US007828866B2

(12) **United States Patent**
Courtney et al.

(10) **Patent No.: US 7,828,866 B2**
(45) **Date of Patent: Nov. 9, 2010**

(54) **DIRT AND DUST CYCLONIC SEPARATING APPARATUS**

(75) Inventors: **Stephen Benjamin Courtney**, Bath (GB); **James Dyson**, Gloucestershire (GB); **Ricardo Gomiciaga-Pereda**, Wiltshire (GB)

(73) Assignee: **Dyson Technology Limited**, Malmesbury, Wiltshire (GB)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 393 days.

(21) Appl. No.: **11/794,226**

(22) PCT Filed: **May 9, 2006**

(86) PCT No.: **PCT/GB2006/001678**

§ 371 (c)(1),
(2), (4) Date: **Feb. 14, 2008**

(87) PCT Pub. No.: **WO2006/125946**

PCT Pub. Date: **Nov. 30, 2006**

(65) **Prior Publication Data**

US 2008/0172994 A1 Jul. 24, 2008

(30) **Foreign Application Priority Data**

May 27, 2005 (GB) 0510862.6

(51) **Int. Cl.**
B01D 45/12 (2006.01)

(52) **U.S. Cl.** **55/343**; 55/349; 55/429; 55/459.1; 55/DIG. 3

(58) **Field of Classification Search** ..... 55/343, 55/349, 429, 459.1, DIG. 3
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,425,192	A	2/1969	Davis	
3,724,176	A	4/1973	Vishnevsky et al.	
4,373,228	A	2/1983	Dyson	
5,129,124	A	7/1992	Gamou et al.	
6,238,451	B1	5/2001	Conrad et al.	
6,607,572	B2	8/2003	Gammack et al.	
2006/0230724	A1*	10/2006	Han et al.	55/345
2009/0031524	A1	2/2009	Courtney et al.	

FOREIGN PATENT DOCUMENTS

EP 0 042 723 8/1985

(Continued)

OTHER PUBLICATIONS

Courtney et al., Express Notice of Abandonment filed in co-pending U.S. Appl. No. 11/794,227 dated Mar. 31, 2009; 2 pages.

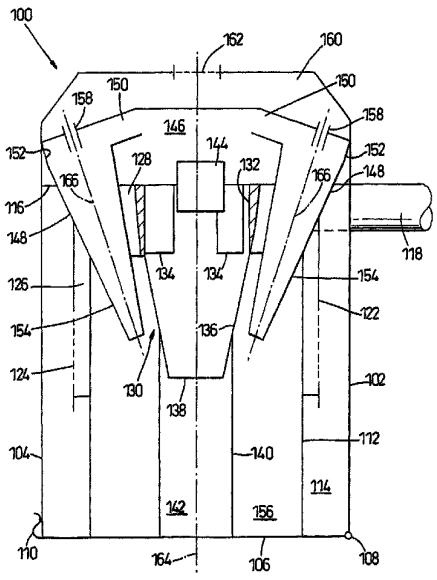
(Continued)

Primary Examiner—Robert A Hopkins
(74) *Attorney, Agent, or Firm*—Morrison & Foerster LLP

(57) **ABSTRACT**

A cyclonic separating apparatus includes a first cyclonic separating unit including at least one first cyclone, a second cyclonic separating unit located downstream of the first cyclonic separating unit and including at least one second cyclone, and a third cyclonic separating unit located downstream of the second cyclonic separating unit and including at least one third cyclone. The separation efficiency of the second cyclonic separating unit is substantially the same as the separation efficiency of either the first cyclonic separating unit or the third separating unit, providing an apparatus which achieves a higher separation efficiency than known separation apparatus.

23 Claims, 6 Drawing Sheets



FOREIGN PATENT DOCUMENTS

EP	0 613 935	9/1994
EP	0728435	8/1996
EP	1157651	11/2001
EP	1 268 076 B1	10/2004
GB	2360719	10/2001
GB	2367019	3/2002
GB	2367511	4/2002
GB	2372470	8/2002
GB	2 424 603	10/2006
GB	2424606	3/2007
JP	50-84964	7/1975
JP	52-14775	2/1977
JP	63-28144	2/1988
JP	7-3270	1/1995
JP	7-186041	7/1995
JP	2002-326041	11/2002
JP	2004-520138	7/2004
KR	2002-0078798	10/2002
WO	WO-02/067753	9/2002

OTHER PUBLICATIONS

Courtney et al., Suggestion of Interference under 37 CFR 41.202(a) filed in co-pending U.S. Appl. No. 11/794,227 dated Dec. 9, 2008; 14 pages.

Courtney et al., Suggestion of Interference under 37 CFR 41.202(a) filed in co-pending U.S. Appl. No. 11/794,227 dated Dec. 30, 2008; 29 pages.

Grounds of Invalidity issued by the High Court, Chancery Division of the United Kingdom served Sep. 10, 2007.

Retail advertisement of Dyson vacuum cleaner model DC07 published Jun. 2001, 12 pages.

Retail advertisement of Dyson vacuum cleaner model DC08 published Apr. 2002, 14 pages.

Retail advertisement of Dyson vacuum cleaners similar to models DC07 and DC08 published Mar. 29, 2005, 4 pages.

GB search report mailed on May 15, 2008 directed at counterpart application No. 0510862.6; 4 pages.

GB Search Report dated Sep. 28, 2005, directed to counterpart GB Application No. 0510864; 1 page.

International Search Report dated Aug. 8, 2006, directed to counterpart International Application No. PCT/GB2006/001661; 3 pages.

Japanese Notice of Reasons for Rejection mailed Feb. 16, 2010, directed to counterpart Japanese Application No. 2008-512898; 5 pages.

Courtney, S., et al., U.S. Office Action mailed Jun. 28, 2010, directed to U.S. Appl. No. 11/794,514; 7 pages.

* cited by examiner

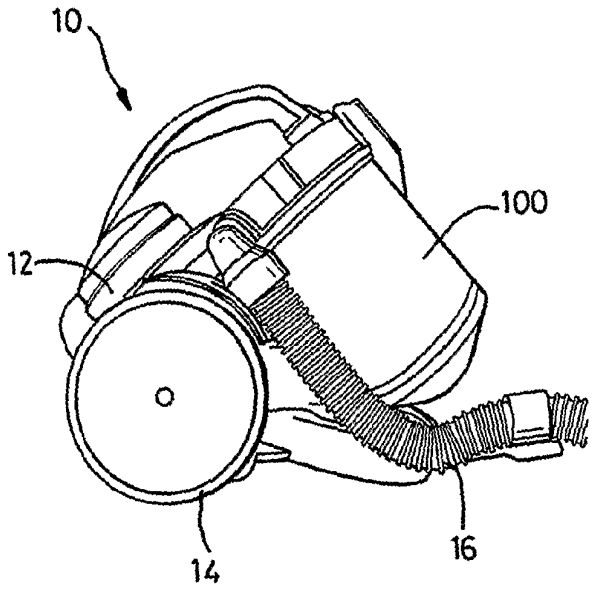


Fig. 1

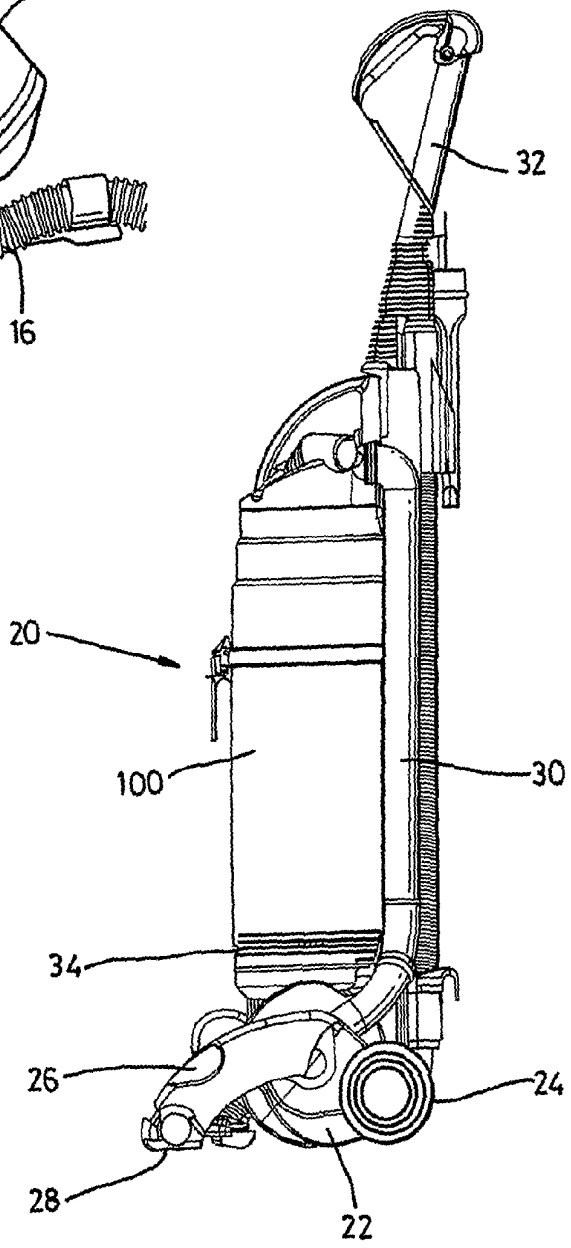


Fig. 2

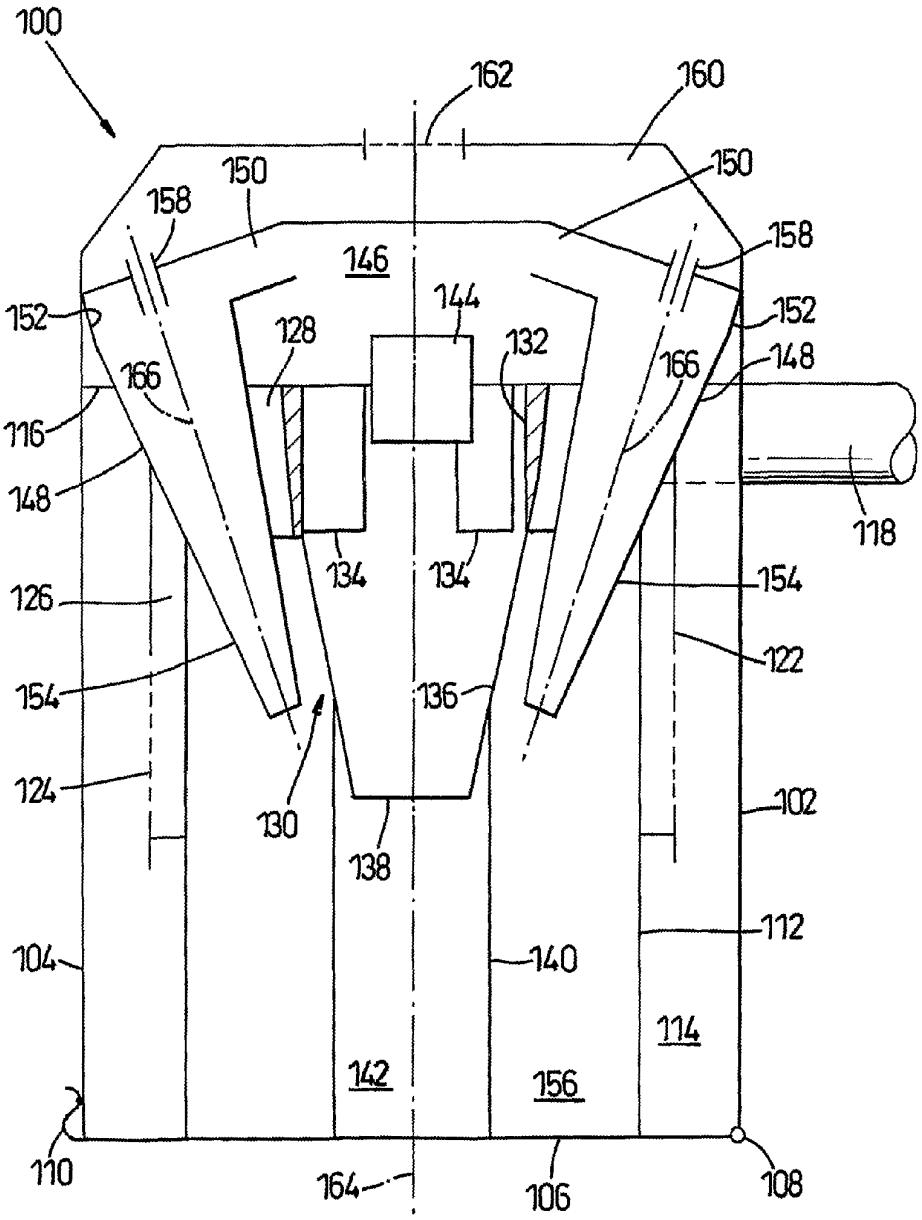

100
162
160
150
150
158
158
146
144
152
152
128
132
166
166
148
116
148
118
134
134
126
154
154
122
136
124
130
102
138
112
104
140
114
142
156
110
164
106
108

Fig. 3

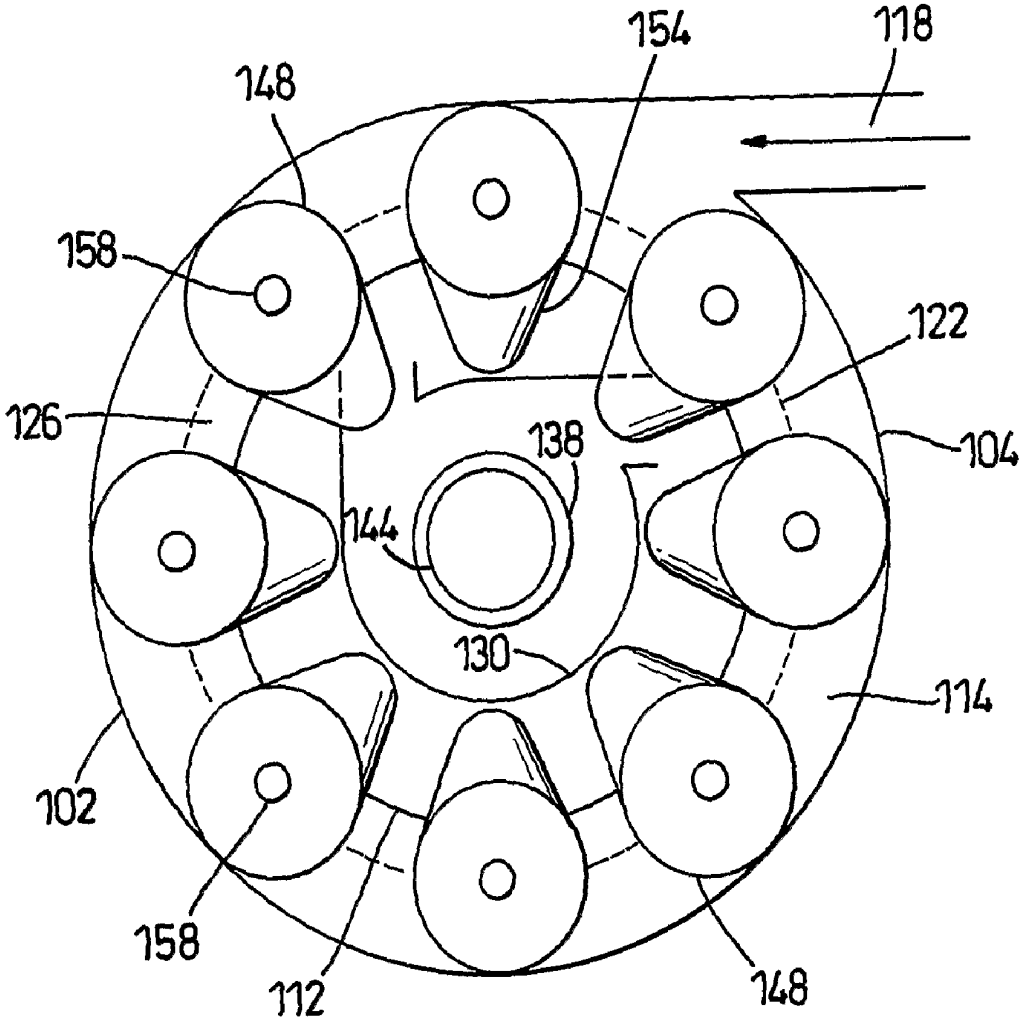


Fig. 4

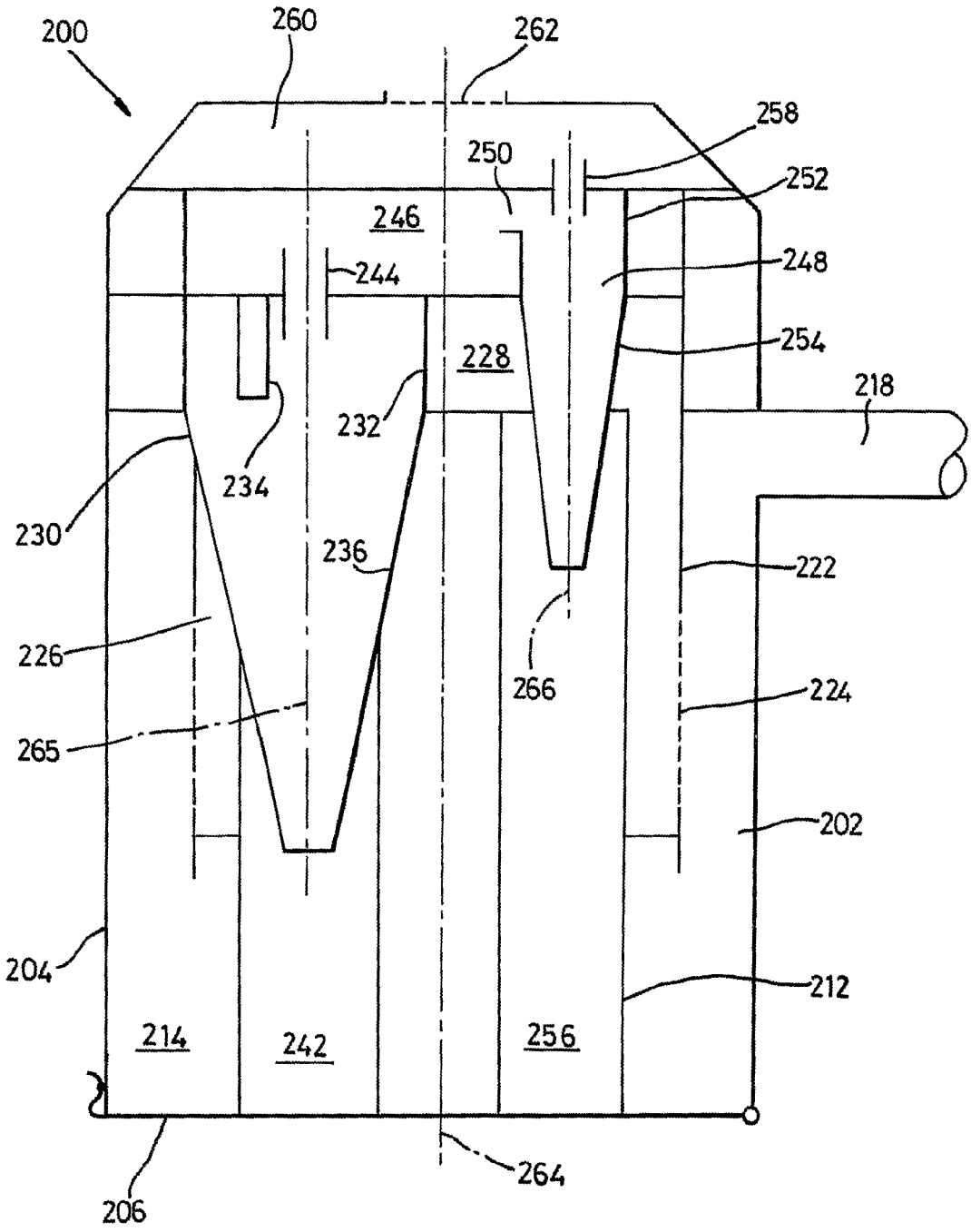

200
260
262
258
250
252
246
244
248
254
228
218
232
234
230
236
222
226
266
224
265
202
204
212
214
242
256
264
206

Fig. 5

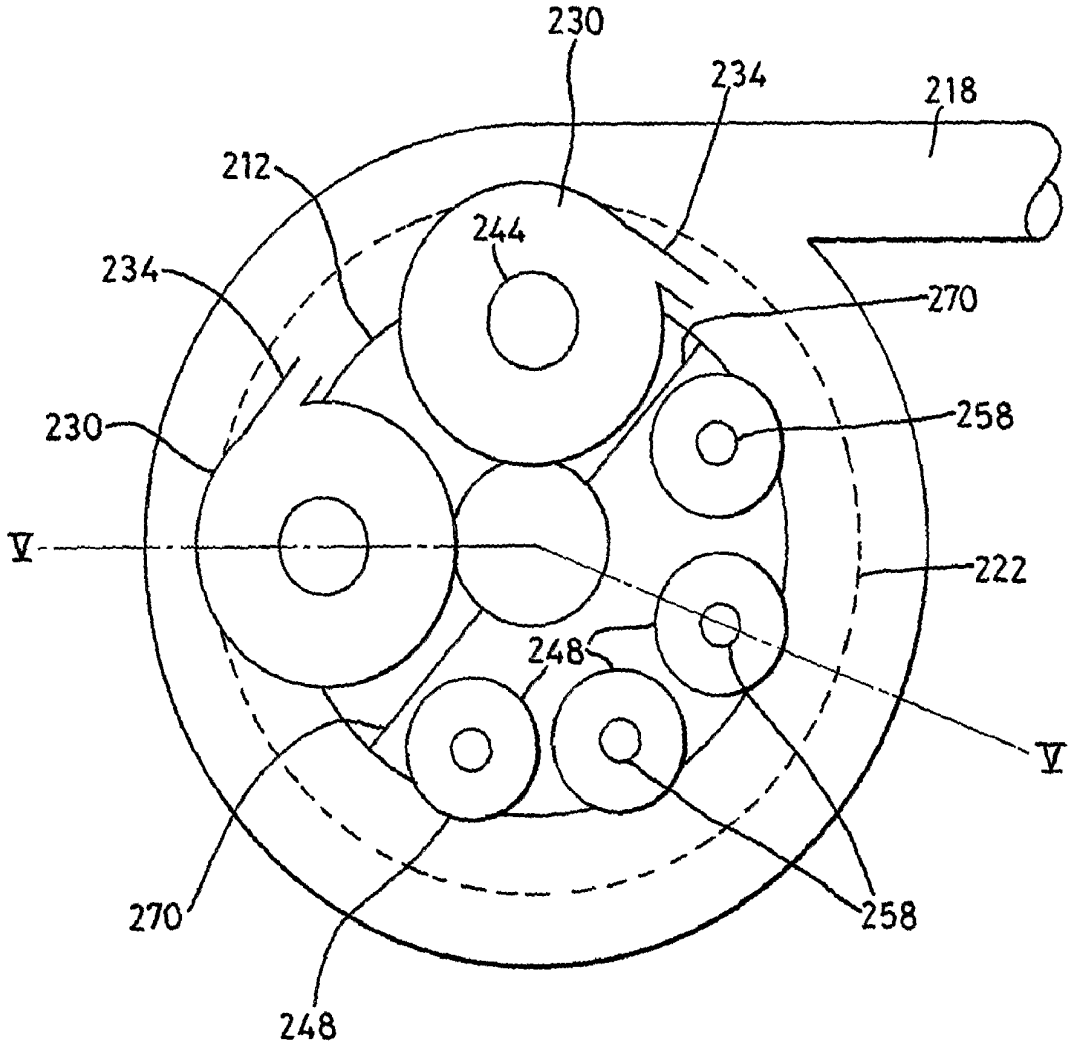


Fig. 6

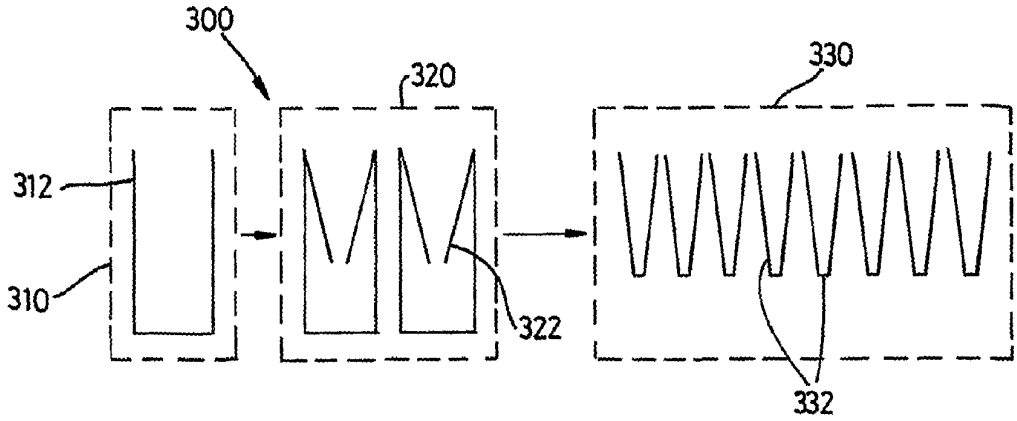


Fig. 7

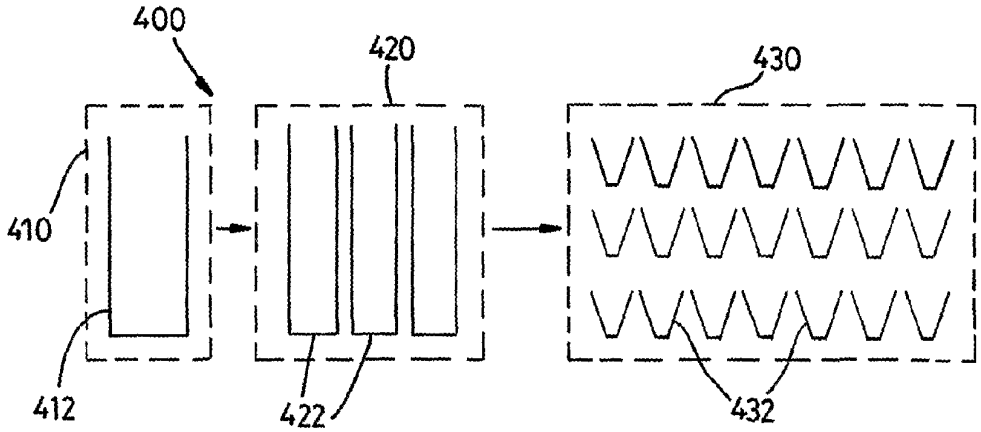


Fig. 8

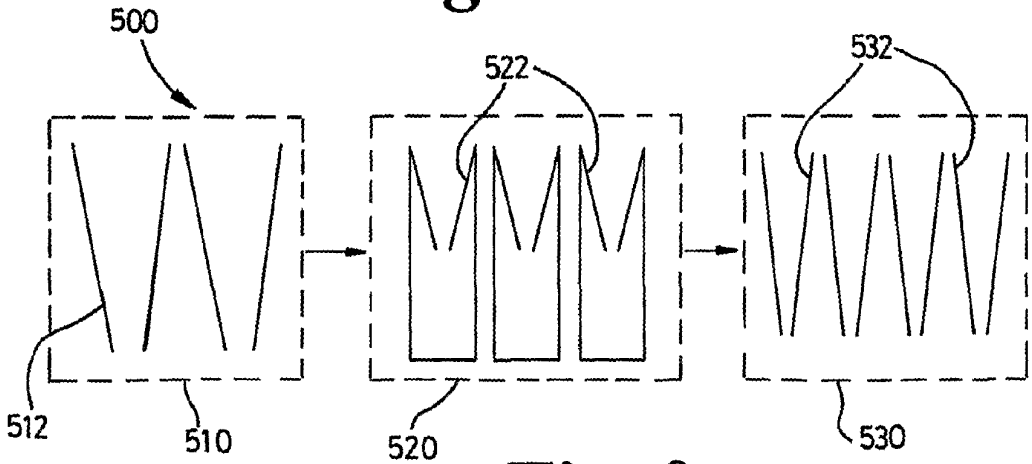


Fig. 9

DIRT AND DUST CYCLONIC SEPARATING APPARATUS

REFERENCE TO RELATED APPLICATIONS

This application is a national stage application under 35 USC 371 of International Application No. PCT/GB2006/001678, filed May 9, 2006, which claims the priority of United Kingdom Application No. 0510862.6, filed May 27, 2005, the contents of both of which prior applications are incorporated herein by reference.

FIELD OF THE INVENTION

The invention relates to cyclonic separating apparatus. Particularly, but not exclusively, the invention relates to cyclonic separating apparatus suitable for use in vacuum cleaners.

BACKGROUND OF THE INVENTION

Vacuum cleaners which utilise cyclonic separating apparatus are well known. Examples of such vacuum cleaners are shown in EP 0042723, U.S. Pat. Nos. 4,373,228, 3,425,192, 6,607,572 and EP 1268076. In each of these arrangements, first and second cyclonic separating units are provided with the incoming air passing sequentially through each separating unit. In some cases, the second cyclonic separating unit includes a plurality of cyclones arranged in parallel with one another.

SUMMARY OF THE INVENTION

None of the prior art arrangements achieves 100% separation efficiency (ie the ability reliably to separate entrained dirt and dust from the airflow), particularly in the context of use in a vacuum cleaner. Therefore, it is an object of the invention to provide cyclonic separating apparatus which achieves a higher separation efficiency than the prior art.

The invention provides cyclonic separating apparatus comprising: a first cyclonic separating unit including at least one first cyclone; a second cyclonic separating unit located downstream of the first cyclonic separating unit and including at least one second cyclone; and a third cyclonic separating unit located downstream of the second cyclonic separating unit and including at least one third cyclone; characterised in that the separation efficiency of the second cyclonic separating unit is substantially the same as the separation efficiency of either the first cyclonic separating unit or the third cyclonic separating unit.

Cyclonic separating apparatus according to the invention has the advantage that, when the apparatus is considered as a whole, it has a separation efficiency which is improved as compared to the individual separation efficiencies of the individual cyclonic separating units. The provision of at least three cyclonic separation units in series increases the robustness of the system so that any variations in the airflow presented to the downstream units have little or no effect on the ability of those units to maintain their separation efficiency. The separation efficiency is therefore also more reliable as compared to known cyclonic separating apparatus.

It will be understood that, by the term "separation efficiency", we mean the ability of a cyclonic separating unit to separate entrained particles from an airflow and that, for comparison purposes, the relevant cyclonic separation units are challenged by identical airflows. Hence, in order for a first cyclonic separating unit to have a higher separation efficiency than a second cyclonic separating unit, the first unit must be capable of separating a higher percentage of entrained particles from an airflow than the second unit when both are challenged under identical circumstances. Factors which can influence the separation efficiency of a cyclonic separating unit include the size of the inlet and outlet, the angle of taper and length of the cyclone, the diameter of the cyclone and the depth of the cylindrical inlet portion at the upper end of the cyclone.

If the second cyclonic separating unit has a separation efficiency which is the same as the first cyclonic separating unit, this has the effect of providing the incoming airflow with two "sweeps" through a relatively low efficiency cyclone separating unit before the third, higher efficiency, cyclone separating unit is challenged. The airflow is therefore cleaned of larger dirt and dust particles, and also a significant proportion of fine dust, prior to entering the third cyclonic separating unit. The third cyclonic separating unit is thus able to operate under favourable conditions which allow it to achieve a relatively high separation efficiency. In this way, the apparatus as a whole cleans the airflow reliably and to a high standard.

If the second separating unit has a separation efficiency which is the same as the third cyclonic separating unit, the airflow has two "sweeps" through a relatively high efficiency cyclonic separating unit before it is ejected from the apparatus. Having had any relatively large dirt and debris removed from the airflow, the airflow then makes a first sweep through a relatively high efficiency cyclonic separating unit in which a large proportion of the remaining dust is separated. The third cyclonic separating unit is then allowed to operate under advantageous conditions in which a high separation efficiency can be achieved.

Preferably, the first cyclonic separating unit comprises a single first cyclone and, more preferably, the or each first cyclone is substantially cylindrical. This arrangement encourages larger particles of dirt and debris to be reliably collected and stored with a relatively low risk of re-entrainment.

Preferably, the second cyclonic separating unit comprises a plurality of second cyclones arranged in parallel and the third cyclonic separating unit comprises a plurality of third cyclones arranged in parallel and, more preferably, the number of second cyclones is lower than the number of third cyclones. The increasing number of cyclones in each successive cyclonic separating unit allows the size of each individual cyclone to decrease in the direction of the airflow. The fact that the airflow has passed through a number of upstream cyclones means that the larger particles of dirt and dust will have been removed which allows each smaller cyclone to operate efficiently and without risk of blockage.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

FIGS. **1** and **2** show cylinder and upright vacuum cleaners respectively incorporating cyclonic separating apparatus according to the invention;

FIG. **3** is a sectional side view through the cyclonic separating apparatus forming part of either of the vacuum cleaners shown in FIGS. **1** and **2**;

FIG. **4** is a sectional plan view of the cyclonic separating apparatus of FIG. **3** showing the layout of the cyclonic separating units;

FIG. **5** is a sectional side view of an alternative embodiment of cyclonic separating apparatus according to the invention;

FIG. **6** is a sectional plan view of the cyclonic separating apparatus of FIG. **5** showing the layout of the cyclonic separating units;

FIG. **7** is a schematic diagram of first alternative cyclonic separating apparatus suitable for forming part of either of the vacuum cleaners shown in FIGS. **1** and **2**; and

FIGS. **8** and **9** are schematic diagrams of second and third alternative cyclonic separating apparatuses suitable for forming part of either of the vacuum cleaners of FIGS. **1** and **2**.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** shows a cylinder vacuum cleaner **10** having a main body **12**, wheels **14** mounted on the main body **12** for manoeuvring the vacuum cleaner **10** across a surface to be cleaned, and cyclonic separating apparatus **100** also mounted on the main body **12**. A hose **16** communicates with the cyclonic separating apparatus **100** and a motor and fan unit (not shown) housed within the main body **12** for drawing a dirty airflow into the cyclonic separating apparatus **100** via the hose **16**. Commonly, a floor-engaging cleaner head (not shown) is coupled to the distal end of the hose **16** via a wand to facilitate manipulation of the dirty air inlet over the surface to be cleaned.

In use, air drawn into the cyclonic separating apparatus **100** via the hose **16** has entrained dirt and dust separated therefrom in the cyclonic separating apparatus **100**. The dirt and dust is collected within the cyclonic separating apparatus **100** while the cleaned air is channeled past the motor for cooling purposes before being ejected from the vacuum cleaner **10** via an exit port in the main body **12**.

The upright vacuum cleaner **20** shown in FIG. **2** also has a main body **22** in which a motor and fan unit (not shown) is mounted and on which wheels **24** are mounted to allow the vacuum cleaner **20** to be manoeuvred across a surface to be cleaned. A cleaner head **26** is pivotably mounted on the lower end of the main body **22** and a dirty air inlet **28** is provided in the underside of the cleaner head **26** facing the floor. Cyclonic separating apparatus **100** is provided on the main body **22** and ducting **30** provides communication between the dirty air inlet **28** and the cyclonic separating apparatus **100**. A handle **32** is releasably mounted on the main body **22** behind the cyclonic separating apparatus **100** so that the handle **32** can be used either as a handle or in the manner of a wand. Such an arrangement is well known and will not be described any further here.

In use, the motor and fan unit draws dirty air into the vacuum cleaner **20** via either the dirty air inlet **28** or the handle **32** (if the handle **32** is configured for use as a wand). The dirty air is carried to the cyclonic separating apparatus **100** via the ducting **30** and entrained dirt and dust is separated from the airflow and retained in the cyclonic separating apparatus **100**. The cleaned air is passed across the motor for cooling purposes and then ejected from the vacuum cleaner **20** via a plurality of outlet ports **34**.

The present invention relates solely to the cyclonic separating apparatus **100** as will be described below and so the detail of the remaining features of the vacuum cleaners **10**, **20** are comparatively immaterial.

The cyclonic separating apparatus **100** forming part of each of the vacuum cleaners **10**, **20** is shown in FIGS. **3** and **4**. The specific overall shape of the cyclonic separating apparatus **100** can be varied according to the type of vacuum cleaner in which the apparatus **100** is to be used. For example, the overall length of the apparatus can be increased or decreased with respect to the diameter of the apparatus, or the shape of the base can be altered so as to be, for example, frusto-conical.

The cyclonic separating apparatus **100** shown in FIGS. **3** and **4** comprises an outer bin **102** which has an outer wall **104** which is substantially cylindrical in shape. The lower end of the outer bin **102** is closed by a base **106** which is pivotably attached to the outer wall by means of a pivot **108** and held in a closed position (illustrated in FIG. **3**) by a catch **110**. In the closed position, the base is sealed against the lower end of the outer wall **104**. Releasing the catch **110** allows the base **106** to pivot away from the outer wall **104** for purposes which will be explained below. A second cylindrical wall **112** is located radially inwardly of the outer wall **104** and spaced therefrom so as to form an annular chamber **114** therebetween. The second cylindrical wall **112** meets the base **106** (when the base is in the closed position) and is sealed thereagainst. The annular chamber **114** is delimited generally by the outer wall **104**, the second cylindrical wall **112**, the base **106** and an upper wall **116** positioned at the upper end of the outer bin **102**.

A dirty air inlet **118** is provided at the upper end of the outer bin **102** below the upper wall **116**. The dirty air inlet **118** is arranged tangentially to the outer bin **102** (see FIG. **4**) so as to ensure that incoming dirty air is forced to follow a helical path around the annular chamber **114**. A fluid outlet is provided in the outer bin **102** in the form of a shroud **120**. The shroud **120** comprises a cylindrical wall **122** in which a large number of perforations **124** are formed. The only fluid outlet from the outer bin **102** is formed by the perforations **124** in the shroud. A passage **126** is formed between the shroud and the second cylindrical wall **112**, which passage **126** communicates with an annular chamber **128**.

The annular chamber **128** is arranged radially outwardly of the upper end of a tapering cyclone **130** which lies coaxially with the outer bin **102**. The cyclone **130** has an upper inlet portion **132** which is generally cylindrical in shape and in which two air inlets **134** are formed. The inlets **134** are spaced about the circumference of the upper inlet portion **132**. The inlets **134** are slot-like in shape and communicate directly with the annular chamber **128**. The cyclone **130** has a tapering portion **136** depending from the upper inlet portion **132**. The tapering portion **136** is frusto-conical in shape and terminates at its lower end in a cone opening **138**.

A third cylindrical wall **140** extends between the base **106** and a portion of the outer wall of the tapering portion **136** of the cyclone **130** above the cone opening **138**. When the base **106** is in the closed position, the third cylindrical wall **140** is sealed thereagainst. The cone opening **138** thus opens into an otherwise closed cylindrical chamber **142**. A vortex finder **144** is provided at the upper end of the cyclone **130** to allow air to exit the cyclone **130**.

The vortex finder **144** communicates with a plenum chamber **146** located above the cyclone **130**. Arranged circumferentially around the plenum chamber **146** are a plurality of cyclones **148** arranged in parallel with one another. Each cyclone **148** has a tangential inlet **150** which communicates with the plenum chamber **146**. Each cyclone **148** is identical to the other cyclones **148** and comprises a cylindrical upper portion **152** and a tapering portion **154** depending therefrom. The tapering portion **154** of each cyclone **148** extends into and communicates with an annular chamber **156** which is formed between the second and third cylindrical walls **112**, **140**. A vortex finder **158** is provided at the upper end of each cyclone **148** and each vortex finder **158** communicates with an outlet chamber **160** having an exit port **162** for ducting cleaned air away from the apparatus **100**.

As has been mentioned above, the cyclone **130** is coaxial with the outer bin **102**. The eight cyclones **148** are arranged in a ring which is centered on the axis **164** of the outer bin **102**.

Each cyclone **148** has an axis **166** which is inclined downwardly and towards the axis **164**. The axes **166** are all inclined to the axis **164** at the same angle. Also, the angle of taper of the cyclone **130** is greater than the angle of taper of the cyclones **148** and the diameter of the upper inlet portion **132** of the cyclone **130** is greater than the diameter of the cylindrical upper portion **152** of each of the cyclones **148**.

In use, dirt-laden air enters the apparatus **100** via the dirty air inlet **118** and, because of the tangential arrangement of the inlet **118**, the airflow follows a helical path around the outer wall **104**. Larger dirt and dust particles are deposited by cyclonic action in the annular chamber **114** and collected therein. The partially-cleaned airflow exits the annular chamber **114** via the perforations **124** in the shroud **122** and enters the passage **126**. The airflow then passes into the annular chamber **128** and from there to the inlets **134** of the cyclone **130**. Cyclonic separation is set up inside the cyclone **130** so that separation of some of the dirt and dust which is still entrained within the airflow occurs. The dirt and dust which is separated from the airflow in the cyclone **130** is deposited in the cylindrical chamber **142** whilst the further cleaned airflow exits the cyclone **130** via the vortex finder **144**. The air then passes into the plenum chamber **146** and from there into one of the eight cyclones **148** wherein further cyclonic separation removes some of the dirt and dust still entrained. This dirt and dust is deposited in the annular chamber **156** whilst the cleaned air exits the cyclones **148** via the vortex finders **158** and enters the outlet chamber **160**. The cleaned air then leaves the apparatus **100** via the exit port **162**.

Dirt and dust which has been separated from the airflow will be collected in all three of the chambers **114**, **142** and **156**. In order to empty these chambers, the catch **110** is released to allow the base **106** to pivot about the hinge **108** so that the base falls away from the lower ends of the cylindrical walls **104**, **112** and **140**. Dirt and dust collected in the chambers **114**, **142**, **156** can then easily be emptied from the apparatus **100**.

It will be appreciated from the foregoing description that the apparatus **100** includes three distinct stages of cyclonic separation. The outer bin **102** constitutes a first cyclonic separating unit consisting of a single first cyclone which is generally cylindrical in shape. In this first cyclonic separating unit, the relatively large diameter of the outer wall **104** means that, primarily, comparatively large particles of dirt and debris will be separated from the airflow because the centrifugal forces applied to the dirt and debris are relatively small. Some fine dust will be separated as well. A large proportion of the larger debris will reliably be deposited in the annular chamber **114**.

The cyclone **130** forms a second cyclonic separating unit. In this second cyclonic separating unit, the radius of the second cyclone **130** is smaller than that of the outer wall **104**. The length of the second cyclone **130** is relatively small and the cone opening **138** is relatively large. The inlets **134** and the vortex finder **144** are enlarged in comparison to a finely-tuned cyclone so that the speed of the airflow inside the second cyclone **130** is relatively low. Appropriate selection of the dimensions of the second cyclone **130** allows the separation efficiency of the second cyclonic separating unit to be selected to be the same as that of the first cyclonic separating unit. However, the performance of the second cyclonic separating unit is enhanced in comparison to that of the first cyclonic separating unit because it is challenged with an airflow in which a smaller range of particle sizes is entrained, the larger particles having been removed in the first cyclone of the first cyclonic separating unit.

The third cyclonic separating unit is formed by the eight smaller cyclones **148**. In this third cyclonic separating unit, each third cyclone **148** has an even smaller diameter than the second cyclone **130** of the second cyclonic separating unit and so is capable of separating finer dirt and dust particles than the second cyclonic separating unit. It also has the added advantage of being challenged with an airflow which has already been cleaned by the first and second cyclonic separating units and so the quantity and average size of entrained particles is smaller than would otherwise have been the case. The separation efficiency of the third cyclonic separating unit is considerably higher than that of the first and second cyclonic separating units.

The separation efficiency of the second cyclonic separating unit is the same as the separation efficiency of the first cyclonic separating unit and the separation efficiency of the third cyclonic separating unit is higher than the separation efficiency of the first and second cyclonic separating units. By this, we mean that each of the separation efficiencies of the first and second cyclones is lower than the separating efficiency of all eight third cyclones taken together.

A second embodiment of cyclonic separating apparatus **200** is shown in FIGS. **5** and **6**. The apparatus **200** is similar in structure to the embodiment shown in FIGS. **3** and **4** and described in detail above in that it is suitable for use in either of the vacuum cleaners **10**, **20** shown in FIGS. **1** and **2** and it comprises three successive cyclonic separating units.

As in the previously described embodiment, the first cyclonic separating unit consists of a single, cylindrical first cyclone **202** which is delimited by an outer cylindrical wall **204**, a base **206** and a second cylindrical wall **212**. A dirty air inlet **218** is provided tangentially to the outer wall **204** to ensure that cyclonic separation occurs in the first cyclone **202** and larger particles of dirt and debris are collected in the annular chamber **214** at the lower end of the cyclone **202**. As before, the only exit from the first cyclone **202** is via the perforations **224** in the shroud **222** into a passage **226** located between the shroud **222** and the second cylindrical wall **212**.

In this embodiment, the second cyclonic separating unit consists of two tapering second cyclones **230** arranged in parallel with one another. The second cyclones **230** are located side by side inside the outer wall of the apparatus **200** as can be seen in FIG. **6**. Each second cyclone **230** has an upper inlet portion **232** in which at least one inlet **234** is provided. Each inlet **234** is orientated for tangential introduction of air into the upper inlet portion **232** and communicates with a chamber **228** which, in turn, communicates with the passage **226**. Each second cyclone **230** has a frusto-conical portion **236** depending from the upper inlet portion **232** and terminating in a cone opening **238**. The second cyclones **230** project into a closed chamber **242**. Each second cyclone **230** has a vortex finder **244** located at the upper end thereof and communicating with a chamber **246**.

The third cyclonic separating unit consists of four third cyclones **248** arranged in parallel. Each third cyclone **248** has an upper inlet portion **252** which includes an inlet **250** communicating with the chamber **246**. Each third cyclone **248** also has a frusto-conical portion **254** depending from the inlet portion **252** and communicating with a closed chamber **256** via a cone opening. The chamber **256** is closed with respect to the chamber **242** by means of a pair of walls **270** (see FIG. **6**). Each third cyclone **248** has a vortex finder **258** located at the upper end thereof and communicating with an outlet chamber **260** having an exit port **262**.

The first cyclone **202** has an axis **264**, each second cyclone **230** has an axis **265** and each third cyclone has an axis **266**. In this embodiment, the axes **264**, **265** and **266** lie parallel to one

another. However, the diameters of the first, second and third cyclones **202**, **230**, **248** decrease in size.

The apparatus **200** operates in a manner similar to the operation of the apparatus **100** shown in FIGS. **3** and **4**. Dirt-laden air enters the first cyclone **202** of the first cyclonic separating apparatus via the inlet **218** and circulates around the chamber **214** so that larger dirt particles and debris are separated by cyclonic action. The dirt and dust collects in the lower portion of the chamber **214** whilst the cleaned air exits the chamber **214** via the perforations **224** in the shroud **222**. The air passes through the passage **226** to the chamber **228** and then to the inlets **234** of the second cyclones **230**. Further cyclonic separation takes place in the second cyclones **230**, which operate in parallel. Dirt and dust separated from the airflow is deposited in the chamber **242** whilst the further cleaned air exits the second cyclones **230** via the vortex finders **244**. The air then enters the third cyclones **248** via the inlets **250** and further cyclonic separation takes place therein with separated dirt and dust being deposited in the chamber **256**. The cleaned airflow exits the apparatus **200** via the chamber **260** and the exit port **262**.

In the embodiment shown in FIGS. **5** and **6**, the second cyclones **230** are designed so that the second cyclonic separating unit has a separation efficiency which is the same as the separation efficiency of the third cyclonic separation unit. This can be achieved by providing the second cyclones **230** with relatively small inlets **234** and vortex finders **244** and by providing each second cyclone **230** with a relatively long, relatively slender frusto-conical portion **236**.

Each cyclonic separating unit removes a proportion of entrained dirt and dust from the airflow. This allows the second and third cyclonic separating units to operate more effectively because they are challenged with an airflow in which a smaller range of particles is entrained.

Each of the cyclonic separating units can consist of different numbers and different shapes of cyclone. FIGS. **7** to **9** illustrate schematically three further alternative configurations which fall within the scope of this invention. In these illustrations, all detail will be omitted other than the number and general shape of the cyclones which make up each cyclonic separating unit.

Firstly, in FIG. **7**, the apparatus **300** comprises a first cyclonic separating unit **310**, a second cyclonic separating unit **320** and a third cyclonic separating unit **330**. The first cyclonic separating unit **310** comprises a single first cyclone **312** which is cylindrical in shape. The second cyclonic separating unit **320** comprises two frusto-conical second cyclones **322** arranged in parallel and the third cyclonic separating unit **330** comprises eight frusto-conical third cyclones **332**, also arranged in parallel. In this embodiment, the dimensions of the third cyclones **332** are much smaller than those of the second cyclones **322** and the separating efficiency of the third cyclonic separating unit **330** is higher than that of the second cyclonic separating unit **320**. The separating efficiency of the second cyclonic separating unit **320** is arranged to be substantially the same as that of the first cyclonic separating unit **310**.

In the arrangement shown in FIG. **8**, the apparatus **400** comprises a first cyclonic separating unit **410**, a second cyclonic separating unit **420** and a third cyclonic separating unit **430**. The first cyclonic separating unit **410** comprises a single first cyclone **412** which is cylindrical in shape. The second cyclonic separating unit **420** comprises three cylindrical second cyclones **422** arranged in parallel and having diameters which are considerably smaller than the diameter of the first cyclone **410**. The third cyclonic separating unit **430** comprises twenty-one frusto-conical third cyclones **432**, also arranged in parallel. The dimensions of the third cyclones **432** will be very much smaller than those of the second cyclones **422** and so the separating efficiency of the third cyclonic separating unit **430** will be higher than that of the second cyclonic separating unit **420**. The separating efficiency of the second cyclonic separating unit **420** is again arranged to be substantially the same as that of the first cyclonic separating unit **410**.

In the arrangement shown in FIG. **9**, the apparatus **500** comprises a first cyclonic separating unit **510**, a second cyclonic separating unit **520** and a third cyclonic separating unit **530**. The first cyclonic separating unit **510** comprises two, relatively large first cyclones **512** which are frusto-conical in shape. The second cyclonic separating unit **520** comprises three frusto-conical second cyclones **522** arranged in parallel but having diameters which are considerably smaller than the diameter of the first cyclones **510**. The third cyclonic separating unit **530** comprises four frusto-conical third cyclones **532**, also arranged in parallel. The dimensions of the third cyclones **532** will be smaller again than those of the second cyclones **522** but the separating efficiency of the second cyclonic separating unit **520** is arranged to be substantially the same as that of the third cyclonic separating unit **530**. These separation efficiencies are higher than the separation efficiency of the first cyclonic separating unit **510**.

The arrangements illustrated in FIGS. **7** to **9** are intended to show that the number and shape of the cyclones forming each cyclonic separating unit can be varied. It will be understood that other arrangements are also possible. For example, the first and second cyclonic separating units may each comprise a single cyclone and the third cyclonic separating unit may comprise fourteen cyclones arranged in parallel. Further, another suitable arrangement is to use a first cyclonic separating unit comprising a single cyclone, a second cyclonic separating unit comprising two cyclones in parallel and a third cyclonic separating unit comprising eighteen cyclones in parallel.

It will be understood that further cyclonic separating units can be added downstream of the third cyclonic separating unit if desired. It will also be understood that the cyclonic separating units can be physically arranged to suit the relevant application. For example, the second and/or third cyclonic separating units can be arranged physically outside the first cyclonic separating unit if space permits. Equally, if any one of the cyclonic separating units includes a large number of cyclones, the cyclones can be arranged in two or more groups or include cyclones of different dimensions. Furthermore, the cyclones included within a multi-cyclone separating unit can be arranged such that their axes lie at different angles of inclination to the central axis of the apparatus. This can facilitate compact packaging solutions.

The invention claimed is:

1. A cyclonic separating apparatus, comprising:

a first cyclonic separating unit including at least one first cyclone;

a second cyclonic separating unit located downstream of the first cyclonic separating unit and including at least one second cyclone; and

a third cyclonic separating unit located downstream of the second cyclonic separating unit and including at least two third cyclones;

wherein a separation efficiency of the second cyclonic separating unit is substantially the same as a separation efficiency of either the first cyclonic separating unit or the third cyclonic separating unit, and

wherein a number of third cyclones is greater than a number of second cyclones.

2. The cyclonic separating apparatus of claim 1, wherein the separation efficiency of the second cyclonic separating unit is the same as the separation efficiency of the first cyclonic separating unit.

3. The cyclonic separating apparatus of claim 1, wherein the separation efficiency of the second cyclonic separating unit is the same as the separation efficiency of the third cyclonic separating unit.

4. The cyclonic separating apparatus of claim 1, 2 or 3, wherein the first cyclonic separating unit includes a single first cyclone.

5. The cyclonic separating apparatus of claim 1, 2 or 3, wherein each first cyclone is substantially-cylindrical.

6. The cyclonic separating apparatus of claim 1, 2 or 3, wherein the second cyclonic separating unit comprises a plurality of second cyclones arranged in parallel and the third cyclonic separating unit comprises a plurality of third cyclones arranged in parallel.

7. The cyclonic separating apparatus of claim 6, wherein the second cyclones are substantially identical to one another and the third cyclones are substantially identical to one another.

8. The cyclonic separating apparatus of claim 1, 2 or 3, wherein each second and third cyclone is tapering in shape.

9. The cyclonic separating apparatus of claim 8, wherein each of the second and third cyclones is frusto-conical.

10. The cyclonic separating apparatus of claim 9, wherein the angle of taper of each second cyclone is greater than the angle of taper of each third cyclone.

11. The cyclonic separating apparatus of claim 1, 2 or 3, wherein each second cyclone has at least two inlets which communicate with the first cyclonic separating unit.

12. The cyclonic separating apparatus of claim 11, wherein the inlets to each second cyclone are circumferentially spaced about an axis of the relevant second cyclone.

13. The cyclonic separating apparatus of claim 1, 2 or 3, wherein each cyclonic separating unit has a collector which can be emptied simultaneously with other collectors.

14. The cyclonic separating apparatus of claim 1, 2 or 3, further comprising additional cyclonic separating units downstream of the third separating unit.

15. A vacuum cleaner comprising the cyclonic separation apparatus of claim 1, 2 or 3.

16. The cyclonic separating apparatus of claim 4, wherein each first cyclone is substantially cylindrical.

17. The cyclonic separating apparatus of claim 4, wherein the second cyclonic separating unit comprises a plurality of second cyclones arranged in parallel and the third cyclonic separating unit comprises a plurality of third cyclones arranged in parallel.

18. The cyclonic separating apparatus of claim 17, wherein the second cyclones are substantially identical to one another and the third cyclones are substantially identical to one another.

19. The cyclonic separating apparatus of claim 4, wherein each second and third cyclone is tapering in shape.

20. The cyclonic separating apparatus of claim 19, wherein each of the second and third cyclones is frusto-conical.

21. The cyclonic separating apparatus of claim 20, wherein the angle of taper of each second cyclone is greater than the angle of taper of each third cyclone.

22. A cyclonic separating apparatus, comprising:

a first cyclonic separating unit including at least one first cyclone;

a second cyclonic separating unit located downstream of the first cyclonic separating unit and including at least one second cyclone; and

a third cyclonic separating unit located downstream of the second cyclonic separating unit and including at least one third cyclone;

wherein a separation efficiency of the second cyclonic separating unit is substantially the same as a separation efficiency of either the first cyclonic separating unit or the third cyclonic separating unit, and

wherein each second cyclone has at least two inlets which communicate with the first cyclonic separating unit.

23. The cyclonic separating apparatus of claim 22, wherein the inlets to each second cyclone are circumferentially spaced about an axis of the relevant second cyclone.

* * * * *