(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 815 788 A2

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.01.1998 Bulletin 1998/02

(51) Int. Cl.$^6$: A47L 9/16

(21) Application number: 96203067.2

(22) Date of filing: 02.11.1996

(84) Designated Contracting States:
DE ES FR GB

(30) Priority: 27.06.1996 IT MI961308

(71) Applicant: CANDY S.p.A.
I-20052 Monza (Milano) (IT)

(72) Inventor: Annovazzi, Lorella
26025 Palazzo Pignano, (Cremona) (IT)

(74) Representative:
Falcetti, Carlo et al
c/o JACOBACCI & PERANI S.p.A.
Via Visconti di Modrone, 7
20122 Milano (IT)

(54) **Electrocyclone vacuum cleaner and electrocyclone filter cartridge for same**

(57) Movable domestic or industrial vacuum cleaner in which the dust is trapped in a dust collecting chamber (7) by a combination of centrifugal and electrostatic actions, dust-laden air being carried at high speed into a helical tube (13) that is housed in the chamber (7) and opens on the inside of the latter. The walls of the tube (13) are given an electric charge by triboelectric action and, while larger and denser particulates are deposited in the chamber (7) by centrifugal action, finer particulates are attracted electrostatically and deposited on the external wall of the helical tube (13).

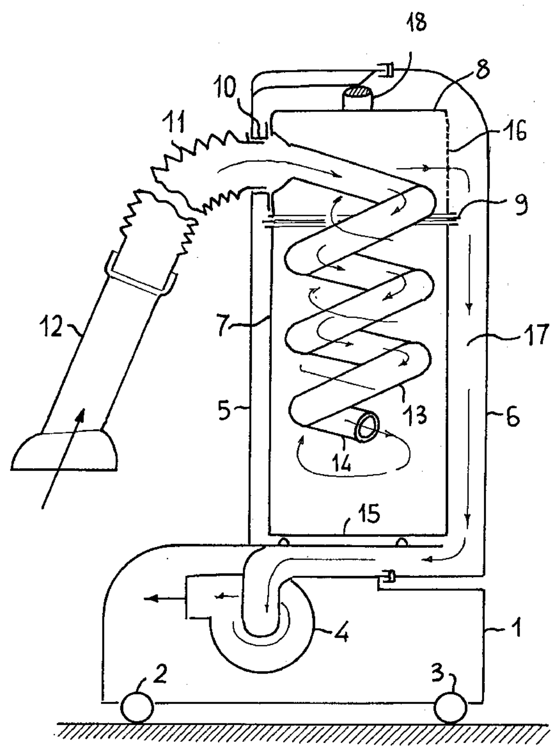


FIG. 1

EP 0 815 788 A2

## Description

The present invention relates to a vacuum cleaner comprising a suction and filter system using a combined cyclonic and electrostatic action.

The system can be used in both industrial and domestic types of vacuum cleaners having high performance and low running costs.

The prior art includes domestic vacuum cleaners containing a suction motor unit which sucks air through a rigid or flexible tube ending in a generally interchangeable suction head made in a variety of shapes to suit the various needs of use.

Interposed between the suction tube and the suction motor unit is a filter for trapping the dust: this is generally in the form of a paper or felt bag which has to be periodically replaced or emptied and cleaned - a very disagreeable job for the user.

Furthermore, the efficiency of these types of vacuum cleaners is low and changes over time, the problem being that a vacuum cleaner must fulfil the requirement of trapping solid particulates whose dimensions may vary from a few millimetres (granules) to a few micrometres (very fine dust) and whose densities may vary from 5 g/cm$^3$ to less than 1 g/cm$^3$ depending on the material (metal powders, inorganic materials and organic materials such as fluff etc.).

In order to trap larger solid particulates of high density, the speed of the sucked air stream must be very high, around 30 m/s or more.

To trap finer particulates, the porosity of the filter must be very fine, of about the same size as the particles that are to be trapped.

These two requirements are difficult to reconcile because a very fine filter represents a major obstacle to the flow of air through the filter and causes significant losses of pressure which increase with the flow rate and speed of the sucked air.

In order to satisfy the necessary requirements, one must therefore use vacuum cleaners of high power and consumption which, even in the case of domestic cleaners, is now well over the kilowatt.

In spite of this, even though a clean filter will trap the entire range of dimensions and densities of the solid particulates present in normal environmental conditions with reasonable efficiency, as use continues the filter becomes more and more clogged up and efficiency declines steeply as the air flow rate is reduced.

It should also be noticed that the sucked air serves as ventilation for the motor, so that a reduction in the flow can cause it to overheat and fail.

Generally speaking, therefore, expensive safety devices have to be provided to turn the machine off if the filter bag fills up or is clogged excessively without being replaced or cleaned.

This has a greater economic impact on the production of the machine and does not solve the problem of the reduction in the efficiency of the vacuum cleaner, which can only be kept efficient by very frequent cleaning or replacement of the filter, thus inevitably causing the user discomfort and loss of time.

An alternative system which has been gaining acceptance even in domestic vacuum cleaners, and dispenses with the use of filter bags, or at least limits the use of filters in the stream of sucked air, involves introducing, in the suction circuit, one or more cyclones in sequence, which, by imparting a swirling motion to the stream of air entering the cyclone chamber, exert a centrifugal action which causes the solid particles to pack together near the walls of the chamber on which, by friction and consequent loss of speed, they are deposited and fall under gravity into the bottom of the chamber, from where they can be periodically removed.

In contrast to bag-type vacuum cleaners, which are often able to operate in a wide range of positions, these vacuum cleaners obviously have to be operated in a particular position, or one not far removed from it, relative to the horizontal plane, to allow the dust to be accumulated by gravity in a particular part of the cyclone chamber.

This condition is not for practical purposes a serious limitation.

An example of a cyclone vacuum cleaner using a series of two cyclones, is described for example in documents EP-A-0018197 and EP-A-0042723.

Despite the appreciable advantages of this filtration system, such as low loss of pressure, consequent low power consumption, no maintenance costs (no need to replace filters), practicality of use (cleaning the cyclone or cyclones is comparatively easy), and the machine's practically constant efficiency over the course of its use, this system is not entirely satisfactory as smaller and lighter particles are little affected by the centrifugal forces set up by the cyclone or cyclones, even the highly efficient types (frustoconical-chamber cyclones) and they tend to a great extent, if not entirely, to escape being trapped.

To avoid this problem it is therefore necessary to use absorbent outlet filters which have to be cleaned or replaced, though not so frequently, and the suction power has to be increased to cope with the inevitable resulting loss of pressure.

The present invention overcomes all these limitations and provides a vacuum cleaner in which the action of filtration is performed jointly by centrifugal force and by the forces of electrostatic attraction generated by an electric charge produced by triboelectric action by the stream of dust itself carried by the sucked air, which is given a swirling motion.

For this reason the vacuum cleaner can be described as "electrocyclonic" or as using an electrostatic cyclone.

In essence, according to the invention, the filter system of the vacuum cleaner consists of a generally cylindrical or frustoconical chamber for collecting the particulates, with an outflow mouth at the top connected to a motorized suction unit.

The collecting chamber houses in its interior a helical pipe, for example a circular-sectioned tube, made of a dielectric material that can be given an electric charge by triboelectric action, with an inlet mouth that opens on the outside of the chamber to receive a stream of dust-laden air fed to it by a suction mouth, and an outlet mouth that opens on the inside of the chamber approximately tangentially to the cylindrical or frusto-conical walls of the chamber, as in an ordinary cyclone.

The air expelled from the pipe and introduced with a swirling motion into the chamber strikes the outer walls of the pipe and is sucked out through the outflow mouth at the top.

The dust carried by the stream of air, which the helical pipe causes to move at high speed, approximately 30-50 m/s or more, gives the walls of the pipe an electric charge.

Whereas the larger particulates carried by the air with a swirling motion of decreasing speed into the collecting chamber are deposited, by centrifugal action, on the walls of the chamber, the finer particulates, which are little influenced by the centrifugal force, are attracted by the electrostatic forces of the electric charge produced on the walls of the pipe and are deposited on these.

The efficiency with which even the finest particulates are trapped is extremely high and there is no need for additional paper or felt filters.

When the electrostatic effect has decayed, or when the machine is tapped lightly, the trapped particulates detach themselves from the walls of the pipe and fall down into the dust collecting chamber.

Another aspect of the present invention is that this filter system is advantageously combined with an additional cyclone filter stage, which may optionally also be made more efficient by electrostatic action.

Another aspect of the present invention is that the filter system consists of a semirigid cartridge designed to replace a conventional cartridge filter in order to convert a conventional vacuum cleaner, using a filter that requires periodic replacement, into an electrocyclone vacuum cleaner that does not require filter replacement but only periodic emptying of the cyclone, without the machine having to be modified in any way.

The features and advantages of the invention will appear more clearly in the following description of a preferred embodiment and of its variants. This description is given by way of non-restrictive example and refers to the attached drawings, in which:

- Figure 1 shows schematically in cross section in its essential aspects a vacuum cleaner made in accordance with the present invention,
- Figure 2 is a side view of a preferred embodiment of an electrocyclone filter cartridge which is completely interchangeable with filter cartridges already available on the market,
- Figure 3 is a cross section through the middle of the filter cartridge of Figure 2,
- Figure 4 is a cross section in front view of the filter cartridge of Figure 2, on the section marked II-II in Fig. 3,
- Figure 5 is a sectional view of the filter cartridge on the section marked I-I in Figure 4,
- Figure 6 is a schematic sectional view of one alternative embodiment of an electrocyclone filter in accordance with the present invention, and
- Figure 7 is a schematic sectional view of a second alternative embodiment of an electrocyclone filter in accordance with the present invention.

With reference to Figure 1, an electrocyclone vacuum cleaner according to the present invention comprises a base 1 mounted on wheels 2, 3 (optionally also rotating brushes) and housing a suction unit 4.

Mounted on the base is a body 5 closed on one side by a removable half-cover 6 and housing in its interior, in such a way as to leave a space 17, a dust collecting container or chamber 7 closed by a removable lid 8 with a gasket 9 between the two.

The body 5 possesses a mouth 10 through which the sucked air enters and which is connected externally, by a flexible tube 11, to a suction head, and internally to the removable lid 8.

Inside the container 7, attached to the lid 8, is a helical tube 13 whose inlet connects, via a suitable gasket, with the inlet mouth 10 while its outlet 14 opens on inside of the chamber 7, at a suitable distance from the bottom 15 of the chamber 7.

The lid 8 contains an opening 16 placing the interior of the chamber 7 in communication with the space 17 formed between the container 7 and the body 5.

As a safety measure, a net can be placed over the opening 16 for trapping particulates larger than a certain size.

The space 17 communicates with the suction mouth of the suction unit 4.

The helical tube 13 is made, preferably by blow-moulding or thermoforming, from a plastic material.

As is known, all plastic materials exhibit to a more or less marked degree the property of acquiring an electric charge when rubbed.

Particularly indicated for this purpose are the styrene and acrylic resins and the polyesters, but polytetrafluoroethylene, polythene, etc., especially if not filled with inert materials that can lower their dielectric constant and resistivity, also exhibit this property.

When the suction unit is turned on, the air sucked in through the head 12 and conveyed to the tube 13 via the flexible tube 11 travels at high speed, approximately 30-50 m/s or even more, through the tube 13, where a swirling motion is imparted to it.

The particulates contained in the air thus experience a centrifugal force which throws the particles against the inner walls of the tube 13.

The particles exert a rubbing action on the inner walls of the tube 13, especially on that portion of the tube walls furthest from the axis of the helix, causing it to become electrically charged.

The particles themselves also acquire an electric charge of opposite sign, but they are not attracted to the walls owing to two factors:

- the force with which they are carried along by the fast-moving stream of air exceeds the electrostatic force of attraction,
- and the electrostatic force of attraction is weak, because the inner walls of the tube 13 behave like a Faraday cage, inside which the electric field is, if not zero, very low.

Whatever the theoretical explanation may be, the experimental fact remains that the inner walls of the tube 13 remain perfectly clean and do not accumulate deposits that could obstruct and block or limit the flow of air.

The dust-laden air that emerges from the tube 13, and enters the container 7, moving approximately tangentially to its walls, develops a swirling flow that strikes against both the walls of the container and the outer walls of the tube 13 as it rises back up towards the top of the container 7.

Because of the greater usable cross section of passage, which is around 20 or more times the usable cross section of the tube 13, and because of the friction with the walls, this swirling flow gradually loses much of its speed.

The transporting force of the air flow therefore drops significantly and the particles of dust are brought to a stop, in the case of the largest, by friction with the inner walls of the container 7 before falling under gravity to the bottom of the container.

The smaller and lighter particles, being less sensitive to the imparted centrifugal acceleration, are attracted electrostatically to the outer walls of the tube 13 on which they collect.

The air stream now rid of the solid particulates then passes out of the mouth 16 of the lid 8 into the space 17 and is sucked in by the suction unit 4 before being expelled into the surrounding environment.

When the suction unit 4 is turned off, the flow of air ceases and the electric charge that was formed on the inner walls of the tube 13, being no longer regenerated by the flow of air, decays gradually within a few tens of seconds, so that the trapped dust drops off the tube 13 and falls to the bottom of the container 7.

Gentle taps to the container 7 through the body 6 assist such detachment and make it happen even faster.

In Figure 1 the container 7, whose shape is a preferably but not necessarily circular-sectioned elongate cylinder, is depicted with its axis upright.

It will nevertheless be clear that the operation of the device is not affected if the container is positioned with its axis inclined to the horizontal, provided the inclination is steep and not less than 30-45°, so that the particulates can accumulate in the bottom of the container.

The body 6, as in many vacuum cleaners available on the market, may therefore be hinged to the base 1 to assume a variable working position dictated by user convenience and by the particular conditions of use.

When the half-cover 6 is opened, the container 7 and its lid 8 can easily be removed from the housing formed in the body 5.

The operation can be facilitated by a handle 18 on the lid 8.

By separating the lid 8 from the container 7, the tube 13 is withdrawn from the container and the latter can easily be emptied of its load of dust into a dustbin.

If desired, both the container 7 and the lid 8 with its associated tube 13 can be washed: this will not affect the properties of the material once it has been dried.

The container 7 together with the lid 8 and the associated tube 13 can be designed in terms of dimensions and geometry so as to be interchangeable with filter bags of rigid structure already available on the market so that they can be installed and housed in vacuum cleaners already existing on the market instead of the originally intended bag/filter.

Figures 2, 3, 4 and 5 show by way of example an structure for an electrocyclone filter which uses as its base a ribbed frame 19 for containing a conventional filter bag. The frame is closed at the top by a ribbed head 20, removable from the frame 19 and provided with an inlet mouth 21, a gasket 22 being provided for the connection of a suction tube.

The frame encloses, instead of the filter, an impervious semirigid container 23, which may also be formed integrally with the frame.

Connected to the inlet mouth 21, via a funnel 24, is a helical tube 25 made of a plastic material, also semirigid, which extends down into the container 23.

Both the frame and the container are in the general form of rectangular parallelepipeds, with rounded edges.

The head 20, which has a handle 26, has one or more outflow openings around its sides, optionally with protective gratings to trap particulates larger than a given size.

The tube 25, whose diameter may be around 15-30 mm and whose thickness around 0.5-1.5 mm, follows in its shape the inner walls of the container 23 at a convenient distance from them, of for example 3-10 mm.

Even if the helix formed by the tube 25 is not in the form of a circular-sectioned cylinder, the efficiency with which dust is trapped is not affected.

An electrocyclone filter of the type described, unlike filter bags or absorbent felt filters, exhibits very little resistance to the passage of a stream of air.

Furthermore the resistance is not influenced by the conditions of use, provided of course that the outlet of the tube 25 (Fig. 3) or 13 (Fig. 1) is not blocked by overfilling the dust collecting container.

Besides the advantage that the filter as thus designed is reusable indefinitely, given periodic emptying, and so saving on running costs, the advantage is therefore obtained that for the same filtering efficiency, or with greater filtering efficiency, when compared with ordinary filter bags, the necessary suction power is much reduced (by 15-20 % or more), so that both the electricity running costs are reduced and the power of the motor installed in a vacuum cleaner designed specifically for use with this filter is reduced, thereby substantially reducing the cost of the appliance.

The preceding description relates only to a preferred embodiment, but it will be obvious that many variants are possible.

For example, Figure 6 shows in diagrammatic cross section an embodiment of an electrocyclone filter in which the dust collecting container 30 is in the form of an open-topped cylindrical tub provided internally with a cyclindrical partition 31 separating it into a central cylindrical volume 31A and an annular ring 31B.

Over the tub 30 is a bell head 32 whose cylindrical walls 33 come between the peripheral walls of the tub 30 and the inner partition 31, forming a labyrinth path.

Accommodated inside the bell head 32 is a helical tube 34 that opens on the outside of the tub for connection to a suction head and reaches into the interior of the cylindrical partition 31.

The dust-laden air entering the tube 34 unloads most of its particulates into the central volume 31A.

A further fraction of the particulates are trapped electrostatically and are deposited on the outer walls of the tube 34.

The cleaned air flows over the rim of the cylindrical partition 31 into the space formed between partition 31 and peripheral walls 33 of the bell.

By appropriately designing the shape and dimensions of the rim of the cylindrical partition 31 and of the bell 32, the air entering the space can have a high speed and a tangential component so that the walls 33 behave like a third cyclone (the first cyclone is that formed through the tube 34 and the second cyclone is that formed by the cylindrical partition 31). The wall 33 may conveniently be in a plastic that becomes electrically charged by triboelectric action.

Any residual dust carried by the air therefore charges the inner surface of the peripheral walls 33 and then, travelling at reduced speed through the space between the walls 33 and the peripheral walls of the tub 30, is attracted to the outer surface of the walls 33, from which it drops into the bottom of the annular ring 31B when the electrostatic charge decays.

The tub is easily cleaned and emptied by removing the bell 32, and with it the tube 34, which may conveniently be made integral with the bell, from the tub.

Figure 7 depicts a further variant, similar in some ways to the embodiment of Figure 6.

In Figure 7 the dust collecting container 35 is provided with an inner cylindrical partition 36 in which is housed a screw 37 with a hollow central core, and edges of the screw sealed in by the cylindrical partition 36 in such a way as to form a helical channel through which a stream of sucked air is conveyed.

The inner cylindrical partition 36 is made of a plastic material that can be given an electric charge by triboelectric action.

A bell 38 mounted over the cylindrical partition 36 forms a labyrinth flow path from the cavity of the core of the screw and out through the space formed between the partition 36 and the bell 38 and between the bell 38 and the peripheral walls of the tub 35.

The air sucked through the screw, and then passing out from it after having unloaded most of the solid particulates onto the bottom of the tub 35, travels back up through the hollow core to strike the outer surface of the cylindrical partition 36, where the residual particulates are deposited by electrostatic attraction.

Many other variants are clearly possible, without thereby departing from the scope of the invention.

## Claims

1. Mobile vacuum cleaner, of domestic or industrial type, in which suction means (4) convey a stream of air through filter means for trapping particulates carried by the stream of air, characterized in that said filter means comprise:

   - a chamber (7, 23, 30, 35) for collecting the particulates, with an outflow mouth (16), and
   - a helical pipe (13, 25, 34, 37) housed inside said collecting chamber with an inlet mouth (21) that opens on the outside of said chamber to receive said stream of air and an outlet mouth (14) that opens on the inside of said chamber,

   said pipe (13, 25, 34, 37) having at least one portion of a wall separating said pipe from said chamber (7, 23, 30, 35) and made of a dielectric material that can be given an electric charge by triboelectric action, in such a way that said particulates carried by said stream charge the surface of said wall portion at least, with an electric charge and said charge attracts the particulates blown into said collecting chamber.

2. Vacuum cleaner according to Claim 1, in which said pipe is formed by a helical plastic tube (13) and said collecting chamber is formed by a cylindrical body (7) closed at one end, which helical tube opens on the inside of said collecting chamber near said closed end.

3. Vacuum cleaner according to Claim 1, in which said

collecting chamber is formed by a tub (30) with an inner partition (31) to divide the internal volume of said tub into a central volume (31A) and an annular ring (31B), and by a bell (32) positioned over said tub and having peripheral walls (33) inserted in said annular ring so as to form a labyrinth path between said central volume and the outside of said tub, said pipe being housed inside said central volume.

**4.** Vacuum cleaner according to Claim 3, in which said inner partition (31) is made of a plastic material that can be given an electric charge by triboelectric action and said pipe is formed by a screw (37) with a hollow core housed inside said inner volume and sealed in by said inner partition.

**5.** Vacuum cleaner according to Claim 3 or 4, in which said peripheral walls (33) of the bell (32) are made of a plastic material that can be given an electric charge by triboelectric action.

**6.** Vacuum cleaner according to previous claims, in which said filter means are housed removably inside a body forming part of said vacuum cleaner.

**7.** Vacuum cleaner according to Claim 6, in which said collecting chamber is separable from said pipe or from at least a portion of said pipe.

**8.** Vacuum cleaner according to Claim 6, as dependent upon Claims 3, 4 or 5, in which said bell is separable from said tub.

**9.** Filter cartridge for vacuum cleaner according to previous claims, comprising said collecting chamber and said pipe.

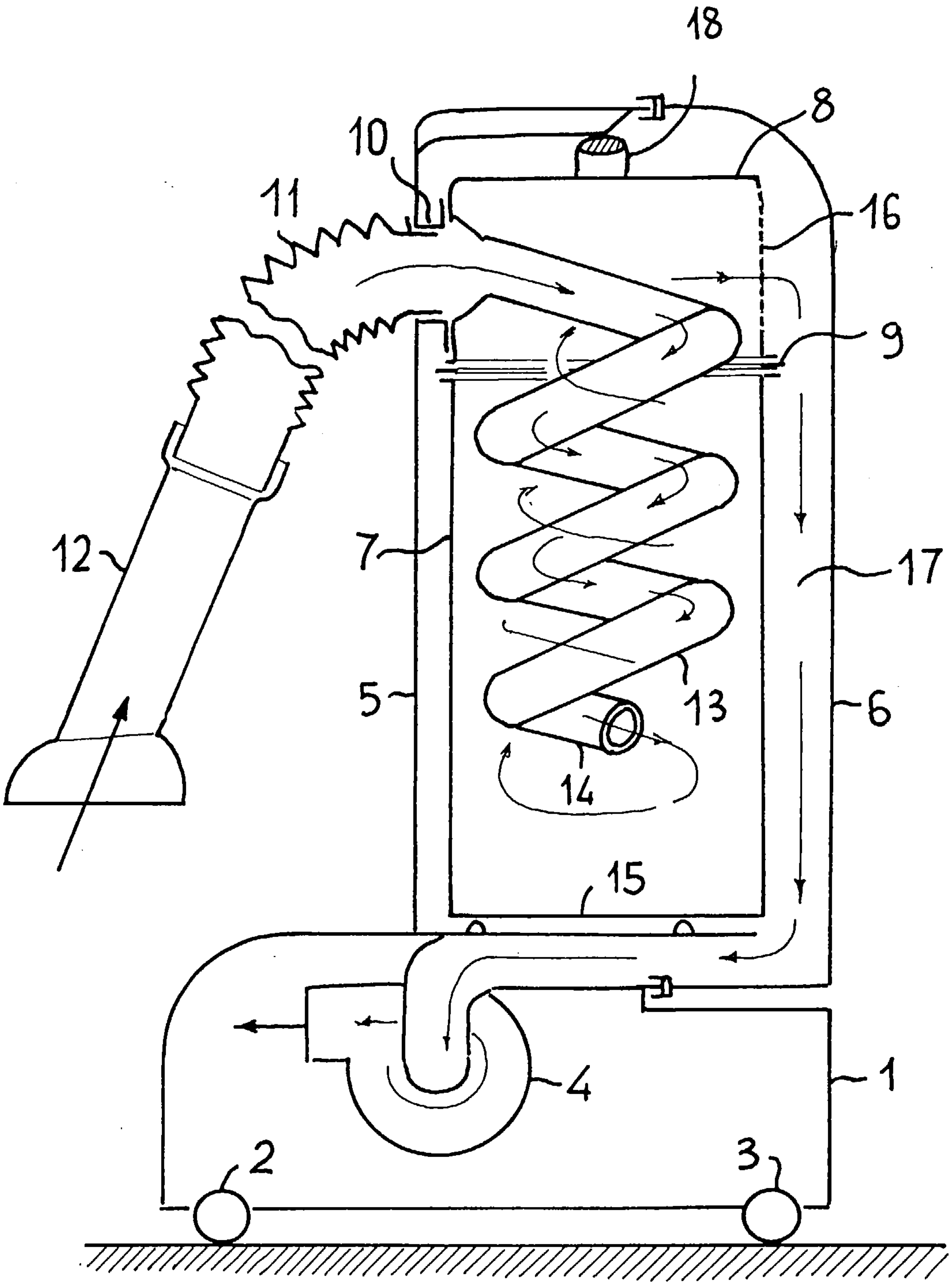


FIG. 1

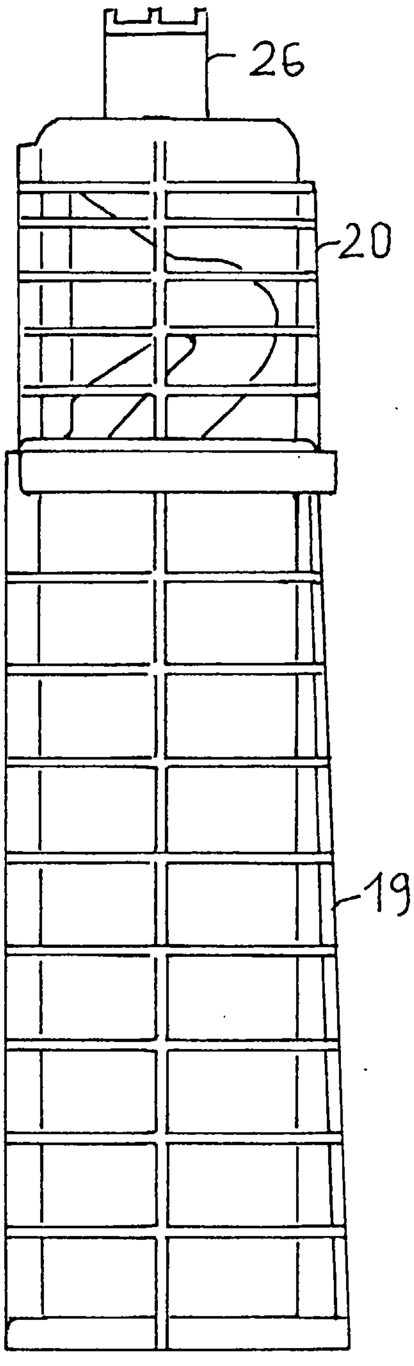


FIG. 2

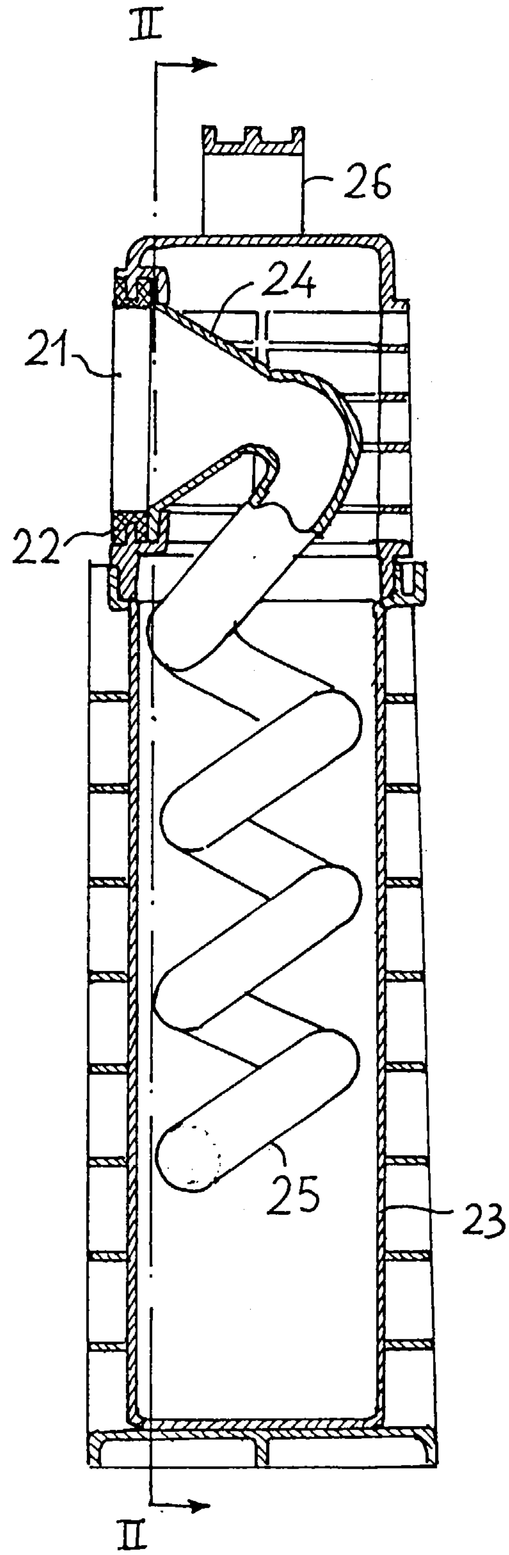


FIG. 3

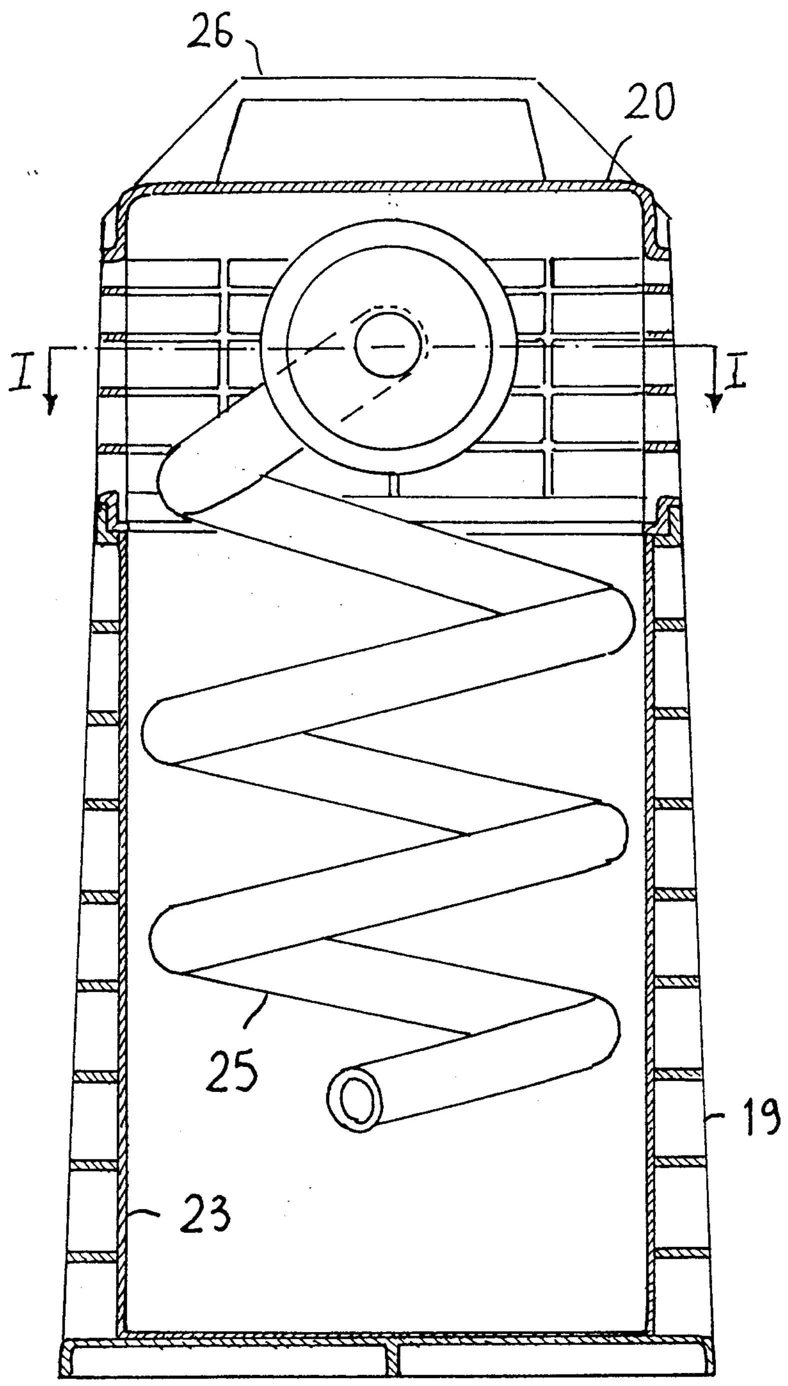


FIG. 4

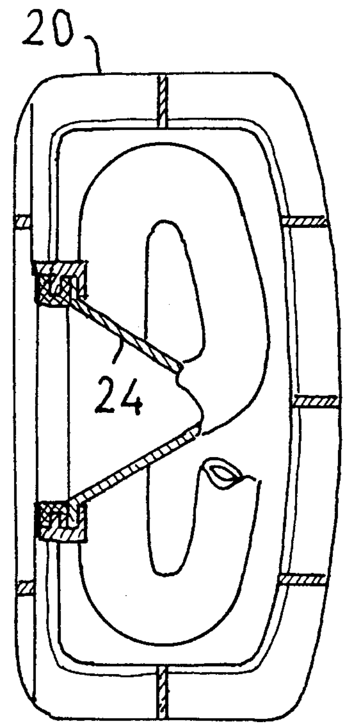


FIG. 5

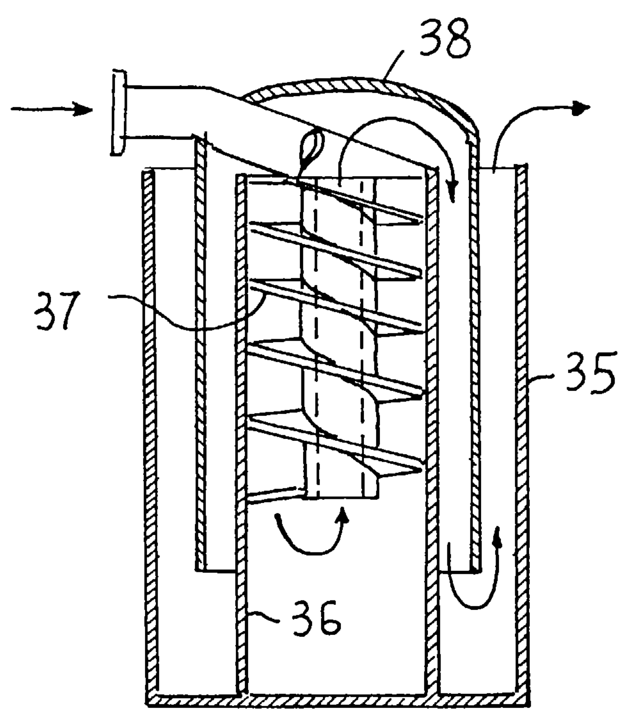


FIG. 7

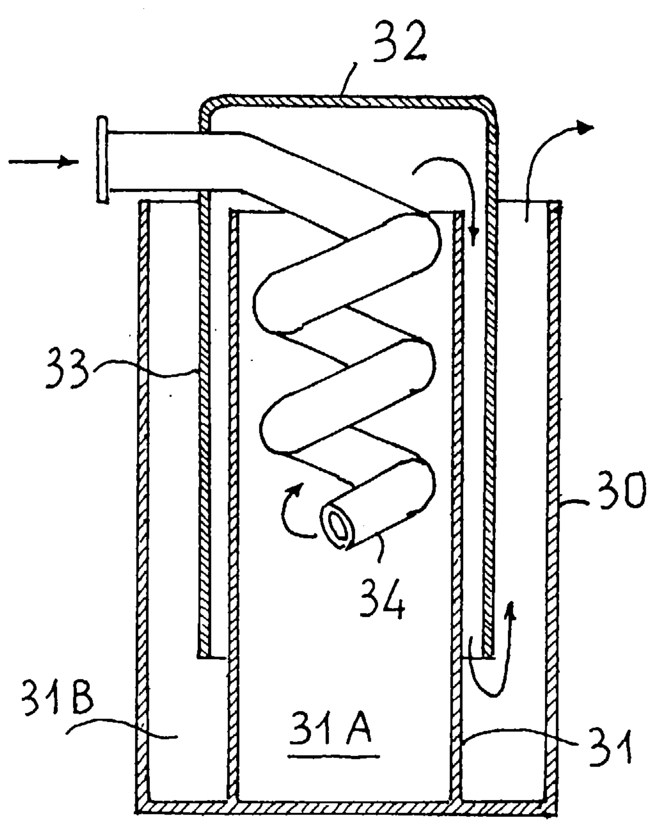


FIG. 6