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(54) **A CLEANER HEAD**

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## Description

**[0001]** The present invention relates to agitating apparatus for a surface treating appliance, and to a cleaner head for a surface treating appliance. In its preferred embodiment, the present invention relates to a cleaner head for a vacuum cleaning appliance.

**[0002]** A vacuum cleaner typically comprises a main body containing dirt and dust separating apparatus, a cleaner head connected to the main body and having a suction opening, and a motor-driven fan unit for drawing dirt-bearing air through the suction opening. The dirt-bearing air is conveyed to the separating apparatus so that dirt and dust can be separated from the air before the air is expelled to the atmosphere.

**[0003]** The suction opening is directed downwardly to face the floor surface to be cleaned. The separating apparatus can take the form of a filter, a filter bag or, as is known, a cyclonic arrangement. The present invention is not concerned with the nature of the separating apparatus and is therefore applicable to vacuum cleaners utilizing any of the above arrangements or another suitable separating apparatus.

**[0004]** A driven agitator, usually in the form of a brush bar, is supported in the cleaner head so as to protrude to a small extent from the suction opening. The brush bar is activated mainly when the vacuum cleaner is used to clean carpeted surfaces. The brush bar comprises an elongate cylindrical core bearing bristles which extend radially outward from the core. The brush bar may be driven by an air turbine or by an electric motor powered by a power supply derived from the main body of the cleaner. The brush bar may be driven by the motor via a drive belt, or may be driven directly by the motor, so as to rotate within the suction opening. Rotation of the brush bar causes the bristles to sweep along the surface of the carpet to be cleaned to loosen dirt and dust, and pick up debris. The suction of air causes air to flow underneath the sole plate and around the brush bar to help lift the dirt and dust from the surface of the carpet and then carry it from the suction opening through the cleaner head towards the separating apparatus.

**[0005]** The bristles of the brush bar are usually formed from nylon. While the use of nylon bristles provides an acceptable cleaning performance on carpeted floor surfaces, we have found that the use of nylon bristles generates static electricity when the floor tool is used on some hard floor surfaces, such as laminate, wood and vinyl surfaces, which attracts fine dust and powders, such as talcum powder, on to the floor surface. This can impair the cleaning performance on the cleaner head on such floor surfaces, as the sweeping action of the nylon bristles is insufficient to overcome the force attracting the fine dust to the floor surface.

**[0006]** GB 2,425,715 describes a vacuum cleaner tool which has a rotatable brush bar with bristles formed from a flexible polymeric material.

**[0007]** The present invention provides agitating appa-

ratus for a surface treating appliance, comprising a rotatable body and characterised in that the body has an outer surface which is substantially covered with filaments having a surface resistivity in the range from  $31 \times 10^{-5}$  to  $1 \times 10^{12} \Omega/\text{sq}$ , the filaments being woven on to a flexible carrier member covering the outer surface of the body.

**[0008]** Providing the rotatable body with an electrically conductive outer surface can enable static electricity residing on a floor surface to be cleaned to be discharged upon contact between the body and the floor surface. This enables fine dust and powder which would otherwise be attracted to the floor surface to be dislodged from the floor surface by the body. Having an outer surface comprising a pile, which is preferably similar to the raised or fluffy surface of a carpet, rug or cloth, can inhibit scratching or other marking of the floor surface upon contact with the rotating body.

**[0009]** The surface resistivity of the pile is in the range from  $1 \times 10^{-5}$  to  $1 \times 10^{12} \Omega/\text{sq}$  (ohms per square). Values of surface resistivity discussed herein are as measured using the test method ASTM D257. The selection of material having a surface resistivity in this range can ensure that any static electricity on the floor surface is effectively discharged by the agitating apparatus.

**[0010]** The pile covers the outer surface of the body so that no patterns of dirt or dust are formed on the floor surface as a cleaner head including the apparatus is manoeuvred over a floor surface.

**[0011]** The apparatus preferably comprises filaments formed from one of metallic, carbon fibre, carbon composite, conductive acrylic, such as Thunderon®, or other composite material. For example, material comprising carbon particles and carbon fibres generally has a surface resistivity in the range from  $1 \times 10^3$  to  $1 \times 10^6 \Omega/\text{sq}$ , whereas metallic material generally has a much lower surface resistivity, generally lower than  $1 \Omega/\text{sq}$ . Other static dissipative materials generally have a surface resistivity in the range from  $1 \times 10^5$  to  $1 \times 10^{12} \Omega/\text{sq}$ .

**[0012]** The filaments are preferably woven on to a flexible carrier member located about the body. For example, the carrier member may be in the form of a strip which is wound about the body, preferably so that there are substantially no gaps between the turns of the carrier member. The carrier member is preferable attached to the body using an adhesive.

**[0013]** The length of the filaments is preferably in the range from 4 to 10 mm. Preferably, the filaments have a diameter in the range from 5 to 20  $\mu\text{m}$ .

**[0014]** The rotatable body may comprise further surface agitating means. The further surface agitating means may be configured to agitate dirt and dust from a carpeted floor surface, and so is preferably relatively stiff in comparison to the electrically conductive pile or filaments. For example, bristles or filaments of the further surface agitating means may have a greater diameter than bristles or filaments of the electrically conductive pile.

**[0015]** The further surface agitating means may be formed from electrically insulating, plastics material, such as nylon, and so may have a surface resistivity which is different to that of the electrically conductive pile or filaments. The surface resistivity of the further surface agitating means is preferably in the range from  $1 \times 10^{12}$  to  $1 \times 10^{16} \Omega/\text{sq}$ . Alternatively, the further surface agitating means may be formed from a similar material as the electrically conductive pile or filaments.

**[0016]** The further surface agitating means may be dispersed within the filaments of the electrically conductive pile. The further surface agitating means is preferably arranged in a plurality of rows along the body, with these rows being preferably discontinuous. For example, where the further surface agitating means comprises a plurality of bristles these bristles are preferably arranged in one or more rows of clusters or tufts of bristles connected to and spaced along the body.

**[0017]** The agitating apparatus is preferably in the form of a rotatable brush bar.

**[0018]** In a second aspect, the present invention provides a cleaner head for a surface treating appliance, the cleaner head comprising a housing and apparatus as aforementioned. Where the agitating apparatus is in the form of a rotatable brush bar, the cleaner head may comprise two such brush bars. The brush bars are preferably rotatable in opposing directions.

**[0019]** In a third aspect, the present invention provides a surface treating appliance comprising a cleaner head or agitating apparatus as aforementioned.

**[0020]** The term "surface treating appliance" is intended to have a broad meaning, and includes a wide range of machines having a main body and a head for travelling over a surface to clean or treat the surface in some manner. It includes, inter alia, machines which simply agitate the surface, such as carpet sweepers, machines which only apply suction to the surface, such as vacuum cleaners (dry, wet and wet/dry), so as to draw material from the surface, and machines which apply material to the surface, such as polishing/waxing machines, pressure washing machines and shampooing machines.

**[0021]** Features described above in connection with the first aspect of the invention are equally applicable to any of the second to third aspects of the invention, and vice versa.

**[0022]** An embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a front perspective view, from above of a floor tool;

Figure 2 is a front perspective view, from below, of the floor tool of Figure 1;

Figure 3 is a bottom view of the floor tool of Figure 1;

Figure 4 is an exploded view of the brush bar of the

floor tool of Figure 1;

Figure 5 is a perspective view of the brush bar of Figure 4;

Figure 6 is a top view of the brush bar of Figure 4;

Figure 7 is a section taken along line A-A illustrated in Figure 3 when the floor tool is located on a carpeted floor surface;

Figure 8 is a section taken along line A-A illustrated in Figure 3 when the floor tool is located on a hard floor surface;

Figure 9 is a perspective view of a modified version of the brush bar of Figure 4; and

Figure 10 is a perspective view of an alternative brush bar for use with the floor tool of Figure 1.

**[0023]** With reference first to Figures 1 to 3, a floor tool 10 comprises a cleaner head 12 rotatably attached to a coupling 14. The free end of the coupling 14 is attachable to a wand, hose or other such duct of a cleaning appliance (not shown). The cleaner head 12 comprises a housing 16 and a lower plate, or sole plate 18, comprising a suction opening 20 through which a dirt-bearing fluid flow enters the cleaner head 12. The housing 16 defines a suction passage extending from the suction opening 20 to an outlet duct 22 located at the rear of the housing 16. The housing 16 preferably comprises a front bumper 23. The sole plate 18 comprises a plurality of support members 24 in the form of rolling elements mounted within recessed portions of the sole plate 18 for supporting the cleaner head 12 on a floor surface. With reference to Figures 7 and 8, the support members 24 are preferably arranged to support the sole plate 18 above the floor surface when the cleaner head 12 is located on a hard floor surface 66, and, when the cleaner head 12 is located on a carpeted floor surface 64, to sink into the pile of the carpet to enable the bottom surface of the sole plate 18 to engage the fibres of the carpet. The sole plate 18 is preferably pivotable relative to the housing 16 to allow the sole plate 18 to ride smoothly over the carpeted floor surface 64 during cleaning.

**[0024]** The coupling 14 comprises a conduit 26 supported by a pair of wheels 28, 30. The conduit 26 comprises a forward portion 32 connected to the outlet duct 22, a rearward portion 34 pivotably connected to the forward portion 32 and connectable to a wand, hose or other such duct of a cleaning appliance which comprises dirt and dust separating apparatus and a motor-driven fan unit for drawing dirt-bearing air through the suction opening 20 from the floor surface. A flexible hose 36 is held within and extends between the forward and the rearward portions 32, 34 of the conduit 26.

**[0025]** The cleaner head 12 comprises agitating appa-

ratus for agitating dirt and dust located on the floor surface. In this example the agitating apparatus comprises a rotatable brush bar 40 which is mounted within a brush bar chamber 42 of the housing 16. The brush bar chamber 42 is partially defined by a generally semi-cylindrical portion 43 of the housing 16, which is preferably formed from transparent material. The brush bar 40 is driven by a motor (not shown) located in a motor housing 44 of the housing 16. The motor is electrically connected to a terminal located in the rearward portion 34 of the conduit 26 for connection with a conformingly profiled terminal located in a duct of the cleaning appliance to enable electrical power to be supplied to the motor.

**[0026]** The brush bar 40 is connected to the motor by a drive mechanism located, at least in part, within a drive mechanism housing 46 so that the drive mechanism is isolated from the air passing through the suction passage. One end of the brush bar 40 is connected to the drive mechanism to enable the brush bar 40 to be driven by the motor, whereas the other end of the brush bar 40 is rotatably supported by an end cap 48 mounted on a side wall of the brush bar chamber 42.

**[0027]** The brush bar 40 is illustrated in more detail in Figures 4 to 6. The brush bar 40 comprises an elongate body 50 bearing two different types of agitating means for agitating dirt and dust from the floor surface as the brush bar 40 is rotated by the motor. Each of the different types of agitating means protrudes from the suction opening 20 in the sole plate 18 as the brush bar 40 is rotated by the motor. A spindle 51 is mounted on one end of the body 50, with the spindle 51 being in turn connected to the end cap 48.

**[0028]** A first agitating means mounted on the body 50 of the brush bar 40 comprises relatively short, preferably relatively stiff, bristles 52. These bristles 52 are preferably formed from nylon. In this embodiment the relatively short bristles 52 are arranged in two angularly spaced, helical rows extending along the body 50. Within each row, the relatively short bristles 52 are arranged in a series of clusters or tufts 53 regularly spaced along the row. Each tuft 53 preferably comprises around 100 to 150 bristles, with each tuft 53 having a diameter in the range from 2 to 4 mm. The diameter of each bristle 52 is preferably in the range from 100 to 200  $\mu\text{m}$ . The length of the relatively short bristles 52 is chosen so that, when the floor tool 50 is assembled, the tips of these bristles 52 do not protrude beneath a plane extending between the lowermost extremities of the support members 24 during rotation of the brush bar 40.

**[0029]** A second agitating means mounted on the body 50 of the brush bar 40 comprises relatively long, preferably relatively soft, bristles 54. As illustrated in Figure 7, the relatively long bristles 54 protrude radially outwardly from the body 50 beyond the relatively short bristles 52. During rotation of the body 50, the relatively short bristles 52 sweep a cylindrical volume having a diameter D1, whereas the relatively long bristles 54 sweep a cylindrical volume having a diameter D2 which is greater than D1.

The difference between D1 and D2 is preferably in the range from 1 to 10 mm, more preferably in the range from 2 to 6 mm. In contrast to the relatively short bristles 52, the length of the relatively long bristles 54 is chosen so that the relatively long bristles 54 protrude beyond the plane extending between the lowermost extremities of the support members 24 during rotation of the brush bar 40.

**[0030]** The relatively long bristles 54 are formed from material having a lower surface resistivity than the material from which the relatively short bristles 52 are formed. The surface resistivity of the relatively long bristles 54 is preferably in the range from  $1 \times 10^{-5}$  to  $1 \times 10^{12}$   $\Omega/\text{sq}$ . In comparison, the surface resistivity of the relatively short bristles 52 is preferably higher than  $1 \times 10^{12}$   $\Omega/\text{sq}$ . The relatively long bristles 54 may be formed from electrically conductive material. The bristles may be formed from metallic, graphite, conductive acrylic or other composite material, but in this example the relatively long bristles 54 comprise carbon fibre bristles. The diameter of each bristle 54 is preferably in the range from 5 to 20  $\mu\text{m}$ .

**[0031]** The body 50 comprises a plurality of angularly spaced, continuous rows of the relatively long bristles 54, which preferably also extend helically along the body 50. In this embodiment the body 50 comprises four continuous rows of the relatively long bristles 54, with each row being angularly spaced from a row of tufts 53 formed from the relatively short bristles 52. Each row of the relatively long bristles 54 preferably contains in the range from 20 to 100 bristles per mm length, and has a thickness in the range from 0.25 to 2 mm.

**[0032]** With particular reference to Figure 4, in this embodiment adjacent rows of the relatively long bristles 54 are formed from a single strip 56 of bristles. Each strip 56 is preferably formed by attaching an elongate, generally rectangular flexible carrier member to a row of bristles so that each row of bristles 54 protrudes outwardly from a respective long side edge of the carrier member. The carrier member may be attached to the row of bristles by stitching or by using an adhesive. Each strip 56 is then located within a respective helical groove 58 formed in the body 50 so that the ends of the bristles protrude outwardly from the body 50. The strips 56 are connected to the body 50 by helical connectors 60 which are mounted on the strips 56 and connected to the body 50 using screws 62 into apertures formed in the connectors 60. The screws 62 may be pushed through the carrier member, or inserted through apertures formed in the carrier member. An adhesive tape may be applied to at least one side of each carrier member to allow the strips 56 to be aligned within the grooves 58 so that the ends of the bristles protrude from the body 50 by a regular amount along the length of the body 50.

**[0033]** With reference to Figure 7, when the cleaner head 12 is located on a carpeted floor surface 64 the support members 24 sink into the pile of the carpet so that the bottom surface of the sole plate 18 engages the

fibres of the carpet. As both the relatively short bristles 52 and the relatively long bristles 54 protrude from the suction opening 20 as the brush bar 40 rotates, both the different types of bristles are able to agitate dirt and dust from the floor surface. When an air flow is generated through the suction passage of the cleaner head 12, this dirt and dust becomes entrained within the air flow and is conveyed through the floor tool 10 to the cleaning appliance.

**[0034]** When the cleaner head 12 is moved from the carpeted floor surface 64 on to a hard floor surface 66, as illustrated in Figure 8, the sole plate 18 becomes spaced from the hard floor surface 66. As the tips of the relatively short bristles 52 do not protrude beneath the plane extending between the lowermost extremities of the support members 24, these bristles do not come into contact with the hard floor surface 66, thereby preventing scratching or other marking of the hard floor surface 66 by these bristles. However, as the relatively long bristles 54 protrude beyond this plane, these bristles engage, and are swept across, the hard floor surface 66 with rotation of the brush bar 40. Due to the relatively low surface resistivity of the relatively long bristles 54, any static electricity residing on the hard floor surface 66 is discharged upon contact with the relatively long bristles 54, thereby enabling fine dust and powder which would otherwise be attracted to the hard floor surface 66 to be dislodged from the floor surface by these bristles and entrained within the air flow.

**[0035]** The invention is not limited to the detailed description given above. Variations will be apparent to the person skilled in the art.

**[0036]** For example, in the embodiment described above, the cleaner head 12 includes a brush bar 40 that is driven by a motor. However, the cleaner head 12 may include alternative means for agitating or otherwise working a surface to be cleaned. By way of example, the brush bar 40 may be driven by an air turbine rather than a motor.

**[0037]** The relatively short bristles 52 may be formed from similar material as the relatively long bristles 54 in order to discharge any static material residing on a carpeted floor surface, and so may also have a surface resistivity in the range from  $1 \times 10^{-5}$  to  $1 \times 10^{12} \Omega/\text{sq}$ .

**[0038]** Each strip 56 may be modified so that the bristles protrude from only one of the relatively long side edges of the carrier member. Thus, each strip 56 may be in the form of a brush, with bristles extending outwardly from only one side of the brush. A modified version of the brush bar 40', in which each strip 56 has been modified as discussed above, is illustrated in Figure 9. This modification of the strips 56 results in the bristles 54 protruding outwardly from one side only of each connecting member 60. Consequently, this brush bar 40' contains only two continuous rows of relatively long bristles 54, with the rows of tufts 53 and the rows of relatively long bristles 54 being alternately arranged about the body 50 of the brush bar 40'. As with the brush bar 40, the relatively long bristles 54 protrude radially outwardly from the

body 50 beyond the relatively short bristles 52.

**[0039]** The different types of bristles 52, 54 need not be spaced apart. The brush bar 40 may comprise a plurality of rows, clumps or tufts of bristles, with each row, clump or tuft comprising both types of bristles. For example, relatively short bristles 52 may be dispersed within each row of relatively long bristles 54. Alternatively, relatively long bristles 54 may be dispersed within each tuft 53 of relatively short bristles 52.

**[0040]** The agitating means may take forms other than bristles, such as flexible or rigid strips of material mounted on the body 50, or filaments sewn into a backing material connected to the body 50.

**[0041]** In the event that the floor tool 10 is not to be used on a carpeted surface, the relatively short bristles 52 may be dispensed with so that the brush bar 40 comprises only electrically conductive agitating members. Consequently, the brush bar 40 may comprise solely the continuous rows of surface agitating members defined by the relatively long bristles 54 illustrated in Figures 2 to 8. Alternatively, the brush bar 40 may comprise a different arrangement of surface agitating members for discharging static electricity residing on a floor surface.

**[0042]** For example, with reference to Figure 10 an alternative brush bar 80 for use in the floor tool 10 comprises a rotatable body 82 having an outer surface comprising an electrically conductive pile 84. In this example, the pile 84 is similar to the raised or fluffy surface of a carpet, rug or cloth, and comprises filaments woven on to a fabric carrier member 86 attached to the body 82, for example using an adhesive. The length of the filaments of the pile 84 is preferably in the range from 4 to 15 mm, and the filaments have a diameter which is preferably in the range from 5 to 20  $\mu\text{m}$ .

**[0043]** These filaments are preferably formed from carbon fibres, but alternatively they may be formed from metallic material, conductive acrylic material or other composite material. Consequently, the surface resistivity of the filaments of the pile 84 is preferably in the range from  $1 \times 10^{-5}$  to  $1 \times 10^{12} \Omega/\text{sq}$ . The fabric carrier member 86 may be in the form of a strip wound on to the body 82 so that the pile 84 is substantially continuous, substantially covering the outer surface of the body 82. Alternatively, the carrier member 86 may be in the form of a cylindrical sleeve into which the body 82 is inserted.

**[0044]** If so desired, clumps of relatively stiff bristles may be dispersed within the pile 84. Alternatively, a strip of the pile 84 may be wound around one or more helical rows of relatively stiff bristles previously attached to the body 82. These bristles may be similar to the relatively short bristles 52 of the brush bar 40, and so may be arranged so as to not protrude radially outwardly beyond the filaments of the pile 84.

## Claims

1. Agitating apparatus for a surface treating appliance,

comprising a rotatable body (82) having an outer surface which is substantially covered with filaments (84), **characterised in that** the filaments (84) have a surface resistivity in the range from  $1 \times 10^{-5}$  to  $1 \times 10^{12} \Omega/\text{sq}$ , the filaments being woven on to a flexible carrier member (86) covering the outer surface of the body (82).

2. Apparatus as claimed in claim 1, wherein the filaments (84) are formed from one of metallic, carbon fibre, conductive acrylic and composite material.
3. Apparatus as claimed in claim 1 or claim 2, wherein the carrier member (86) is wound about the body (82).
4. Apparatus as claimed in claim 3, wherein the carrier member (86) is adhered to the body (82).
5. Apparatus as claimed in any of the preceding claims, wherein the body (82) is substantially cylindrical.
6. Apparatus as claimed in any of the preceding claims, wherein the filaments (84) have a diameter in the range from 5 to 20  $\mu\text{m}$ .
7. Apparatus as claimed in any of the preceding claims, wherein the length of the filaments (84) is in the range from 4 to 10 mm.
8. Apparatus as claimed in any of the preceding claims, in the form of a rotatable brush bar (80).
9. A cleaner head for a surface treating appliance comprising an apparatus as claimed in any of the preceding claims.

#### Patentansprüche

1. Aufbürstvorrichtung für eine Vorrichtung zur Oberflächenbehandlung, die einen drehbaren Körper (82) aufweist, der eine Außenfläche hat, die im Wesentlichen mit Filamenten (84) bedeckt ist, **dadurch gekennzeichnet, dass** die Filamente (84) einen Oberflächenwiderstand im Bereich von  $1 \times 10^5$  bis  $1 \times 10^{12} \Omega/\text{cm}^2$  haben, wobei die Filamente an ein flexibles, die Außenfläche des Körpers (82) bedeckendes Trägerelement (86) gewebt sind.
2. Vorrichtung nach Anspruch 1, wobei die Filamente (84) aus einem der Folgenden hergestellt sind: metallisches, Kohlenstofffaser-, leitfähiges Acryl- und Verbundstoffmaterial.
3. Vorrichtung nach Anspruch 1 oder Anspruch 2, wobei das Trägerelement (86) um den Körper (82) gewickelt ist.

4. Vorrichtung nach Anspruch 3, wobei das Trägerelement (86) am Körper (82) angehaftet ist.
5. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei der Körper (82) im Wesentlichen zylindrisch ist.
6. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Filamente (84) einen Durchmesser im Bereich von 5 bis 20  $\mu\text{m}$  haben.
7. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Länge der Filamente (84) im Bereich von 4 bis 10 mm beträgt.
8. Vorrichtung nach einem der vorhergehenden Ansprüche in der Form einer drehbaren Bürstwalze (80).
9. Reinigungskopf für eine Vorrichtung zur Oberflächenbehandlung, die eine Vorrichtung nach einem der vorhergehenden Ansprüche aufweist.

#### Revendications

1. Appareil d'agitation pour un appareil de traitement de surface, comprenant un corps pivotable (82) ayant une surface externe qui est substantiellement couverte de filaments (84), **caractérisé en ce que** les filaments (84) ont une résistivité en surface de l'ordre de  $1 \times 10^{-5}$  à  $1 \times 10^{12} \Omega/\text{au carré}$ , les filaments étant tissés sur un élément porteur flexible (86) recouvrant la surface externe du corps (82).
2. Appareil tel que revendiqué à la revendication 1, où les filaments (84) sont formés à partir de l'un d'un matériau métallique, à fibres de carbone, acrylique conducteur et composite.
3. Appareil tel que revendiqué à la revendication 1 ou revendication 2, où l'élément porteur (86) est enroulé autour du corps (82).
4. Appareil tel que revendiqué à la revendication 3, où l'élément porteur (86) est collé sur le corps (82).
5. Appareil tel que revendiqué dans une quelconque des revendications précédentes, où le corps (82) est substantiellement cylindrique.
6. Appareil tel que revendiqué dans une quelconque des revendications précédentes, où les filaments (84) ont un diamètre de l'ordre de 5 à 20  $\mu\text{m}$ .
7. Appareil tel que revendiqué dans une quelconque des revendications précédentes, où la longueur des filaments (84) est de l'ordre de 4 à 10 mm.

8. Appareil tel que revendiqué dans une quelconque des revendications précédentes, sous la forme d'une barre à brosse pivotable (80).
9. Tête de nettoyage pour un appareil de traitement de surface comprenant un appareil tel que revendiqué dans une quelconque des revendications précédentes.

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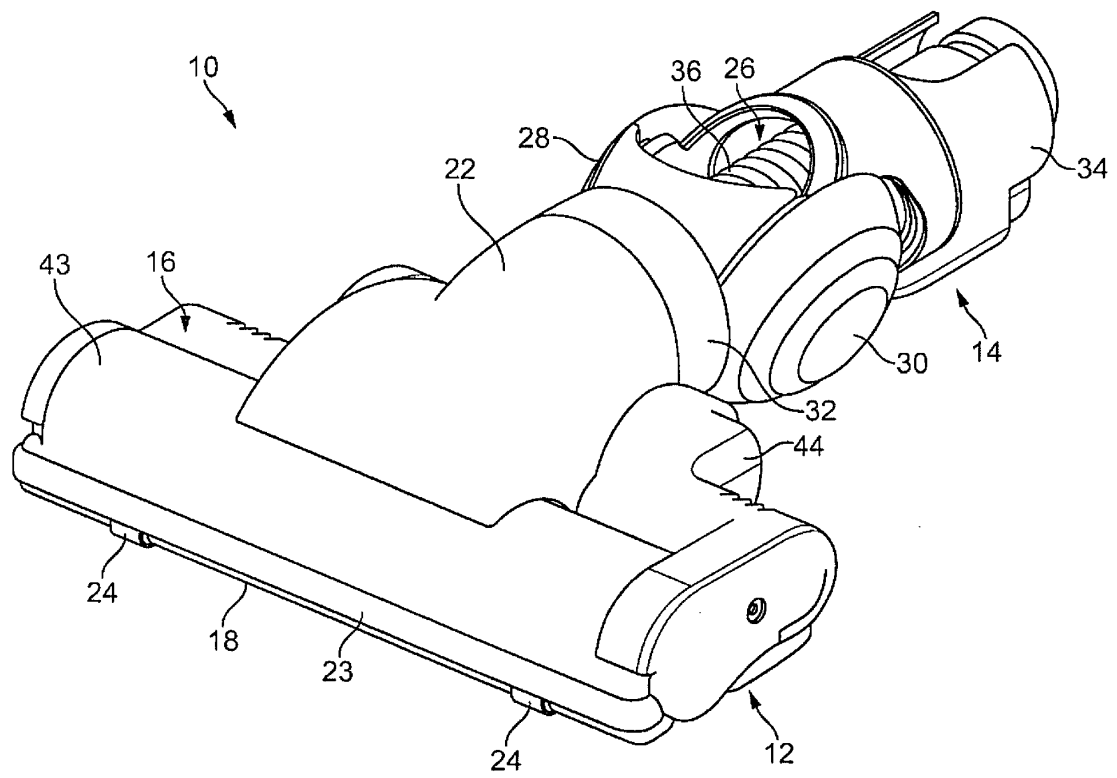


FIG. 1

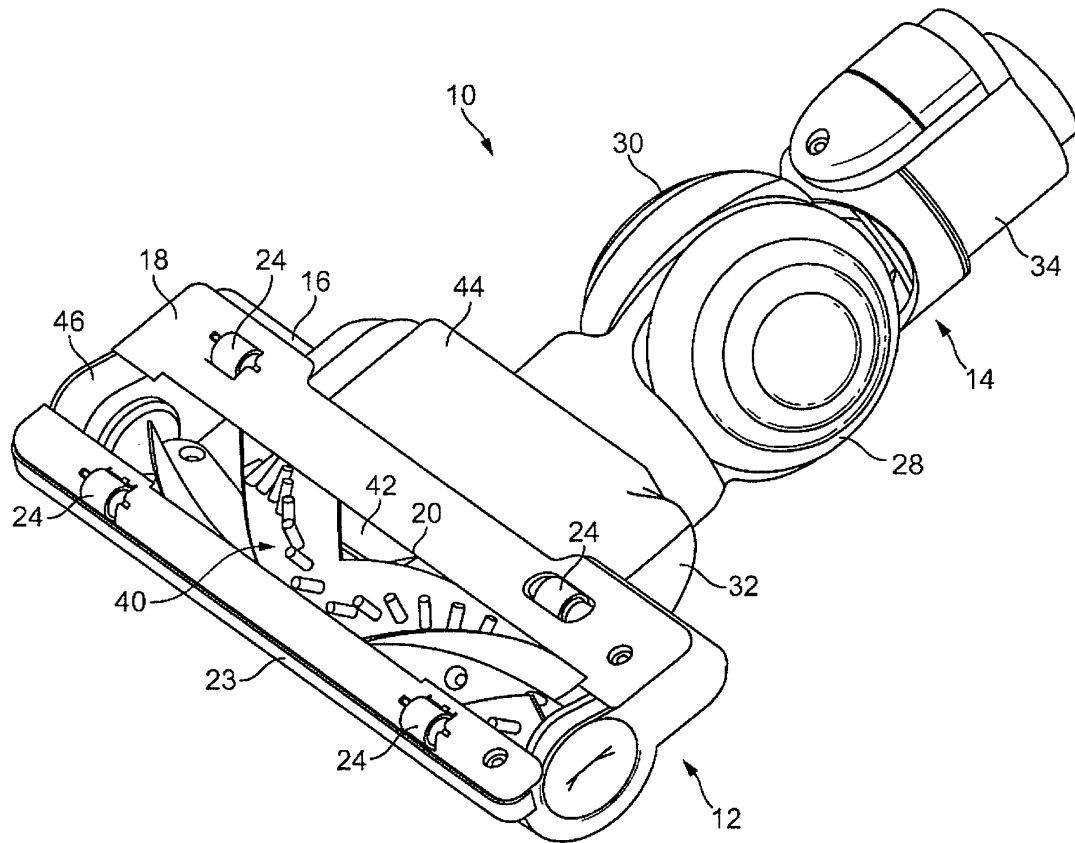


FIG. 2

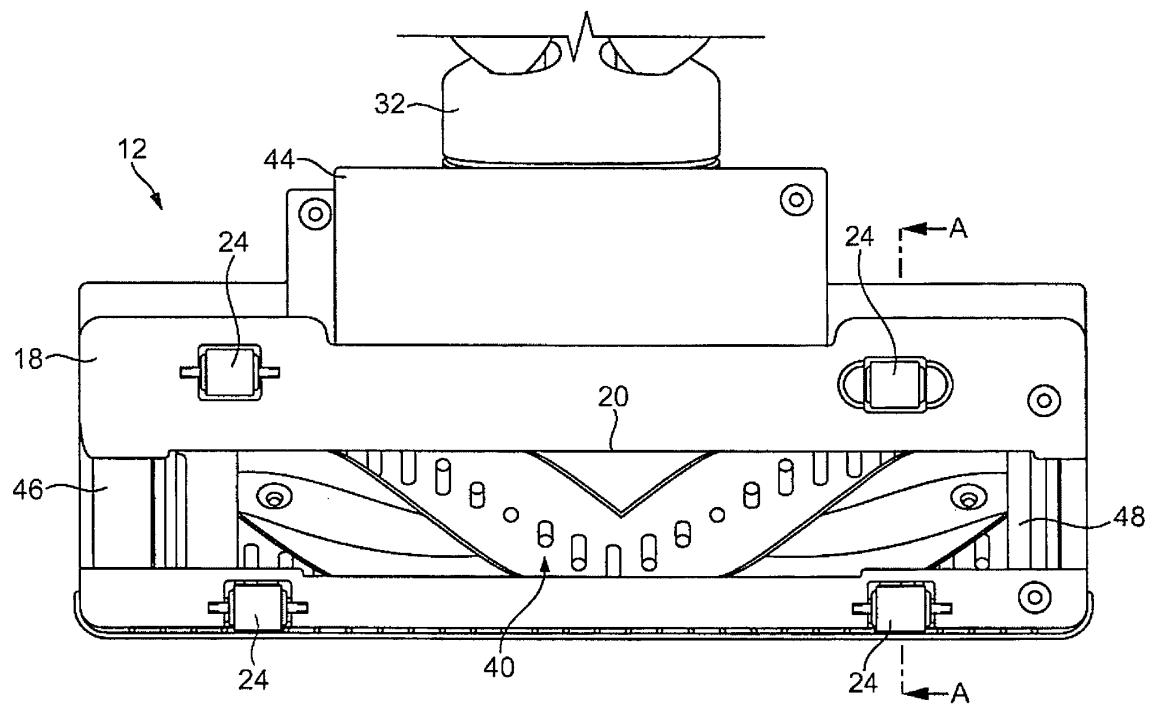


FIG. 3

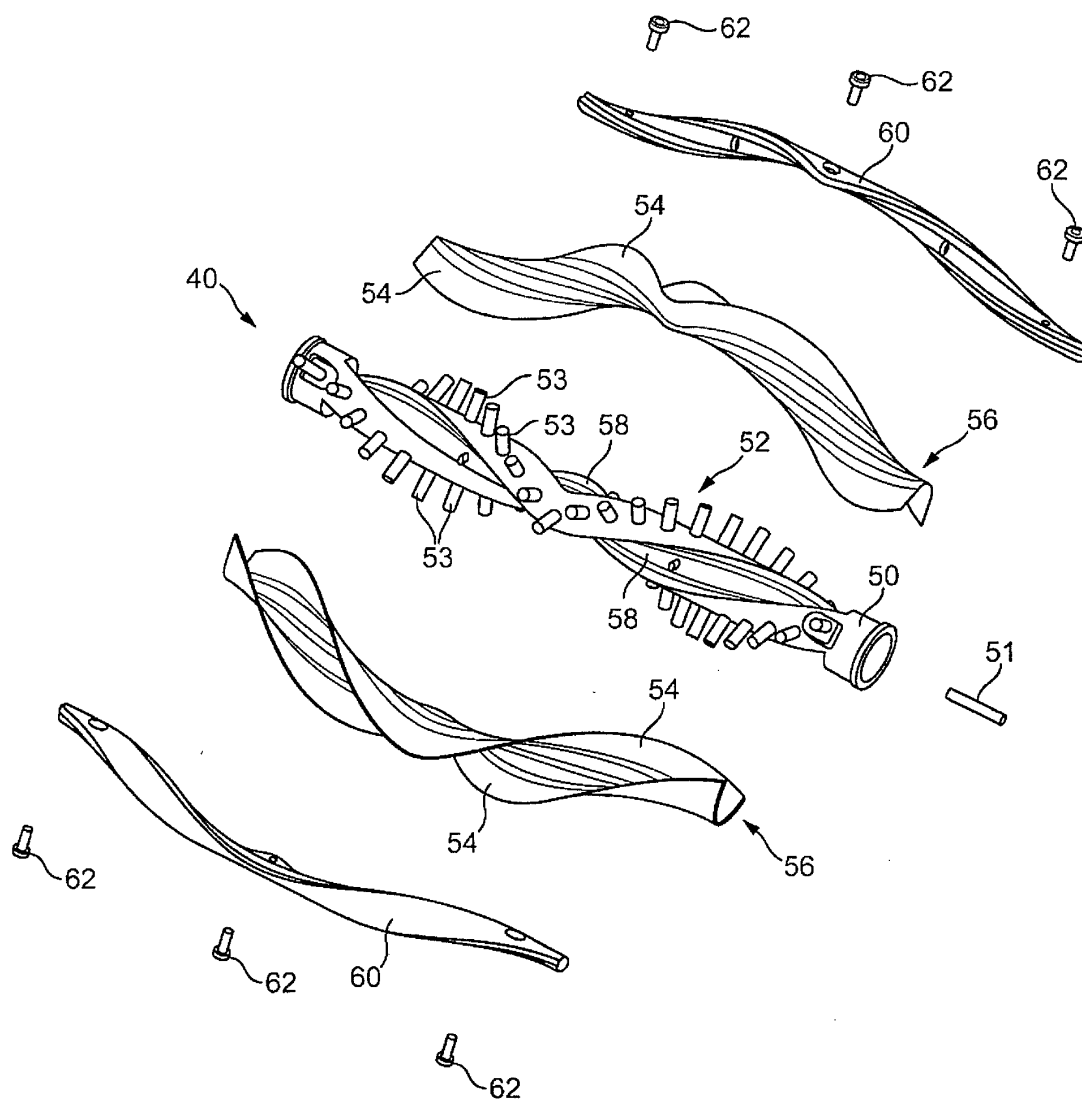
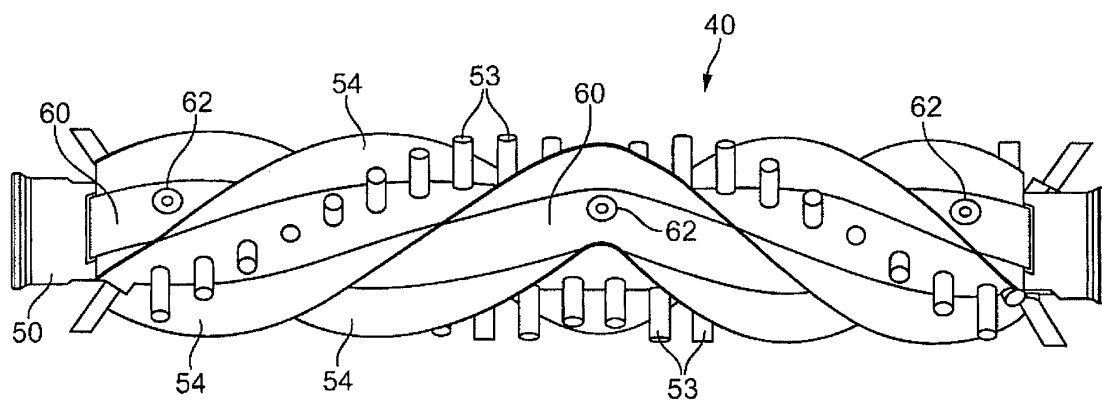
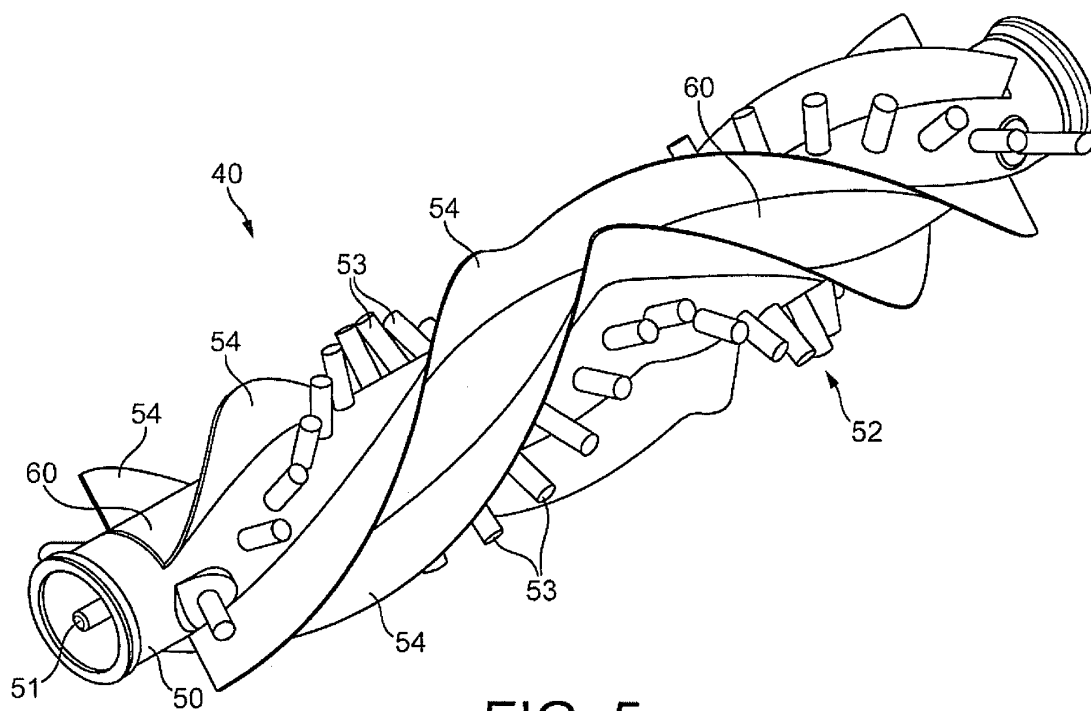


FIG. 4



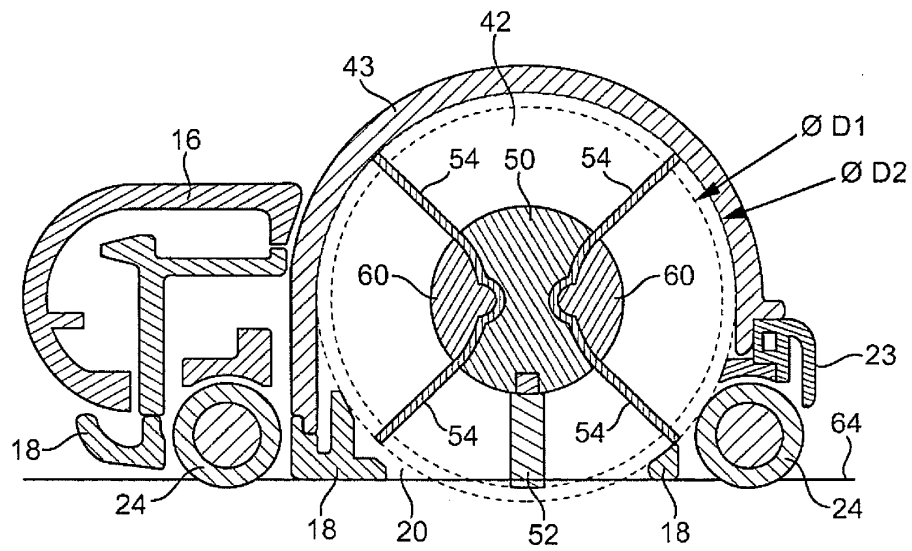


FIG. 7

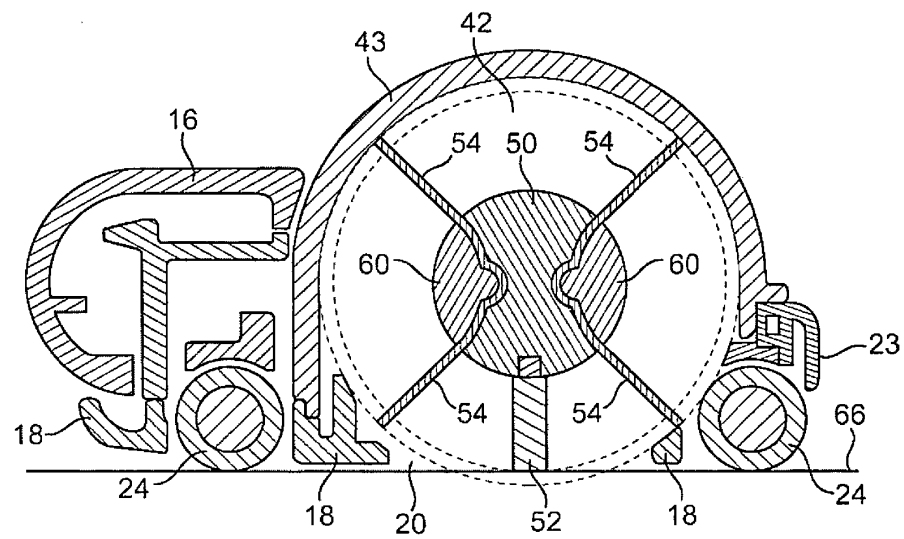


FIG. 8

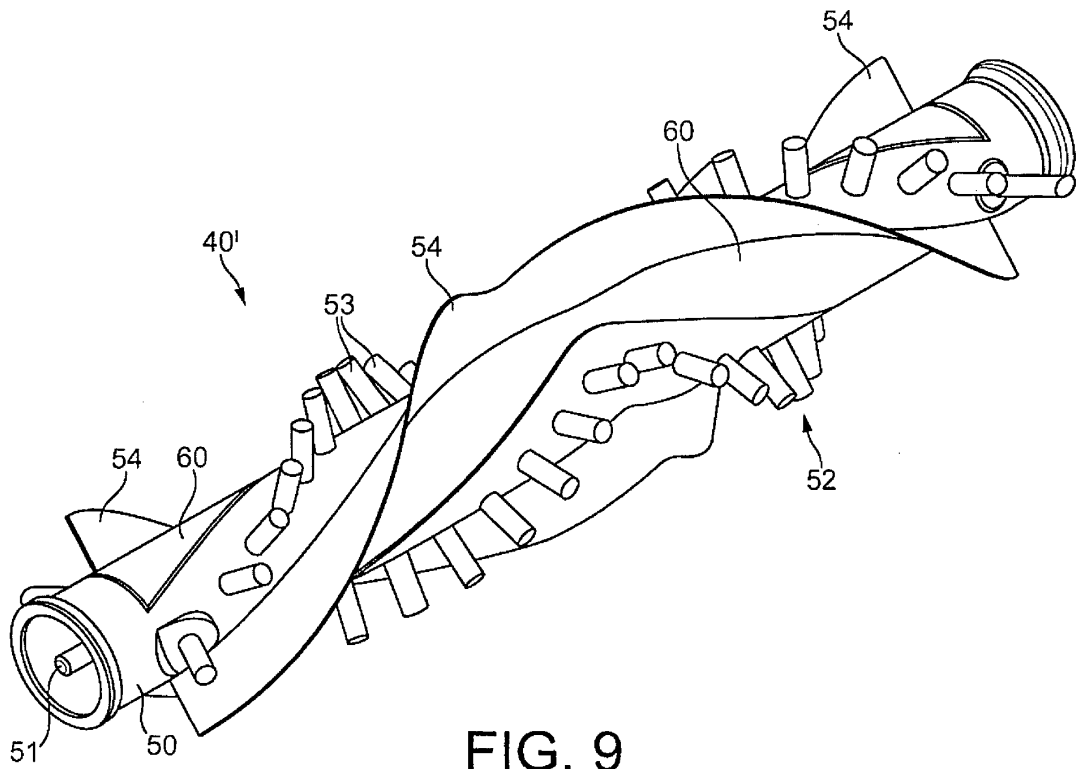


FIG. 9

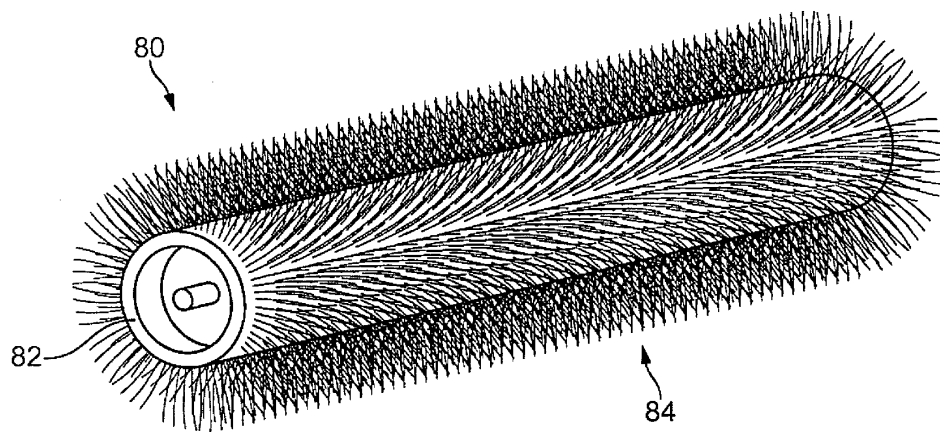


FIG. 10

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- GB 2425715 A [0006]