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(54) **Cyclonic separation apparatus and vacuum cleaner having such a separation apparatus**

Zyklonische Trennvorrichtung und Staubsauger mit solch einer Trennvorrichtung

Appareil de séparation cyclonique et aspirateur muni d'un tel appareil de séparation

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Description

[0001] This invention relates to cyclonic separation apparatus.

[0002] Cyclonic separators are well known apparatus for removing particles from a gas flow without the use of filters. Cyclone separators have found utility in the field of vacuum cleaners to separate dirt and dust from the airflow. It is well known that the separation efficiency of cyclonic separators is dependent upon the force which is applied to the particles in the airflow, in accordance with the following formula.

$$f=2mv^2/d,$$

where

f = the force applied to the particles
m = the mass of the particle
v = the flow velocity
d = the diameter of the cyclonic airflow

[0003] Thus it will be appreciated that the separation efficiency is inversely proportional to the diameter of the cyclone chamber, such that smaller diameter cyclones are more suited to separating lighter particles than larger cyclones.

[0004] Accordingly, it is well known for vacuum cleaners to incorporate a first upstream stage, comprising a relatively large diameter cyclone having a maximum diameter of approximately 200mm, and a plurality of parallel-connected downstream cyclones having a maximum diameter of approximately 20mm. In use, the upstream cyclone separates course dirt and dust from the airflow, whereas the downstream cyclones separate the finer dirt and dust.

[0005] Vacuum cleaners of the above-mentioned type are disclosed in EP1361815, US3425192 and GB2406067 and comprise a plurality of small cyclones mounted in an array above or adjacent the larger upstream cyclone. A main airflow duct leads from the outlet of the upstream cyclone, the duct branching into a plurality of secondary ducts feeding one or more of the respective downstream cyclones.

[0006] One disadvantage of the above-mentioned arrangement is that the main duct can cause a restriction in the air flow and the resultant drop in air flow velocity reduces the separation efficiency. Another disadvantage of the above-mentioned arrangement is that the secondary ducts are complex, small and susceptible to blockage.

[0007] DE1739315 discloses a cyclonic separation apparatus comprising a plurality of cyclone separators arranged in a plurality of groups which are grouped together, each group of cyclone separators comprising a respective inlet duct connected at its downstream end to the cyclone separators of its respective group. The upstream end of the inlet ducts are connected to a main inlet duct of the apparatus.

[0008] WO2006/125946 discloses a cyclonic separation apparatus comprising a plurality of cyclone separators arranged in a group having an inlet duct connected at its downstream end to the cyclone separators of the group. The upstream end of the inlet duct is connected to the outlet of an upstream cyclone separator having a dirty air inlet. In another embodiment the apparatus comprises a plurality of groups of cyclone separators arranged in series downstream of the upstream cyclone separator.

[0009] GB2399780A discloses a cyclonic separation apparatus comprising a plurality of downstream cyclone separators arranged in a plurality of groups which are grouped together, each group of downstream cyclone separators comprising a respective inlet duct, each duct being connected at its downstream end to the cyclone separators of its respective group, the apparatus further comprising an upstream cyclone separator having a dirty air inlet and an annular or circular outlet chamber, said inlet ducts extending in parallel from said outlet chamber.

[0010] We have now devised a cyclonic separation apparatus of the kind disclosed in GB2399780 which alleviates the above-mentioned problems and which is characterised in that the apparatus further comprises a body, the cyclonic separators being disposed side-by-side in an array in said body, the inlet ducts extending through the body between opposite sides thereof.

[0011] The combined cross-sectional area of the plurality of inlet ducts is large and hence the ducts do not cause a restriction in the air flow and as such the separation efficiency is maximised. Also, since the cyclones are arranged in groups, with each inlet duct only feeding some cyclone separators of the apparatus, the need for complex and small secondary ducts is avoided and the apparatus is thus less susceptible to blockage. Furthermore, any pressure drop is minimised because the inlet ducts can positioned be in close proximity to the cyclone separators.

[0012] Preferably the inlet duct of each group extends parallel to the rotational axis of the cyclone separators of the respective group.

[0013] Preferably the cyclone separators in each group are arranged around the longitudinal axis of the respective inlet duct of the group.

[0014] Preferably the radial distance between the longitudinal axis of each inlet duct and each cyclone separator of their respective group is substantially equal, thereby ensuring that the airflow path to each cyclone separator is substantially the same. This helps to ensure that the volume of air flowing along each inlet duct is substantially equal, so that the dirt loadings on each cyclone are the same.

[0015] Preferably the inlet duct of each group extends alongside the cyclone separators of the group.

[0016] Preferably the inlet ducts are disposed at se-

lected circumferentially-spaced points on a circular line.

[0017] Preferably the inlets are open on opposite sides of the body for ease of moulding, a cover being provided for fitting to one side of the body to close the downstream end of the inlets.

[0018] Preferably the inlets are connected at their downstream ends to respective radially-extending passages leading to the respective cyclone separators of the group.

[0019] Preferably the passages are formed in the body.

[0020] Preferably the cyclone separators of each group are disposed at selected positions along an arcuate line centred about the longitudinal axis of the inlet duct of the group. An advantage of this arrangement is that it maximises the density of the cyclonic separators and thereby enables a larger cyclonic separators to be used than permitted by prior arrangements.

[0021] Preferably the arcuate lines of adjacent groups are interleaved to maximise the density of the cyclone separators of the apparatus.

[0022] Preferably the groups of cyclone separators are grouped in a group around the longitudinal axis of the upstream cyclone separator.

[0023] An embodiment of the present invention will now be described by way of an example only, and with reference to the accompanying drawings in which:

Figure 1 is a longitudinal-sectional view through the separation portion of a 2-stage cyclonic vacuum cleaner in accordance with the present invention;

Figure 2 is a perspective view of the top of the first stage of the cyclonic vacuum cleaner of Figure 1, when the second stage is removed therefrom;

Figure 3 is a perspective view of the bottom of the second stage of the cyclonic vacuum cleaner of Figure 1;

Figure 4 is a perspective view of the top of the second stage of the cyclonic vacuum cleaner of Figure 1, when fitted to the first stage; and

Figure 5 is a perspective view of the top of the second stage of the cyclonic vacuum cleaner of Figure 1, when fitted to the first stage and when a cover portion is fitted thereto.

[0024] Referring to Figure 1 of the drawings, there is shown the separation portion of an upright vacuum cleaner. The separation portion is mounted to a chassis (not shown) incorporating a handle, the lower end of the chassis being pivotally interconnected to a wheeled floor-cleaning head incorporating a rotatable agitator brush.

[0025] The separation portion comprises a generally cylindrical upright housing, which houses the first and second separation stages 10, 11 at its lower and upper ends respectively, the second stage 11 being fluidly connected downstream of the first stage 10.

[0026] The first stage 10 comprises a tubular side wall 12 defining a circular-section cyclone chamber 13. The lower end of the tubular side wall 12 is provided with a closure 14, which can be opened to allow separated dirt and dust to be emptied from the chamber 13.

[0027] An inlet duct 15 for carrying dirt and dust laden air from the floor cleaning head extends tangentially into the upper end of the tubular side wall 12 of the first stage 10. An elongate tubular container 16 extends through the cyclone chamber 13 along the centre axis thereof. The lower end of the container 16 is sealingly closed by a disk 17, which is mounted to the closure 14 such that the lower end of the container 16 is also opened when the closure 14 is opened. The upper end of the container 16 communicates with the an outlet of the second stage 11 from which the separated fine dust which is discharged.

[0028] The upper end of the first stage 10 is closed by an annular end wall 18 having a central aperture 19, through which the elongate container 16 extends. A perforated shroud 20 depends from the upper end wall into the cyclone chamber 13, the lower end of the shroud being sealed against the external surface of the tubular container 16.

[0029] Referring also to Figure 2 of the drawings, a circular manifold 21 is sealingly mounted on top of the upper end wall 18 of the first stage 10. The manifold 21 comprises six upstanding tubular projections 22, which are disposed at equally spaced circumferential positions on a concentric circular line on the manifold 21. The lower end of the projections 22 fluidly communicate with the space inside the shroud 22 through the aperture 19 in the upper end wall 18 of the first stage 10.

[0030] Referring to Figure 3 of the drawings, the second stage 11 comprises a cylindrical main body 23, which is fitted to the upper end of the first stage 10, the manifold projections 22 extending into corresponding apertures 24 which extend through the body 23 between opposite sides thereof. Each aperture 24 is surrounded by six cyclone separators 25 which extend axially therewith and which are equally spaced around the circumference of the apertures 24. The cyclone separators 25 are contained within hexagonal tubular boundary walls 26. Each cyclone separator 25 comprises a frusto-conical side wall 27 (as shown in Figure 1 of the drawings), which tapers inwardly to a cone opening at the lower end of the body 23.

[0031] Referring to Figure 4 of the drawings, the cyclone separators 25 are arranged in six groups, each group e.g A (as denoted by the shaded area in Figure 4) comprises five cyclone separators 25 arranged about a respective aperture 24 and disposed in an arc, which is centred on the central axis of the respective aperture 24. It will be appreciated that one of the six cyclone separators 25 surrounding each aperture 24 belongs to an adjacent group of separators.

[0032] Five channels 28 extend radially outwardly from the upper end of each aperture 24 in the upper surface

of body 23. The channels 28 lead tangentially into the upper ends of respective cyclone separators 25 of the group of separators associated with that aperture.

[0033] The lower ends of the frusto-conical walls 27 of the cyclone separators 25 terminate above the level of their respective hexagonal tubular boundary walls 26, in order to prevent any cyclonic air flow from being carried over to below the bottom surface of the body 23. As shown in Figure 2, baffles 40 supported by stems 41 extending from the upper surface of the manifold 21 may be positioned inside each hexagonal tubular boundary wall 26, just below the opening of each cone. The bottom end of the hexagonal boundary walls 26 open into a gallery 29 formed below the body 23 and above the manifold 21. The floor of the gallery 29 comprises an opening at its centre which is connected to the upper end of the elongate tubular container that extends through the cyclone chamber 13 of the first stage 10.

[0034] Referring to Figure 5 of the drawings, an apertured cover plate 30 is fitted to the upper surface of the body 23. The apertures 31 in the plates 30 are disposed axially above respective cyclone separators 25, the lower surface of the cover plate 30 comprising tubular projections 32 which extend from the apertures 31 into the upper ends of the cyclone separators to form so-called vortex finders.

[0035] A filter housing 33 is disposed above the second stage 11 and, in use, a vacuum is applied to the filter housing 33 to cause an airflow through the first and second stages 10, 11 from the dirty air inlet 15. The tangential orientation of the inlet 15 with respect to the wall 12 creates a cyclonic air flow inside the chamber 13 of the first stage 10, whereby air spirals downwardly around the chamber 13 towards its lower end. As the air flows downwards, the volume of air in the spiral flow is constantly being diminished by virtue of it having been drawn radially through the perforated shroud 20 towards the second stage 11.

[0036] As the air swirls inside the chamber 13, larger (denser) particles in the rotating airflow have too much inertia to follow the tight curve of the airflow and strike the outside wall 12 of the chamber, moving then to the bottom of the cyclone where they are deposited in the lower region of the chamber 13.

[0037] The air flowing through the perforated shroud 20 is divided equally into six separate parallel paths along the respective tubular projections 22 of the manifold 21. The six separate air flows then divide below the lower surface of the cover plate 31 into five further air flows along the respective channels 28. The channels 28 direct the airflows tangentially into the upper end of respective cyclone separators 25 to create a cyclonic airflow therein. The airflows spiral downwardly around the frusto-conical walls 27 of the separators 25 towards their lower ends. As the air flows downwards, the volume of air in the spiral flow is constantly being diminished, by virtue it having been drawn radially inwardly and axially upwardly through the vortex finders 32.

[0038] Any light particles of dust remaining in the airflow from the first stage 10 have too much inertia to follow the very tight curve of the airflow and strike the frusto-conical walls 27 of the separators 25, the dust being carried downwardly through the cone openings and into the gallery 29. The fine dust then falls into the elongate tubular container 16. It will be appreciated that the dust separated by both the first and second stages 10, 11 can be emptied by removing the closure 14.

[0039] A vacuum cleaner in accordance with the present invention is relatively simple in construction, yet has a substantially improved separation efficiency by enabling large numbers of high-efficiency cyclones to be compactly accommodated.

Claims

1. Cyclonic separation apparatus comprising a plurality of downstream cyclone separators (25) arranged in a plurality of groups (e.g. A) which are grouped together, each group (e.g. A) of downstream cyclone separators (25) comprising a respective inlet duct (22,24), each duct (22,24) being connected at its downstream end to the cyclone separators (25) of its respective group (e.g. A), the apparatus further comprising an upstream cyclone separator (13) having a dirty air inlet (15) and an annular or circular outlet chamber (29), said inlet ducts (22,24) extending in parallel from said outlet chamber (29). **characterised in that** the apparatus comprises a body (23), the cyclonic separators (25) being disposed side-by-side in an array in said body (23), the inlet ducts (22,24) extending through the body (23) between opposite sides thereof.

2. Cyclonic separation apparatus as claimed in claim 1, **characterised in that** the inlet duct (22,24) of each group (e.g. A) extends parallel to the rotational axis of the downstream cyclone separators (25) of the respective group (e.g. A).

3. Cyclonic separation apparatus as claimed in claims 1 or 2, **characterised in that** the downstream cyclone separators (25) in each group (e.g. A) are arranged around the longitudinal axis of the respective inlet duct (22,24) of the group (e.g. A).

4. Cyclonic separation apparatus as claimed in claim 3, **characterised in that** the radial distance between the longitudinal axis of each inlet duct (22,24) and each downstream cyclone separator (25) of their respective group (e.g. A) is substantially equal.

5. Cyclonic separation apparatus as claimed in any preceding claim, **characterised in that** the inlet duct (22,24) of each group (e.g. A) extends alongside the downstream cyclone separator of the group (e.g. A).

6. Cyclonic separation apparatus as claimed in any preceding claim, **characterised in that** the inlet ducts (22,24) are disposed at selected circumferentially-spaced points on a circular line.

7. Cyclonic separation apparatus as claimed in any preceding claim, **characterised in that** the inlet ducts (22,24) are open on opposite sides of the body (23), a cover 930) being provided for fitting to one side of the body (23) to close the downstream end of the inlet ducts (22,24).

8. Cyclonic separation apparatus as claimed in claim 7, **characterised in that** the inlet ducts (22,24) are connected at their downstream ends to respective radially-extending passages (28) leading to the respective downstream cyclone separators (25) of the group (e.g. A).

9. Cyclonic separation apparatus as claimed in claim 8, **characterised in that** the radially-extending passages (28) are formed in the body (23).

10. Cyclonic separation apparatus as claimed in any preceding claim, **characterised in that** the downstream cyclone separators (25) of each group (e.g. A) are disposed at selected positions along an arcuate line centred about the longitudinal axis of the inlet duct (22,24) of the group (e.g. A).

11. Cyclonic separation apparatus as claimed in claim 10, **characterised in that** the arcuate lines of adjacent groups (e.g. A) are interleaved.

12. Cyclonic separation apparatus as claimed in any preceding claim, **characterised in that** the groups (e.g. A) of downstream cyclone separators (25) are grouped around the longitudinal axis of the upstream cyclone separator (13).

13. A vacuum cleaner comprising cyclonic separation apparatus as claimed in any preceding claim.

Patentansprüche

1. Zyklonische Trennvorrichtung, umfassend eine Vielzahl von stromabwärtigen Zyklonseparatoren (25), angeordnet in einer Vielzahl von Gruppen (z.B. A), die zusammen gruppiert sind, wobei jede Gruppe (z.B. A) von stromabwärtigen Zyklonseparatoren (25) einen jeweiligen Einlasskanal bzw. -schacht (22, 24) umfasst, wobei jeder Kanal bzw. -schacht (22, 24) an seinem stromabwärtigen Ende mit den Zyklonseparatoren (25) seiner jeweiligen Gruppe (z.B. A) verbunden ist, wobei die Vorrichtung weiterhin einen stromaufwärtigen Zyklonseparator (13) umfasst, der einen Einlass für schmutzige Luft (15) und eine kranzförmige oder ringförmige Auslasskammer (29) aufweist, wobei die Einlasskanäle bzw. -schächte (22, 24) sich parallel von der Auslasskammer (29) erstrecken, **dadurch gekennzeichnet, dass** die Vorrichtung einen Körper (23) umfasst, wobei die zyklonischen Separatoren (25) Seite an Seite in einer Anordnung im Körper (23) angeordnet sind, die Einlasskanäle bzw. - schächte (22, 24) sich durch den Körper (23) zwischen entgegengesetzten Seiten davon erstrecken.

2. Zyklonische Trennvorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** der Einlasskanal bzw. -schacht (22, 24) jeder Gruppe (z.B. A) sich parallel zur Rotationsachse der stromabwärtigen Zyklonscparatoren (25) der jeweiligen Gruppe (z.B. A) erstreckt.

3. Zyklonische Trennvorrichtung nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die stromabwärtigen Zyklonseparatoren (25) in jeder Gruppe (z.B. A) um die longitudinale Achse des jeweiligen Einlasskanals bzw. -schachts (22, 24) der Gruppe (z.B. A) herum angeordnet sind.

4. Zyklonische Trennvorrichtung nach Anspruch 3, **dadurch gekennzeichnet, dass** die radiale Entfernung zwischen der longitudinalen Achse jedes Einlasskanals bzw. -schachts (22, 24) und jedem stromabwärtigen Zyklonseparator (25) der jeweiligen Gruppe (z.B. A) im Wesentlichen gleich ist.

5. Zyklonische Trennvorrichtung nach irgendeinem vorhergehenden Anspruch, **dadurch** gekennzeichet, dass der Einlasskanal bzw. -schacht (22, 24) jeder Gruppe (z.B. A) sich entlang dem stromabwärtigen Zyklonseparator der Gruppe (z.B. A) erstreckt.

6. Zyklonische Trennvorrichtung nach irgendeinem vorhergehenden Anspruch, **dadurch gekennzeichnet, dass** die Einlasskänale bzw. -schächte (22, 24) an ausgewählten, auf einer kreisförmigen Linie in Umfangsrichtung beabstandeten Punkten angeordnet sind.

7. Zyklonische Trennvorrichtung nach irgendeinem vorhergehenden Anspruch, **dadurch gekennzeichnet, dass** die Einlasskanäle bzw. -schächte (22, 24) auf entgegengesetzten Seiten des Körpers (23) offen sind, wobei eine Abdeckung (30) vorgesehen ist, die auf einer Seite des Körpers (23) passt, um das stromabwärtige Ende der Einlasskanäle bzw. -schächte (22, 24) zu verschließen.

8. Zyklonische Trennvorrichtung nach Anspruch 7, **dadurch gekennzeichnet, dass** die Einlasskänale bzw. -schächte (22, 24) an ihren stromabwärtigen Enden mit jeweiligen sich radial erstreckenden Pas-

sagen bzw. Durchgängen (28) verbunden sind, die zu den jeweiligen stromabwärtigen Zyklonseparatoren (25) der Gruppe (z.B. A) führen.

9. Zyklonische Trennvorrichtung nach Anspruch 8, **dadurch gekennzeichnet, dass** die sich radial erstreckenden Passagen bzw. Durchgänge (28) im Körper (23) gebildet sind.

10. Zyklonische Trennvorrichtung nach irgendeinem vorhergehenden Anspruch, **dadurch gekennzeichnet, dass** die stromabwärtigen Zyklonseparatoren (25) jeder Gruppe (z.B. A) an ausgewählten Stellen entlang einer bogenförmigen Linie, zentriert um die longitudinale Achse der Einlasskanäle bzw. -schächte (22, 24) der Gruppe (z.B. A) angeordnet sind.

11. Zyklonische Trennvorrichtung nach Anspruch 10, **dadurch gekennzeichnet, dass** sich die bogenförmigen Linien benachbarter Gruppen (z.B. A) überlappen.

12. Zyklonische Trennvorrichtung nach irgendeinem vorhergehenden Anspruch, **dadurch** gekennzeichet, dass die Gruppen (z.B. A) der stromabwärtigen Zyklonseparatoren (25) um die longitudinale Achse des stromaufwärtigen Zyklonseparators (13) gruppiert sind.

13. Staubsauger, umfassend die Zyklonische Trennvorrichtung nach irgendeinem vorhergehenden Anspruch.

Revendications

1. Appareil de séparation cyclonique comprenant une pluralité de séparateurs à cyclone en aval (25) agencés dans une pluralité de groupes (par exemple A) qui sont groupés ensemble, chaque groupe (par exemple A) de séparateurs à cyclone en aval (25) comprenant un conduit d'entrée (22, 24) respectif, chaque conduit (22, 24) étant raccordé au niveau de son extrémité en aval aux séparateurs à cyclone (25) de son groupe (par exemple A) respectif, l'appareil comprenant en outre un séparateur à cyclone en amont (13) ayant une entrée d'air sale (15) et une chambre de sortie annulaire ou circulaire (29), lesdits conduits d'entrée (22, 24) s'étendant en parallèle à partir de ladite chambre de sortie (29), **caractérisé en ce que** l'appareil comprend un corps (23), les séparateurs cycloniques (25) étant disposés côte à côte dans une rangée dans ledit corps (23), les conduits d'entrée (22, 24) s'étendant à travers le corps (23) entre ses côtés opposés.

2. Appareil de séparation cyclonique selon la revendication 1, **caractérisé en ce que** le conduit d'entrée (22, 24) de chaque groupe (par exemple A) s'étend parallèlement à l'axe de rotation des séparateurs à cyclone en aval (25) du groupe (par exemple A) respectif.

3. Appareil de séparation cyclonique selon les revendications 1 ou 2, **caractérisé en ce que** les séparateurs à cyclone en aval (25) dans chaque groupe (par exemple A) sont agencés autour de l'axe longitudinal du conduit d'entrée (22, 24) respectif du groupe (par exemple A).

4. Appareil de séparation cyclonique selon la revendication 3, **caractérisé en ce que** la distance radiale entre l'axe longitudinal de chaque conduit d'entrée (22, 24) et chaque séparateur à cyclone en aval (25) de leur groupe (par exemple A) respectif est sensiblement égale.

5. Appareil de séparation cyclonique selon l'une quelconque des revendications précédentes, **caractérisé en ce que** le conduit d'entrée (22, 24) de chaque groupe (par exemple A) s'étend le long du séparateur à cyclone en aval du groupe (par exemple A).

6. Appareil de séparation cyclonique selon l'une quelconque des revendications précédentes, **caractérisé en ce que** les conduits d'entrée (22, 24) sont disposés à des points circonférentiellement espacés sélectionnés sur une ligne circulaire.

7. Appareil de séparation cyclonique selon l'une quelconque des revendications précédentes, **caractérisé en ce que** les conduits d'entrée (22, 24) sont ouverts sur les côtés opposés du corps (23), un couvercle (30) étant prévu pour s'adapter à un côté du corps (23) afin de fermer l'extrémité en aval des conduits d'entrée (22, 24).

8. Appareil de séparation cyclonique selon la revendication 7, **caractérisé en ce que** les conduits d'entrée (22, 24) sont raccordés au niveau de leurs extrémités en aval aux passages s'étendant de manière radiale (28) respectifs menant aux séparateurs à cyclone en aval (25) respectifs du groupe (par exemple A).

9. Appareil de séparation cyclonique selon la revendication 8, **caractérisé en ce que** les passages s'étendant radialement (28) sont formés dans le corps (23).

10. Appareil de séparation cyclonique selon l'une quelconque des revendications précédentes, **caractérisé en ce que** les séparateurs à cyclone en aval (25) de chaque groupe (par exemple A) sont disposés dans des positions sélectionnées le long d'une ligne arquée centrée autour de l'axe longitudinal du con-

duit d'entrée (22, 24) du groupe (par exemple A).

11. Appareil de séparation cyclonique selon la revendication 10, **caractérisé en ce que** les lignes arquées des groupes (par exemple A) adjacents sont entrelacées.

12. Appareil de séparation cyclonique selon l'une quelconque des revendications précédentes, **caractérisé en ce que** les groupes (par exemple A) des séparateurs à cyclone en aval (25) sont groupés autour de l'axe longitudinal du séparateur à cyclone en amont (13).

13. Aspirateur comprenant l'appareil de séparation cyclonique selon l'une quelconque des revendications précédentes.

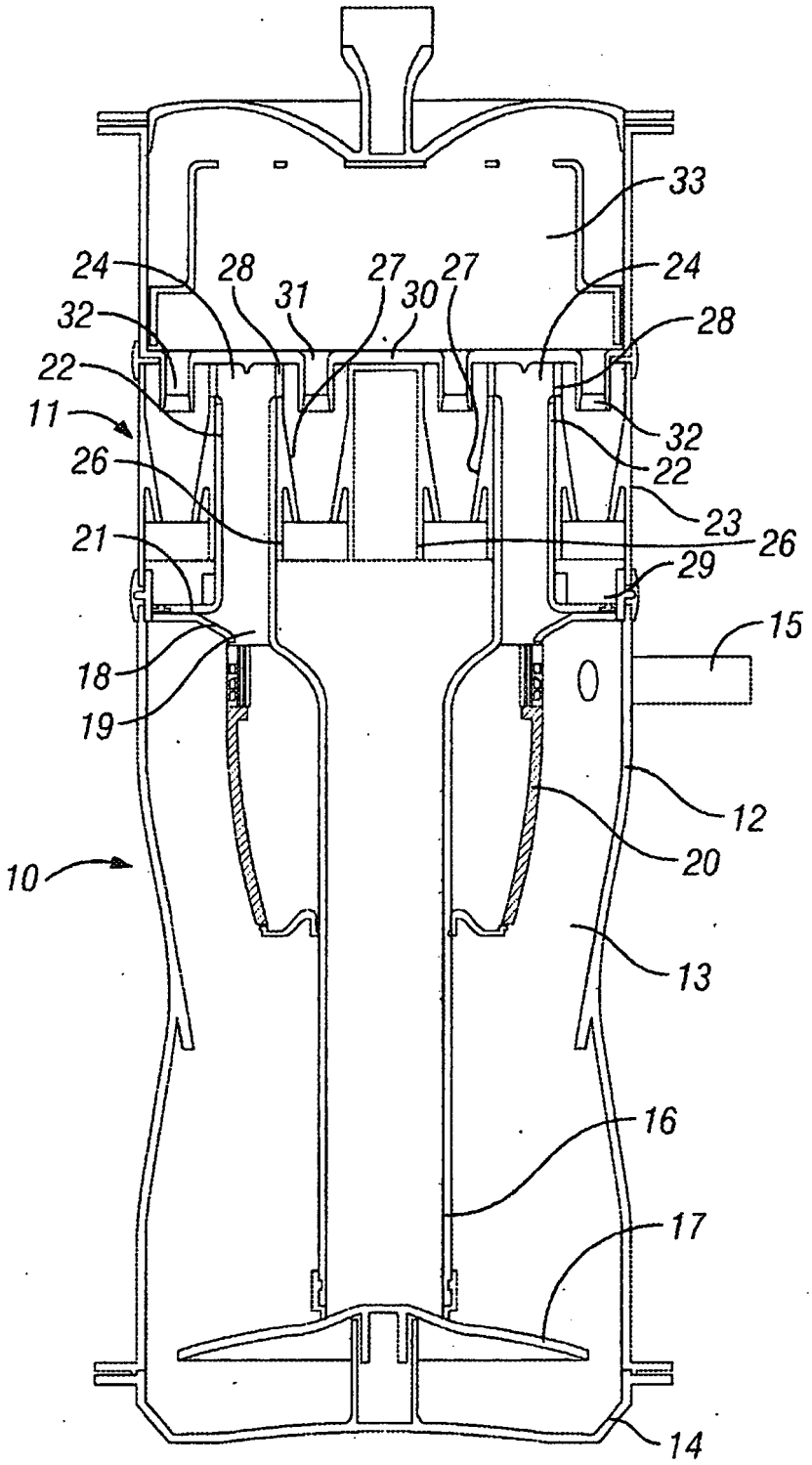
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FIG. 1

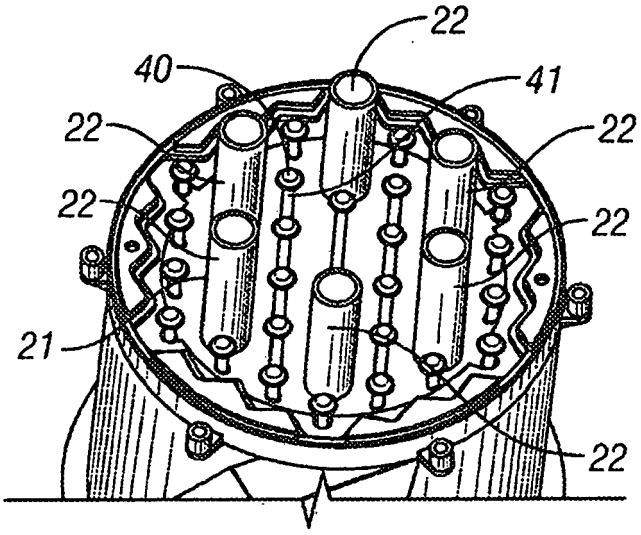

FIG. 2

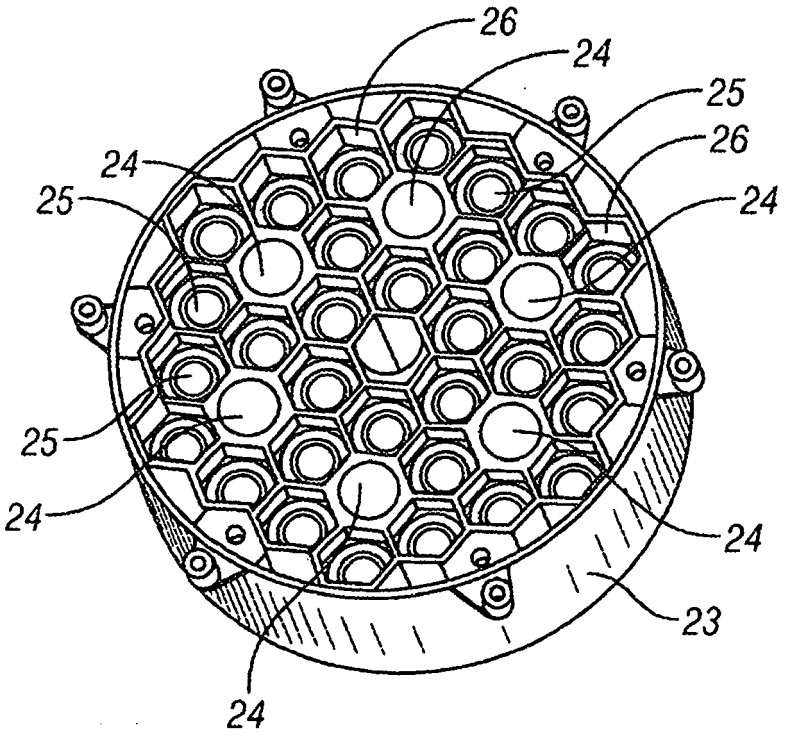

FIG. 3

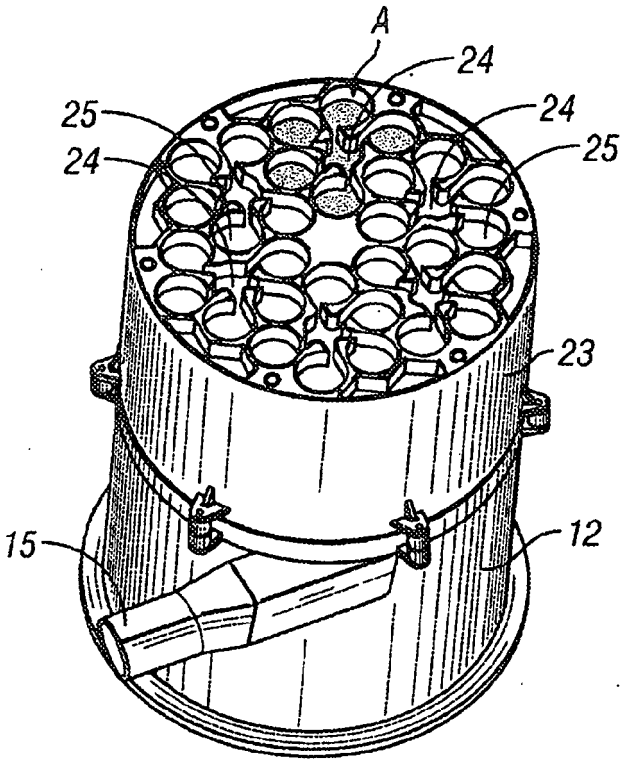

FIG. 4

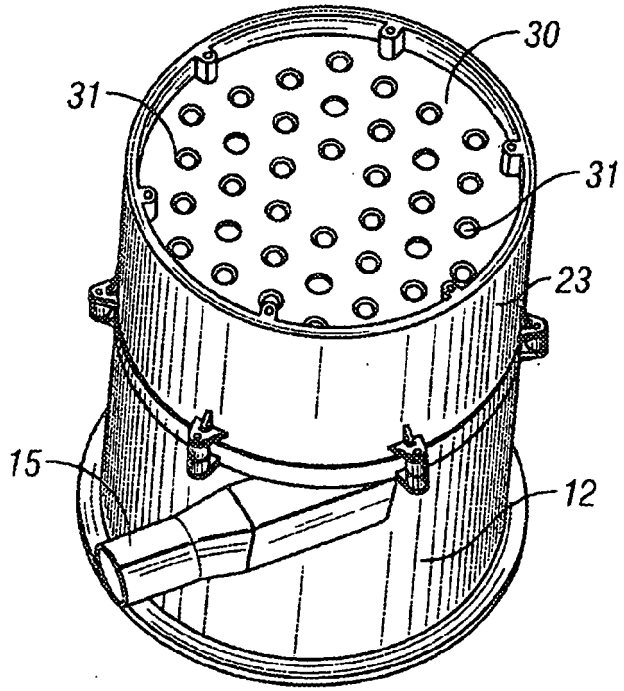

FIG. 5

REFERENCES CITED IN THE DESCRIPTION

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