc 11 has an outer peripheral part 12, a central region 13 and, between them, three apertures 14, 15, 16 which are all substantially identical in shape and spaced angularly from one another. Each of the apertures 14, 15, 16 has a "teardrop" shape and adjacent apertures 14, 15, 16 are separated by respective substantially radially directed arms 17, 18, 19 which are generally curved as illustrated in Figure 1 for reasons which will be explained in more detail below.

The central region 13 may be thicker than the remainder of the disc 11, or may have substantially the same thickness such that a stack 21 of discs 11, for example as shown in Figure 2, can be formed with each disc 11 spaced from its neighbour by a very narrow space 22 the dimensions of which are less than or equal to the thickness of the discs 11.

As can be seen in Figure 2, a stack 21 comprising a plurality of identical discs 11 oriented (as far as the curvature of the arms 17, 18, 19 is concerned) in the same way may be carried on a central shaft 23 the ends 24, 25 of which are threadedly engaged in internally threaded mounts 26, 27 having respective tangs 28, 29 by which the shaft 23 may be driven to rotate. The mounts 26, 27 press the central regions 13 of the discs together (with interposed spaces if needed) so that rotary drive from the shafts 28, 29 is transmitted to the stack 21 of the discs 11.

Figure 3 illustrates a typical configuration of a dust separator utilising a stack 21 of discs 11 shown schematically in Figure 3 mounted on a drive shaft 30 within a stationary shroud 31, the shroud 31 has a diameter matching that of the apertures 14, 15, 16 and a terminal flange 32 parallel to the stack 21 of discs 11 and forming therewith a narrow space 33 matching the inter space 22 between adjacent discs 11. A terminal disc 34 at the free end of the stack 21 has a diameter matching that of the other discs but is devoid of apertures whereby to constitute a terminal guard which rotates with the discs 11.

The stack 21 of discs 11 carried on the shelf 30 is housed within a chamber 35 defined within a housing 36 formed in two parts, namely an upper part 37 and a lower part 38 which is removable therefrom for reasons which will be described in more detail below. A flange 39 around the perimeter of the lower part 38 of the housing 36 ensures an air-tight seal is formed upon fitting the two parts together.

The upper part 37 of the housing 36 carries a sub-assembly generally indicated 40 comprising a casing 41 on which is mounted an electric motor 42 to which the drive shaft 30 is attached, and which carries two radial flow fans 43, 44, housed in respective chambers 45, 46 within the casing 41 and separated by a partition wall 47 with an opening 48 which allows air to flow from the chamber 46 into an inlet region 49 of the radial flow fan 43. The radial flow fan 44 has a similar opening 50 which communicates with the interior 51 of the shroud 31.

The housing 36 has an inlet duct 52 having an outlet opening 53 leading into the chamber 35 adjacent to the shroud 31 and at a higher level than the stack 21 of discs 11, and the casing 41 has an outlet duct connector 56 for directing air from the chamber 45. The configuration illustrated in Figure 3 is suitable for use in a vacuum cleaner in which the inlet duct 52 is connected to a cleaner head which is pressed against a region of a surface to be cleaned from dust.

In operation of the device rotation of the motor 42 drives the shaft 32 to rotate and, with it, the discs 11 in the stack 21. It will be appreciated that the discs 11 rotate at the same speed as the shaft 30. Likewise, the two radial-flow fans 43, 44 which are carried on the shaft 30 are also driven to rotate at the same speed. Air is thus drawn from the chamber 46 into the fan 43 and driven from the chamber 45 along the outlet duct 56. Likewise the fan 44 creates a depression in the region 51 within the shroud 31 and delivers air into the chamber 46 from which it can flow through the opening 48 into the inlet 49 of the fan 43. The pressure difference the interior 51 of the shroud 31 and the surrounding chamber 35 causes air within the chamber 35 to be drawn between the discs 11 of the stack 21 creating a depression in the duct 52 which is transferred to the vacuum cleaner head (not shown) in manner which will be understood. Dust-laden air will thus eventually start to arrive along the duct 52 passing out through the opening 53 into the chamber 35. As it enters the chamber 35 the speed of the air flow in the duct 52 will reduce and heavier particles entrained with the air will fall to the bottom of the chamber 35 to form a layer 60 as illustrated in Figure 3. Finer particles still entrained in the air moving within the chamber 35 will be carried towards the stack 21 of discs 11 through which the air is passing as a consequence of the pressure differential between the interior of the chamber 51 and the interior of the chamber 35. Because it is rotating at high speed, however, the stack 21 of discs 11 will create sets of boundary layers between facing surfaces of adjacent discs 11, and the spacing between these discs 11 is such that the boundary layers overlap so that any particles entering between two adjacent discs 11 are caused to rotate by these boundary layers in the direction of rotation of the discs 11. The kinetic energy thus imparted to the particles causing them to exit tangentially from the perimeteral region of the discs 11 before they enter any significant distance radially inwardly of the perimeter. Continual ejection of air particles from the discs will gradually cause a build up of the particle density within the chamber 35 and collisions between particles will result in a loss of the kinetic energy of the particle to an extent that these will collect on the dust layer 60 at the bottom of the chamber 35. Meanwhile, the air, now separated from the entrained dust particles, can enter the chamber 51 from where it passes through the fans 43, 44 to the outlet duct 56.

Only very microscopic particles of dust the dimensions of which are such that the mass of the particle is insufficient for its kinetic energy to overcome the viscosity effects of the air will remain entrained such particles account for an extremely small proportion of the overall dust content of the dust-laden air, however, significantly less than 0.1%. The air is, thus, thoroughly cleaned in its passage through the separator which, however, because no particles of dust can become trapped between adjacent discs 11 does not loose its effectiveness by clogging as more and more particles are separated from the air.

Moreover, because the discs are substantially flat with no surfaces which are "frontal" to the air flow, the drag on the air between the chamber 35 and the chamber 51 is limited to the frictional effects of clean air on the disc surfaces. To minimise this friction the disc surfaces can be polished to a high level. The higher the surface finish, of course, the narrower is the boundary layer which is in part created by frictional effects, and, consequently, for effective utilisation of the device the spacing between adjacent discs must be narrower the more highly polished these surfaces are.

The arms 17, 18, 19 are relatively thin such that, upon acceleration or deceleration of the motor 42, and therefore the discs 11 in the stack 21, the mass of the peripheral portion 12 crates an inertial lag such that the peripheral portion 12 will lag behind the shaft 30 upon acceleration or lead the shaft 30 upon deceleration such that, in these conditions, relative movement between adjacent discs can occur which tend to allow any particles which have become trapped between adjacent discs to be dislodged. Other means for ensuring dislodgement of any trapped particles are provide in other embodiments as will be described in more detail hereinbelow.

Referring now to Figure 4 a similar application of the disc separator is shown in the form of a vacuum cleaner and in this embodiment those components which are the same as or fulfil the same functions as corresponding components in the embodiment of Figure 3 have been allocated the same reference numerals. This embodiment differs from that of Figure 3 in particular in that the stack 21 of discs 11 is mounted at the upper end of the shaft 30 with the electric motor (which may alternatively be a turbine) 42 carried at the lower end. In this embodiment the inlet duct 52 leads to an opening 53 in a removable upper part 38 of the housing 36 with a lower part 37 carrying the casing 41 for the fans 43, 44.

In the embodiment of Figure 3 the discs 11 are made from highly polished rigid sheet metal whereas in the embodiment of Figure 4 the discs 11 are made from a plastics or other polymeric material which is relatively flexible and which is not sufficiently stiff to be self supporting when stationary. The form adopted by the stack 21 of discs 11 is illustrated in Figure 4a. In this configuration, which is adopted when the shaft 30 is stationary, the adjacent discs 11 are in contact with one another and therefore effectively close the flow passage through the chamber 51 within the shroud 31.

In the embodiment of Figure 5, which represents the upper and lower parts of an assembly such as that in Figure 4, but in which the motor 42 is replaced by a turbine, the shaft 30 is driven by the rotation of a plurality of rotor blades 61, 62, 63, 64 interspersed between respective rings of stator blades 65, 66, 67 and all housed within a casing 68 from which a tangential outlet 69 leads to a vacuum source (not shown). Also connected to the shaft 30 is a stack of discs 11 (Figure 5) of the form illustrated in Figure 1, interspersed with spacers 70.

In the embodiment illustrated in Figure 5 the openings 14, 15, 16 in adjacent discs 11 are all aligned with one another to form respective chambers 614, 615, 616. These chambers extend substantially axially of the stack 21.

In other embodiments (not shown) adjacent discs 11 are angularly offset from one another such that the chambers formed from adjacent openings, corresponding to the chambers 614, 615 and 616 have a helical rather than an axial form. Figure 6 shows a stack with sequentially offset orientation forming a set of three helical chambers 711, 712, 713.

Likewise, in other embodiments not illustrated, the arms 17, 18, 19, rather than being purely parallel to the plane of the disc 11, have an inclination such as to assist in urging the air stream axially. As well as being inclined the arms may have an aerofoil section, again for the purpose of encouraging axial flow of the air and, thereby, reducing the pressure drop through the entire separator and consequently increasing its efficiency without in any way reducing its ability to separate particles from an air stream.

Referring now to Figure 7 there is shown a separator unit 810 which may be used in a vacuum cleaner or in other separating apparatus. The unit 810 comprises an outer casing in the form of a rectangular main collection chamber 811 from the upper end of which projects a transverse separator chamber 712. Also at the upper end of the collection chamber 811 is an inlet duct 813 traversing the wall of the collection chamber 8911 and having at its outlet end a deflector 814 to ensure that fluid flowing through the duct 813 as represented by the arrow 815 is deflected by the deflector 814 within the collection chamber 811 downwardly as represented by the arrows 816.

In the separator chamber 812 is located a separator device generally indicated 817, which may be of the type generally illustrated in Figure 5 and comprising a stack of closely spaced discs generally indicated 818 driven to rotate by an electric motor 819. Surrounding the lower end of the stack of discs 818 is a peripheral duct 820 leading to an outlet duct 821. In use of this separator the pressure to drive the fluid through the device is created by the rotation of the motor 819 driving impeller blades (not visible in Figure 8, but corresponding to those illustrated in Figure 5) to cause fluid within the separator chamber 812 to flow radially between the discs 818 down the central chamber (not illustrated) to the duct 820 and then out through the outlet duct 821 as represented by the arrow 822. By providing a deep collection chamber and diverting the incoming fluid stream as represented by the arrows 816 towards the lower part of the chamber 811 a preliminary separation of the heavier dust or other particles entrained with the fluid stream can take place as the fluid slows its motion, and likewise particles separated at the discs 818 by the boundary layer separating effect described hereinabove, can settle within the collection chamber 811. It is to be anticipated that the incoming fluid stream within the collection chamber 811 is likely to flow mostly down one side as illustrated by the arrows 816 and to rise along the opposite side as represented by the arrow 823.

Figure 8 schematically illustrates a structure which will allow substantially rigid discs to separate to a pre-determined distance when subject to high speed rotation, and to move together, to close the spaces between them when not in rotation. The major components of such a structure comprise a drive shaft 910 having a deep helical thread, for example of an ajax or square thread conformation 911 formed in the upper end. As illustrated in figure 8 the thread 911 is a four-start thread. Disc 912, illustrated as a stack of identical discs in Figure 8, have a central opening 913 of circular form with four radially inwardly projecting tabs or lugs 914 each of identical form and shaped so as to fit into a corresponding flight of the four-start thread 911 when the disc 912 is fitted onto the shaft 910. This allows each disc 912 to turn angularly with respect to the shaft 810 and to move axially as a consequence of the thread 911.

Each disc 912 has three separator apertures 914 which are all identical to one another, and which are located in the central portion of the disc 912 radially inwardly from the arms 915 which join the outer perimeter portion 916 to the central or boss portion 917.

The apertures 914 are generally rectangular or square in shape and are orientated with two opposite radially extending sides and two opposite circumferentially extending sides, these latter being curved with a centre of curvature coincident with the axis of the disc 912. Projecting axially from a radial side of the aperture 914 is an abutment arm 918 the length of which is such that it can project into the corresponding aperture 914 of an underlying disc 912. When the shaft 910 is stationary all the discs 912 lie in contact with one another with the co-operating abutment arms 918 engaged each in a corresponding aperture 914 of an underlying disc. The thickness of the abutment arms 918 results in a slight angular offset of each disc 912 with respect to the adjacent disc resulting in a helical configuration of the opening 919 defined by the radial arms 915.

When the shaft 910 is driven to rotate in the direction of the arrow B of Figure 8, the inertia of the disc 912 results in relative angular movement of the shaft 910 with respect to the disc 912 causing the discs 912 to be displaced axially along the helical thread 911 by virtue of the engagement of the radially inwardly projecting lugs or tabs 914. Each disc 912, however, can move axially away from its neighbour only by a distance determined by the dimensions of the apertures 914 since, once an angular separation between adjacent discs 912 has caused the abutment arm 918 of one disc to move from one side to the other of the aperture 914 in the underlying disc 912 it will contact the opposite radial wall of the aperture 914 in the underlying disc preventing further angular relative movement and therefore preventing further axial separation. Each disc 912 cooperates with the adjacent underlying disc 912 such that each may become separated by a given distance determined by the dimension of the aperture 914 and the continuing drive of the shaft 910 together with the resistance to motion due to the frictional contact of the disc 912 with the fluid medium will result in this angular separation being maintained whilst the shaft 910 is accelerating or rotating at a steady speed. When the shaft 910 starts to decelerate the momentum of the discs 912 will cause them to turn angularly with respect to the shaft 910 and move axially towards one another until, when the shaft 910 is stationary, the discs 912 will all be in contact and thus close the fluid path through the separator. A light spring bins may be provided to ensure that this occurs.

This embodiment enables the separation of the discs 912 in use to be varied in a particularly simple manner by varying the dimensions of the aperture 914 from one disc to the other so that those discs closer to the source of the suction driving the fluid movement (the lower discs in the stack as illustrated in figure 7, for example) can be more closely spaced to compensate for the higher pressure deferential between the perimeter and the openings 919, and more widely spaced near the upper part of the stack which is further from the suction source. In this way the boundary layer effect can be rendered more uniform along the axial dimension of the separator so that there is not a tendency for more fluid to flow through a certain portion of the stack.

CLAIMS

1. A disc for a radial flow parallel plate disc separator of the type having a plurality of closely spaced plates mounted so as to be rotatable together about a common axis substantially perpendicular to the plane of the plates, with a flow path extending radially inwardly between adjacent pairs of plates from the perimeter thereof towards a radially inner region in which there is a void forming part of an exit route of the said flow path, in which at least one opening in the disc lies between a central portion of the disc and a radially outer part thereof which opening together with other such openings in adjacent discs define the said void.

2. A disc as claimed in Claim 1, in which there are a plurality of said openings in the said disc.

3. A disc as claimed in Claim 2, in which the said openings are separated by generally radially extending arms of the disc, joining a central region with a peripheral region.

4. A disc as claimed in any of Claims 1 to 3, in which the radially inner region has a generally axially extending lug or tab and an aperture for cooperation with the lug or tab of an adjacent disc in a stack whereby to limit relative angular and/or axial separation of adjacent said discs.

5.. A separator device, including a plurality of discs as claimed in any of Claims 1 to 4, in which a limited relative movement between at least part of adjacent discs can take place whereby to tend to dislodge any particles trapped between them.

6. A separator device as claimed in Claim 5, in which at least alternate discs have at least a part thereof which is resilient whereby to provide the said relative movement between at least part of adjacent discs.

7. A separator device as claimed in Claim 6, in which the said at least alternate discs comprise a radially inner part and a radially outer part joined by relatively narrow connecting arms which between them define a respective said aperture of the disc.

8. A separator device as claimed in Claim 7, in which the said arms are curved and sufficiently resilient as to allow the radially outer part and radially inner part of the disc to experience relative angular movement when subject to angular acceleration or deceleration about the said axis.

9. A separator device as claimed in any of Claims 5 to 8, in which the said adjacent discs are spaced apart by spacers located on the said drive shaft between adjacent discs.

10. A separator device as claimed in any of Claims 5 to 9, in which the said arms of adjacent discs are angularly offset from one another.

11. A separator device as claimed in Claim 10, in which the arm of adjacent discs

are offset from one another in the same direction whereby to define a generally helical void in the array of discs so as to minimise swirl of the fluid passing axially therethrough.

12. A separator device as claimed in any of Claims 5 to 11, in which each disc has a radially inner part and a radially outer part joined by arms which between them define the said apertures in each disc, in which the radially inner part of each disc is thicker than the radially outer part such that the radially outer part of adjacent discs are spaced from one another when the radially inner part of the discs are in contact with one another.

13. A separator device as claimed in any of Claims 5 to 12, in which the said generally radially extending arms are inclined to the general plane of the disc and/or have an aerofoil section such as to exert an axial displacement on fluid in the said void when the discs are rotated.

14. A separator device as claimed in any of Claims 5 to 13, in which at least some of the said discs are flexible.

15. A separator device as claimed in Claim 14, in which the degree of flexibility of the said flexible discs is such that adjacent discs touch one another when the discs are not in rotation.

16. A separator device as claimed in any of Claims 5 to 15, in which at least some

of the said discs have surface features in the form of apertures or recesses thereon.

17. A separator device as claimed in any of Claims 5 to 16 further including means for securing a plurality of discs to a common shaft for rotation therewith and means for driving the said shaft to rotate in operation of the device.

18. A separator device as claimed in Claim 17, in which the said shaft has at least one helical groove or flight in its cylindrical surface and the discs have projecting/uses which engage in the said groove on flight whereby to cause relative axial displacement of the disc and shaft upon the occurrence of relative angular displacement between them.

19. A separation device as claimed in Claim 18, in which the discs are formed or provided with interengaging elements for limiting the maximum relative angular displacement of adjacent discs and thereby limiting the relative axial separation of the discs.

20. A separator device as claimed in any of Claims 17 to 19, in which the said means for driving the said shaft to rotate is a motor.

21. A separator device as claimed in any of Claims 5 to 20, in which the said discs are spaced more closely in the vicinity of the fluid outlet from the separator and move widely at a distance from the fluid outlet from the separation..

22. A separator device as claimed in Claim 19, in which the said means for driving the said common shaft to rotate is a turbine.

23. A separator device as claimed in Claim 19, in which the turbine is driven by fluid flowing between the discs and into the said void.

24. A separator device as claimed in any of Claims 5 to 23, in which all the said discs are flexible and the arrangement is such that, when the discs are not driven to rotate they lie in contact with one another at least substantially to close the flow path through the device..

25. A separator device as claimed in any of Claims 5 to 24, in which there are in plurality of apertures in the discs and the form of those parts of the disc separating the apertures is such that, when the discs are rotated they impart energy to the fluid in which the disc is located with at least a component directed axially of the discs.

26. A vacuum cleaner including a separator device as claimed in any of Claims 5 to 24 housed in a chamber casing thereof.

27. A vacuum cleaner as claimed in Claim 26, in which the discs are carried in a stack at or adjacent one end of a driven shaft at a height within a chamber or casing of the vacuum cleaner such as to allow particulate matter separated from the air streams to collect in a region below the separators.

28. A vacuum cleaner as claimed in Claims 26 or 27, in which an air inlet to the said chamber or casing is located at a position between the said disc and means for causing the air to flow through the spaced between the discs, the flow passage being defined by a sheath surrounding the said common drive shaft.

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Claims searched: 1-28

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): B1T (TPPA, TPJX) B2P

Int Cl (Ed.6): B01D 45/14

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2 061 136A	(SAGET) See apertured discs in figures & page 4 lines19-35	1,2 at least
X	GB 720 391	(CARTER) See apertured discs in figures	1,2 at least
X	EP 0 088 657A1	(SAGET) See apertured discs in Figure 1	1,2 at least
X	US 5 244 479	(DEAN) See apertured discs 44 in Figure 1	1,2 at least
X	US 3 234 716	(SEVIN) See apertured discs in figures	1,2 at least
X	US 2 425 410	(ZEITLIN) See apertured discs in figures	1,2 at least

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