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

(11) EP 3 379 528 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
26.09.2018 Bulletin 2018/39

(21) Application number: **17162150.1**

(22) Date of filing: **21.03.2017**

(51) Int Cl.:
G10K 11/16 *(2006.01)*
A45D 20/12 *(2006.01)*
F24F 13/24 *(2006.01)*
F24H 3/04 *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(71) Applicant: **Koninklijke Philips N.V.**
5656 AE Eindhoven (NL)

(72) Inventor: **van den Bosch, Michael**
5656 AE Eindhoven (NL)

(74) Representative: **Steenbeek, Leonardus Johannes et al**
Philips Intellectual Property & Standards
High Tech Campus 5
5656 AE Eindhoven (NL)

(54) **FLUID CONDUIT**

(57) A fluid conduit having a rigid fluid conduit wall (H) provided with a plurality of acoustically transparent openings (O) that prevent fluid from passing through the openings. The acoustically transparent openings (O) may cover at least 6 % of a surface of the rigid fluid conduit wall (H). The acoustically transparent openings (O) may be substantially evenly distributed over the rigid fluid conduit wall (H). A diameter of the acoustically transparent openings (O) may be between 5 and 35 mm, and preferably about 10 mm. For an optimal acoustic transparency of the acoustically transparent film compared to the rigid fluid conduit wall (H), a coincidence frequency of the acoustically transparent openings (O) is at least 5 times a coincidence frequency of a remainder of the rigid fluid conduit wall (H). The acoustically transparent openings (O) may be formed by perforations, in which case the rigid fluid conduit wall (H) is further provided with an acoustically transparent film to prevent the fluid from passing through the perforations in the rigid fluid conduit wall (H). The rigid fluid conduit wall (H) may be covered by an acoustically transparent protective cover. The fluid conduit may be used in a fluid pump device, further comprising a fluid pump. The fluid pump may have a perforated fluid pump housing covered by the acoustically transparent film.

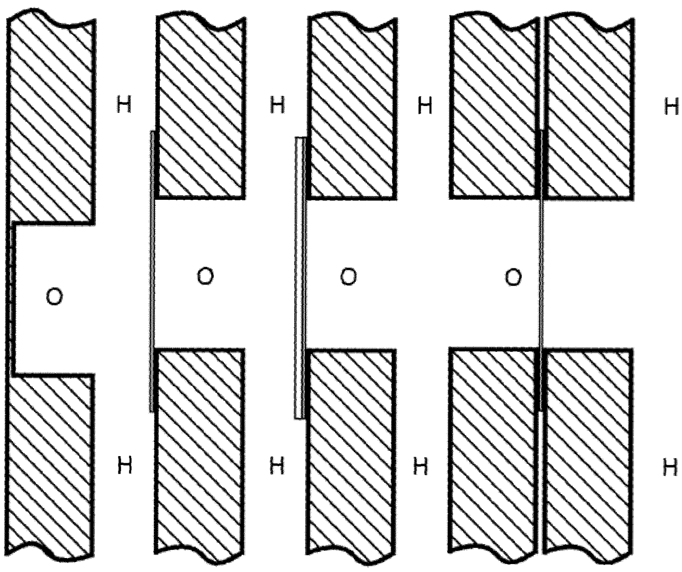

Fig. 5

Printed by Jouve, 75001 PARIS (FR)

Description

FIELD OF THE INVENTION

[0001] The invention relates to a fluid conduit, such as present in a domestic or personal care appliance having a fan to pump air or a pump to move a liquid like water.

BACKGROUND OF THE INVENTION

[0002] Many household appliances use a motor with a fan or a pump in order to displace a fluids like air or water for its primary function. To hold the motor or pump in place, it is mounted in a device housing. Due to moving components, magnetic forces, etc., the motor or pump generates vibrations. These vibration forces are transmitted, sometimes via a suspension system, towards the housing or housing component of the device, which radiates it as tonal noise. This is often unpleasant for the user and needs to be prevented. In acoustics, this way of generating noise is referred to as so called "structure born noise".

[0003] In general, methods to reduce the structure born noise include reducing vibration levels at the source, reducing transmission of the forces towards housing parts (via a suspension system), reducing the surface area of the housing it is connected to, etc.. In most cases, this is sufficient.

[0004] However, there are cases where the above mentioned methods are not sufficient and/or possible. One such an example is where the housing or housing parts are also used as a conduit for a fluid.

[0005] To prevent panels from radiating noise, it is known to perforate their surface, so the pressure waves can be equalized through the plate rather than going around the plate. The problem with this method is that if a housing is used as a conduit, perforating the housing would change the fluid flow (direction, leakage, etc.). This influences the primary function of the device, which obviously is undesired.

SUMMARY OF THE INVENTION

[0006] It is, inter alia, an object of the invention to provide an improved fluid conduit. The invention is defined by the independent claims. Advantageous embodiments are defined in the dependent claims.

[0007] One aspect of the invention provides perforated panels / housing parts to reduce radiated noise by the appliance while maintaining the conduit function for fluid flow. The invention provides a generic method of reducing structure born noise in devices with displace fluids (could be air, water or other fluids) where vibrations are transmitted to the conduit wall which then radiates structure born noise, like hair dryers, mini-vacs, vacuum cleaners, hair styling devices with a fan, attachments for hair care devices, air cleaners, air purifiers, air humidifiers, coffee machines, kitchen appliances, respiratory support devices, breast pumps, and many other devices where structure born noise is normally present.

[0008] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

Fig. 1 shows an embodiment of a perforated fluid conduit in accordance with the invention.
Fig. 2 shows alternative layouts of a perforated fluid conduit in accordance with the invention.
Fig. 3 shows an embodiment of a hair dryer housing having an air conduit perforated in accordance with the invention.
Fig. 4 shows an embodiment of a motor housing perforated in accordance with the invention.
Fig. 5 illustrates various embodiments of acoustically transparent openings in a rigid fluid conduit wall.

DESCRIPTION OF EMBODIMENTS

[0010] Conduits used as a device housing are commonly constructed from rigid components (e.g. standard pipes, ducts, etc.) that have large surface areas that easily radiate structure born sound. Conduits made of flexible materials that do not easily radiate structure born sound, such as flexible ventilation tubes, do not provide sufficient rigidity in order to be used as a device housing.

[0011] From an acoustics standpoint, a perforated plate (especially a wire mesh) cannot easily radiate structure born noise since the "acoustically closed" surface area is very small. This is especially true for very open perforated plates in combination with low vibration frequencies because the normally generated pressure wave at one side of the plate is equalized through the perforations. Example of such "acoustically open" perforated plates can be found in front of speaker cones and ventilation openings.

[0012] It would be ideal to use an acoustically open perforated plate as a conduit, but due to its perforations a perforated plate cannot function as a fluid conduit as it does not block the fluid flow (e.g. air, water) through the plate.

[0013] Aspects of the invention thus provide a conduit wall that is acoustically open while closed for fluids, but still sufficiently strong to be used as a device housing or housing component, in order to reduce structure born sound compared to a standard conduit housing. This could be done by a perforated fluid conduit wall to ensure that there is no acoustically closed surface area, which conduit wall is covered with a thin material (e.g. a film) to keep the fluid inside the conduit. This thin material may be at the inside or at the outside of the fluid conduit wall. This thin material should be acoustically transparent. In certain embodiments / circumstances (depending on frequency), a suitable film material appeared to be 3M Kapton tape/foil. The thickness of the film preferably does not exceed 0.1 mm.

[0014] In this way, it is not necessary to use relatively expensive vibration reducing methods (mechanical balancing of components, balancing vibration forces, suspension systems, damping of housing vibrations, box in box constructions, etc.) to reduce structure born noise. Nevertheless, the problem of structure born noise radiation by the conduit wall and/or other housing parts is solved, as is an unpleasant tonal noise regarding sound perception for many devices.

[0015] Embodiments of the invention may provide:

1. A perforated fluid conduit wall (or section thereof) where the perforations are covered with an acoustically transparent material (generally a thin sheet). This might also be achieved by creating indentations in the wall.
2. A fluid conduit wall where the remaining wall size between perforations is similar or smaller in size than the wavelength of the frequencies of the structure born noise that need to be reduced. This is for optimal noise reduction.
3. A fluid conduit wall that is perforated at locations where the amplitude of the vibration mode-shape(s) of the wall are highest. This is for optimal noise reduction.
4. A perforation shape which allows the amplitude of the vibration mode-shape(s) of the acoustically transparent material to match with the structure born noise frequencies to be reduced. This is for optimal acoustic transparency.

[0016] Fig. 1 shows an embodiment of a rigid fluid conduit wall, e.g. a fluid pump device housing H in accordance with the invention, provided with a plurality of acoustically transparent openings O. Such a housing H can be used in a fluid pump device, comprising a fluid pump, and a fluid pump device housing H, wherein the fluid pump device housing H is provided with a plurality of acoustically transparent openings O that prevent fluid from passing through the acoustically transparent openings O.

[0017] Fig. 2 shows alternative layouts of a perforated fluid conduit in accordance with the invention. Fig. 3 shows an embodiment of a hair dryer housing having an air conduit perforated in accordance with the invention. Fig. 4 shows an embodiment of a motor housing perforated in accordance with the invention, indicating the dimensions of the openings. This motor could be the fan motor of a vacuum cleaner. As appears from Figs. 2-4, the openings O do not need to be circles; other shapes like rectangles, triangles, special shapes, etc. are alternatively possible, and the openings O do not need to be all of the same size and shape. The openings O do not need to cover the entire surface either.

[0018] Fig. 5 illustrates various embodiments of acoustically transparent openings O in a rigid fluid conduit wall H. From left to right, the openings O are formed by indentations in the rigid fluid conduit wall H, by a perforation covered by a single layer of an acoustically transparent film, by a perforation covered by multiple layers of an acoustically transparent film, and by one (or more) layers of an acoustically transparent film clamped between two layers of the rigid fluid conduit wall H.

[0019] Preferably, the acoustically transparent openings O cover at least 6%, and preferably about 25% (i.e. between 20 and 30%) of a surface of the fluid pump device housing H. When the openings O cover only 1%, the plate provides 10 dB isolation, thus no significant amount of noise energy would go through the plate, so that most noise energy is still available to generate structural noise. When the openings O cover 6%, the plate provides about 3 dB isolation, i.e. a reduction by 50%, which is a useful effect. When the openings cover 25%, the plate provides about 0.2 dB isolation, i.e. the plate is about fully acoustically transparent.

[0020] Preferably, the acoustically transparent openings O are substantially evenly distributed over the fluid pump device housing H. Preferably, a diameter of the acoustically transparent opening (O) is larger than $1/10^{th}$ of a thickness of the rigid conduit wall (H), preferably between 1 and 10 times the thickness of the rigid conduit wall (H). This way, the dimensions of the perforations automatically scale correctly with the conduit wall thickness, which is often also frequency dependent. Alternatively, a diameter of the acoustically transparent openings O is between 5 and 35 mm, and preferably about 10 mm.

[0021] The acoustically transparent openings O may be formed by indentations in the housing H, i.e. the thickness of the housing H is relatively thin at the acoustically transparent openings O, preferably not thicker than 0.1 mm. Because the indentations are not real openings but merely acoustically open in view of the reduced thickness, the conduit is still able to contain the fluid.

[0022] In an advantageous implementation, the acoustically transparent openings O are formed by perforations, and in that case the fluid pump device further comprises an acoustically transparent layer (e.g. a film) to prevent the fluid from passing through the perforations in the fluid pump device housing H.

[0023] Preferably, the fluid pump device housing is covered by an acoustically transparent protective cover that makes the openings O less visible so that from the outside, the housing surface is not replete with holes, and external items are prevented from too easily entering the inside of the housing H through the openings O. This protective cover could be a fabric, for example of the same kind that is known from covering the front of loudspeakers. This protective cover does not need to be suitable to keep the fluid inside the fluid conduit; it just prevents external items from entering the inside of the housing H and/or damaging the film.

[0024] To ensure that not only the housing H itself but also inside components of the fluid pump device are such as to minimize structure born noise, preferably the fluid pump has a perforated fluid pump housing covered by an acoustically transparent layer.

[0025] To further reduce the radiated noise, the acoustically transparent thin sheet can be made of a material with internal vibration damping (like rubber of the type used for balloons, or other material with viscoelastic properties). This might be very useful when it is difficult to create or apply a sufficiently thin and sufficiently flexible sheet. In other words, acoustic transparency of the thin sheet can be improved by using vibration damping in the sheet. There are several ways to achieve this vibration damping in the sheet. Some examples are:

- Compound damping = friction between two stacked thin sheets (thus placed on top of each other), preferably with different thicknesses
- Viscoelastic damping = internal vibration converted to heat due to internal deformation, etc. (like a balloon)

[0026] Depending on the rigidity of the film and operating conditions (e.g. very thin film, large perforations and high pressure differences in fluid conduit), it might be required to provide additional supporting means for the thin acoustically transparent film, such as a web structure or a sublayer having openings smaller than the acoustically transparent openings O in the housing H.

[0027] The acoustic transparency of the acoustically transparent film and the acoustic transparency of the fluid conduit wall depend not only on the material properties, layer/wall thicknesses and wall perforation size, but also strongly on the frequency of the vibrations / noise. In acoustics (regarding transmission through plates), there is a frequency at which the flexural wave speed matches / coincides with the acoustic wave speed. This is called the coincidence frequency fc of a plate, which is defined as follows:

$$f_c = \frac{c^2}{2\pi d} \cdot \sqrt{\frac{12\,\rho\,(1 - \nu^2)}{E}}$$

in which

c = speed of sound in fluid (e.g. air)
d = thickness of the plate
E = modulus of elasticity of the plate
ρ = density of the plate
v = poisson ratio of the plate

with the plate being the fluid conduit wall or the acoustically transparent film.

[0028] The ability of a plate to radiate noise depends on this coincidence frequency fc: below this frequency fc, the mass is dominant while above this frequency fc, the bending stiffness is dominant. Since we would like the film to be acoustically transparent compared to the conduit wall, it seems logical that we define a minimum ratio r_fc = fc_film / fc_wall between the coincidence frequency fc_film of the acoustically transparent film and the coincidence frequency fc_wall of the fluid conduit wall. If the coincidence frequency ratio r_fc is at least 5, the fluid conduit wall isolates noise by about 10 dB better than the acoustically transparent film (at the above-mentioned 6% perforation of plate), meaning that the acoustically transparent film is effectively acoustically transparent compared to the fluid conduit wall. This way, all parameters will scale correctly, and acoustic transparency of the film with regard to the conduit wall is maintained. Note that this reasoning also applies if the acoustically transparent openings O are formed by thinner parts (e.g. indentations) of the rigid fluid conduit wall H instead of by perforations that are covered by a film.

[0029] Salient aspects of embodiments can be summarized as follows. A fluid conduit having a rigid fluid conduit wall

H provided with a plurality of acoustically transparent openings O that prevent fluid from passing through the openings. The acoustically transparent openings O may cover at least 6 % of a surface of the rigid fluid conduit wall H. The acoustically transparent openings O may be substantially evenly distributed over the rigid fluid conduit wall H. A diameter of the acoustically transparent openings O may be between 5 and 35 mm, and preferably about 10 mm. For an optimal acoustic transparency of the acoustically transparent film compared to the rigid fluid conduit wall H, a coincidence frequency of the acoustically transparent openings O is at least 5 times a coincidence frequency of a remainder of the rigid fluid conduit wall H. The acoustically transparent openings O may be formed by perforations, in which case the rigid fluid conduit wall H is further provided with an acoustically transparent film to prevent the fluid from passing through the perforations in the rigid fluid conduit wall H. The rigid fluid conduit wall H may be covered by an acoustically transparent protective cover. The fluid conduit may be used in a fluid pump device, further comprising a fluid pump. The fluid pump may have a perforated fluid pump housing covered by the acoustically transparent film.

[0030] It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. There is no need for the plurality of openings to all have the same shape and/or size. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" does not exclude the presence of elements or steps other than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. For example, the acoustically transparent layer may be composed of multiple layers. In the device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

Claims

1. A fluid conduit having a rigid fluid conduit wall (H) provided with a plurality of acoustically transparent openings (O) that prevent fluid from passing through the openings (O).

2. A fluid conduit as claimed in claim 1, wherein the acoustically transparent openings (O) cover at least 6%, and preferably about 25% of a surface of the rigid fluid conduit wall (H).

3. A fluid conduit as claimed in any of the preceding claims, wherein the acoustically transparent openings (O) are substantially evenly distributed over the rigid fluid conduit wall (H).

4. A fluid conduit as claimed in any of the preceding claims, wherein a diameter of the acoustically transparent opening (O) is larger than 1/10th of a thickness of the rigid fluid conduit wall (H), preferably between 1 and 10 times the thickness of the rigid fluid conduit wall (H).

5. A fluid conduit as claimed in any of the preceding claims, wherein a diameter of the acoustically transparent openings (O) is between 5 and 35 mm, and preferably about 10 mm.

6. A fluid conduit as claimed in any of the preceding claims, wherein a coincidence frequency of the acoustically transparent openings (O) is at least 5 times a coincidence frequency of a remainder of the rigid fluid conduit wall (H).

7. A fluid conduit as claimed in any of the preceding claims, wherein the acoustically transparent openings (O) are formed by perforations, and the rigid fluid conduit wall (H) is further provided with an acoustically transparent layer to prevent the fluid from passing through the perforations in the rigid fluid conduit wall (H).

8. A fluid conduit as claimed in claim 7, wherein the acoustically transparent layer is arranged to damp vibrations in the acoustically transparent layer.

9. A fluid conduit as claimed in claim 8, wherein the acoustically transparent layer is made of an elastic material.

10. A fluid conduit as claimed in claim 8, wherein the acoustically transparent layer comprises at least two layers of a mutually different material.

11. A fluid conduit as claimed in any of claims 7 - 10, wherein the rigid fluid conduit wall (H) is covered by an acoustically transparent protective cover.

12. A fluid pump device, comprising:

a fluid pump, and
a fluid pump device housing formed by a fluid conduit as claimed in any of the preceding claims.

13. A fluid pump device as claimed in claim 12, wherein the fluid pump has a perforated fluid pump housing covered by an acoustically transparent layer.

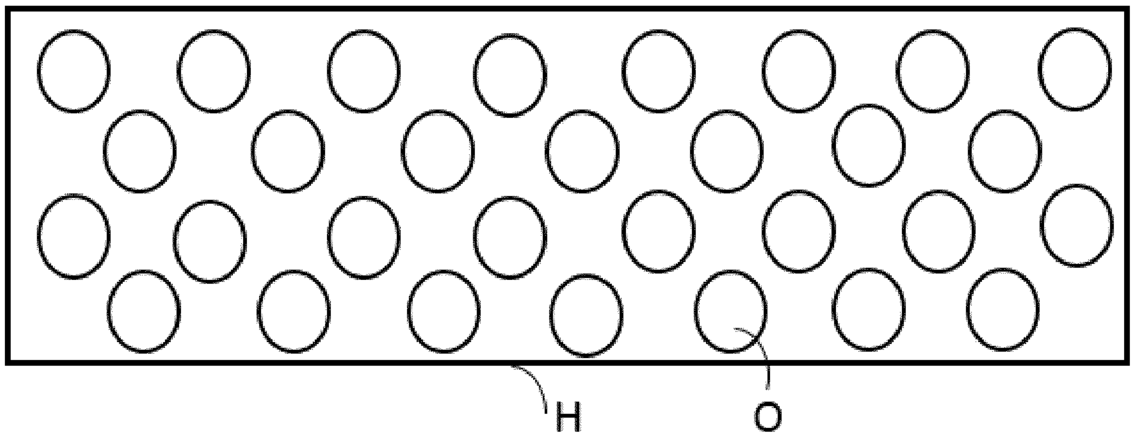

Fig. 1

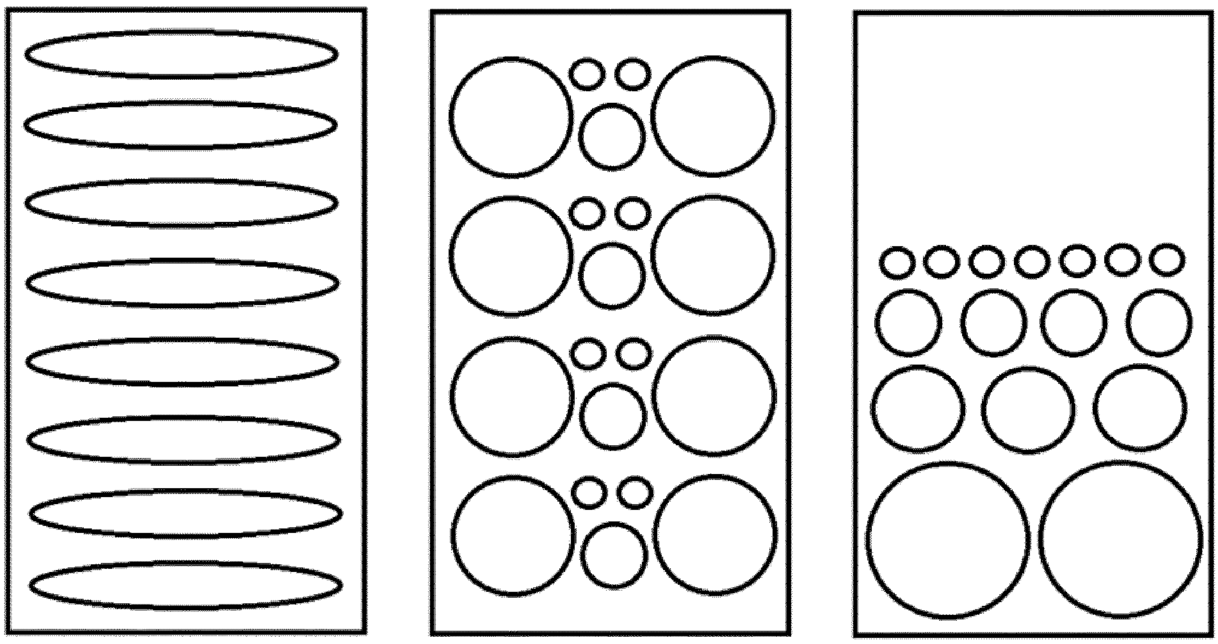

Fig. 2

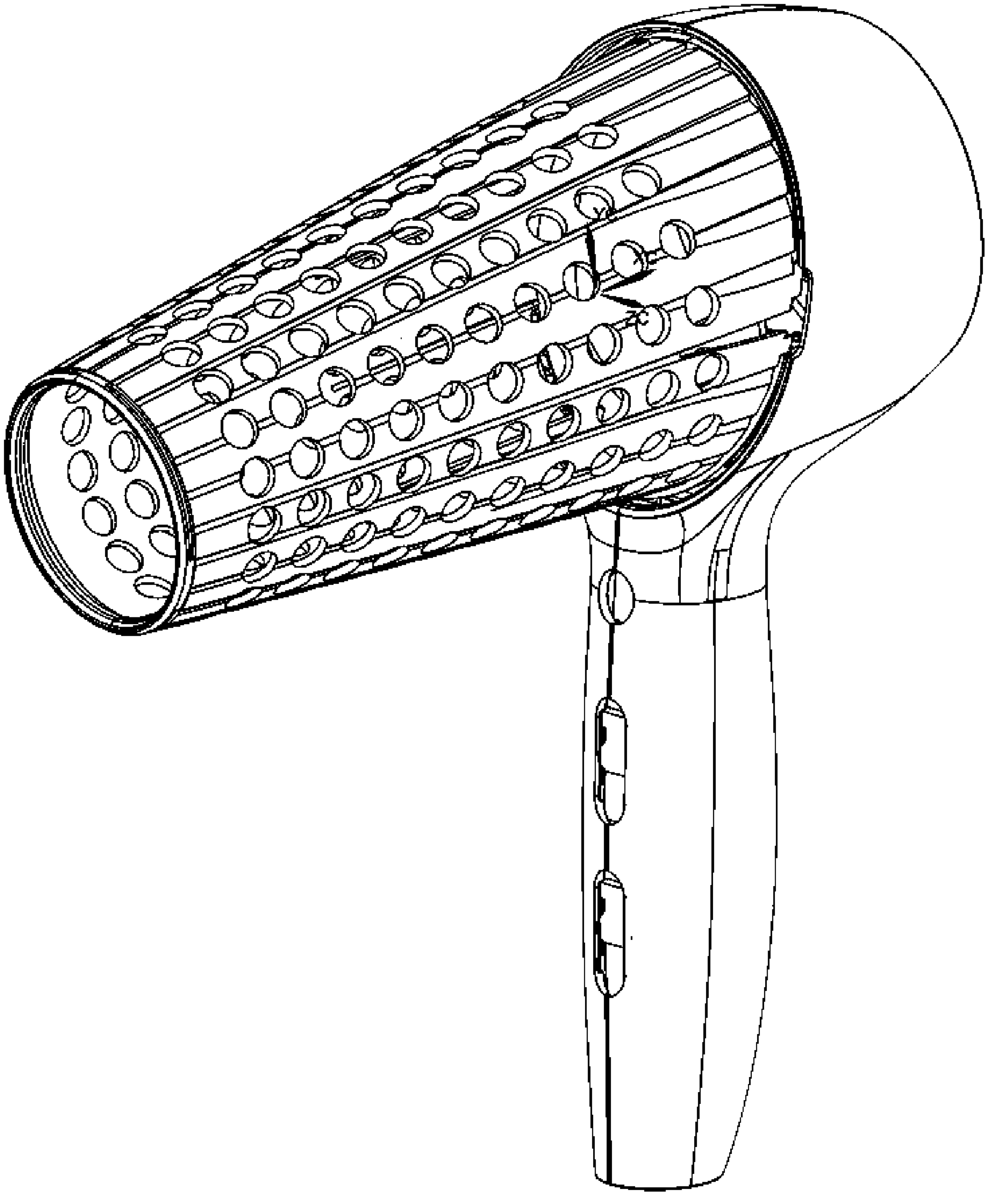

Fig. 3

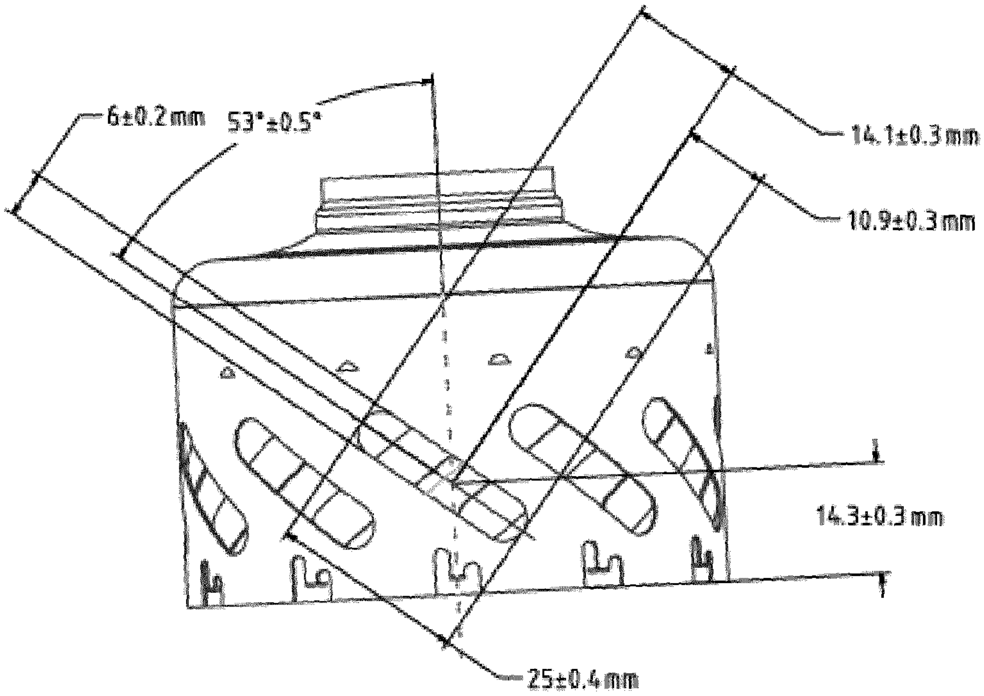

Fig. 4

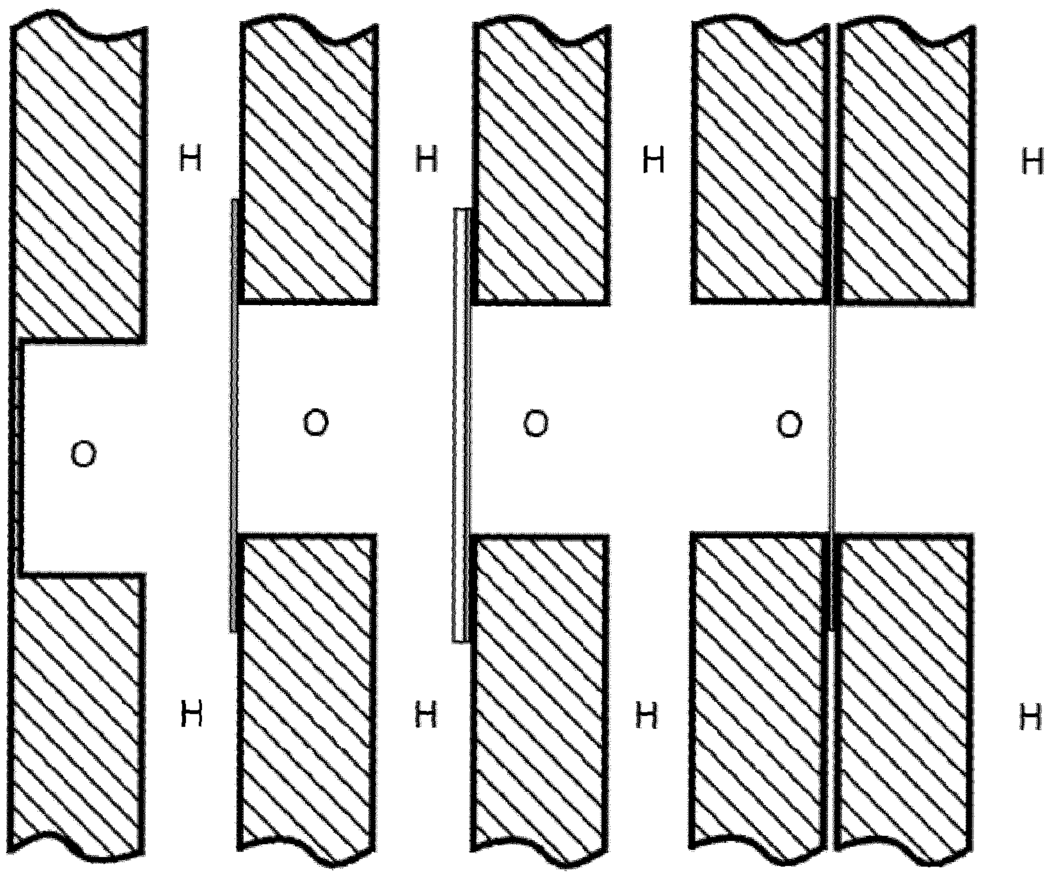

Fig. 5

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 16 2150

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2006/269077 A1 (BOLTON J S [US] ET AL) 30 November 2006 (2006-11-30) * abstract; figures 7,9 * * paragraphs [0044] - [0058], [0064] - [0070] *	1-13	INV. G10K11/16 A45D20/12 F24F13/24 F24H3/04
X	US 4 130 175 A (HEHMANN HORST W W) 19 December 1978 (1978-12-19) * abstract; figures 1,2 * * column 2, line 45 - column 3, line 58 *	1-3,7,9	
X	US 2011/284689 A1 (THOMAS CHRISTIAN [DE] ET AL) 24 November 2011 (2011-11-24) * abstract; figure 5 * * paragraphs [0086], [0136] - [0140] *	1,3,7, 10,12,13	
X	US 4 700 805 A (TANAKA HIDEHARU [JP] ET AL) 20 October 1987 (1987-10-20) * column 1, line 66 - column 2, line 18 * * column 3, line 59 - column 4, line 22 *	1-3,7,9	TECHNICAL FIELDS SEARCHED (IPC)
A	US 2009/283356 A1 (TSUGIHASHI KAZUKI [JP] ET AL) 19 November 2009 (2009-11-19) * abstract; figure 17 * * paragraphs [0096] - [0098], [0169] - [0171] *	1-13	G10K A45D F24F F24H F01N
A	US 2007/123159 A1 (VENKATAPPA SUHAS [US] ET AL) 31 May 2007 (2007-05-31) * abstract; figures 1,2 * * paragraphs [0023], [0024] *	1-13	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	24 August 2017	de Jong, Frank

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 16 2150

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-08-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006269077 A1	30-11-2006	CN 101198302 A	11-06-2008
		JP 4685932 B2	18-05-2011
		JP 2008541494 A	20-11-2008
		KR 20080012991 A	12-02-2008
		US 2006269077 A1	30-11-2006
		WO 2006127332 A2	30-11-2006
US 4130175 A	19-12-1978	NONE	
US 2011284689 A1	24-11-2011	CA 2746333 A1	24-06-2010
		CN 102256870 A	23-11-2011
		DE 102008062703 A1	01-07-2010
		EP 2358589 A1	24-08-2011
		US 2011284689 A1	24-11-2011
		WO 2010070071 A1	24-06-2010
US 4700805 A	20-10-1987	CA 1238583 A	28-06-1988
		DE 3571854 D1	31-08-1989
		EP 0176657 A1	09-04-1986
		JP H0250289 B2	01-11-1990
		JP S6176714 A	19-04-1986
		MX 162598 A	27-05-1991
		US 4610329 A	09-09-1986
		US 4700805 A	20-10-1987
US 2009283356 A1	19-11-2009	CN 101460993 A	17-06-2009
		US 2009283356 A1	19-11-2009
		WO 2008010554 A1	24-01-2008
US 2007123159 A1	31-05-2007	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82