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(54) **A ventilation device**

(57) A device is described for controlling the airflow through an airduct, the airduct having a housing, an inlet and an outlet. The device comprises a self-regulating valve having a diaphragm, the position of the diaphragm being determined by the difference between the pressure at the inlet and the pressure at the outlet. The diaphragm is rotatably suspended on a support so that, under influence of an increasing difference in pressure, the dia-

phragm can rotate between a minimum rotation angle and a maximum rotation angle over an intermediate rotation angle, the intermediate angle being situated between the minimum and maximum angle. The diaphragm is provided with a counterbalance and that, within the angle range between the intermediate rotation angle and the maximum rotation angle, the rotation movement of the diaphragm under influence of an increasing pressure difference is counteracted by an elastic resisting force.

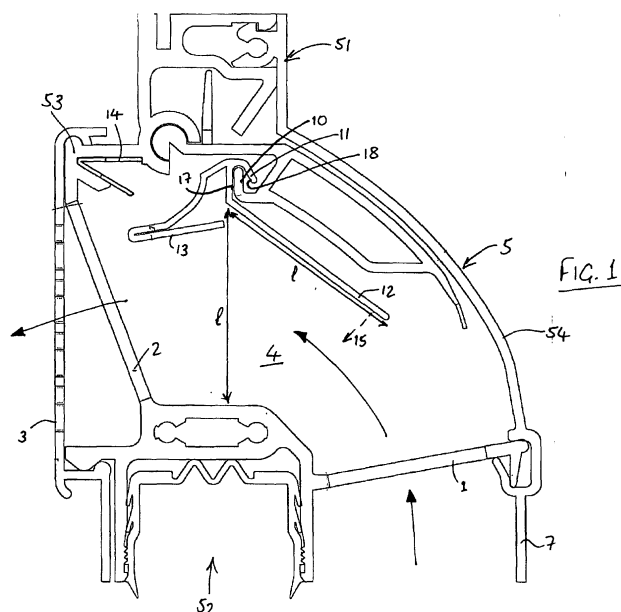


FIG. 1

Description

FIELD OF THE INVENTION

[0001] This invention relates to a ventilation device which can regulate airflow as well as to a method of controlling air flow through a ventilation device and to an insert for a ventilation device that provides control of the air flow.

BACKGROUND TO THE INVENTION

[0002] Ventilation devices are widely used in the walls and windows of buildings to allow fresh air to enter a building. In many countries, the use of a ventilator is recommended or mandatory. Standards can also define certain requirements for the performance of a ventilator. One such requirement defines the performance of the ventilator in terms of airflow rate versus pressure difference between the inlet and outlet of the device. Typically, there is a requirement for a constant, or a near constant, airflow rate across a range of pressure differences. This requirement will provide a user with a pleasing environment within a building, with a constant flow of air, regardless of weather conditions outside the building. One requirement is that the inflow of air should reach a limit as the incoming wind speed increases while maintaining good ventilation at low speeds. Hence, the flow characteristic of the valve should be non-linear and self-limiting.

[0003] A ventilation device typically comprises a housing which defines an airflow duct. A valve is positioned within the flow duct. The position of the valve can be controlled by a pressure monitor and an actuator (e.g. an electrical actuator or motor) or the valve can be self-regulating, without the use of an actuator. A self-regulating ventilation device is described in EP 1 568 947 B1. A valve is rotatably suspended about a suspension point in the air duct. The valve is arranged to move in the air duct. The valve firstly rotates to a maximum turning angle around the free suspension point, and then subsequently deforms, without further rotation about the free suspension point. Operation of this ventilation device relies on the flexibility of the valve, formed from plastic. However, as the properties of the valve part vary with temperature, the performance of this ventilation device can vary as temperature fluctuates.

[0004] It is desirable that a ventilation device has a good performance (e.g. offering near-constant flow rate across a wide range of pressure differences) and is capable of being manufactured at low cost.

SUMMARY OF THE INVENTION

[0005] A first aspect of the present invention provides a device for controlling the airflow through an airduct, the airduct having a housing, an inlet and an outlet, the device comprising:

- a self-regulating valve having a diaphragm, the position of the diaphragm being determined by the difference between the pressure at the inlet and the pressure at the outlet, the diaphragm being rotatably located, e.g. journaled or suspended, on a support so that, under influence of an increasing difference in pressure, the diaphragm can rotate between a minimum rotation angle and a maximum rotation angle over an intermediate rotation angle, the intermediate angle being situated between the minimum and maximum angle, and characterized in that the diaphragm is provided with a counterbalance and that, within the angle range between the intermediate rotation angle and the maximum rotation angle, the rotation movement of the diaphragm under influence of an increasing pressure difference is counteracted by an elastic resisting force.

[0006] A ventilation device of this kind has been found to provide a well-regulated flow of air across a wide range of values of pressure difference. In particular, it has been found to offer a plateau at high pressure differences (i.e. values of external wind speed). The counterbalance helps to ensure that the valve member does not unduly restrict the air duct at low values of pressure difference, and can readily respond to changes in pressure difference at the lower values of pressure difference.

[0007] The elastic resisting force can be generated by contact between the counterbalance, or the diaphragm, and a resilient means. The resilient means may be a spring of any suitable form. The resilient means can be attached to, or form part of, the housing. Alternatively, the elastic resisting force can be generated by contact between a part of the housing and a resilient means which forms part of, or is mounted to, the counterbalance or diaphragm. For example, the resilient means can be provided by a part of the counterbalance or diaphragm which is formed from a resilient material, such as a resiliently deformable plastic material. In either case, the resilient means can be a spring.

[0008] Preferably, the resilient means provides substantially constant performance over a normal operating temperature range, e.g. -20°C to +40°C. A resilient means formed of metal has been found to be particularly advantageous. The spring properties of the resilient means preferably change by less than 20%, or less than 10% over the range -20°C to +40°C or for some temperate countries 0-35°C.

[0009] In an alternative embodiment of the invention, the elastic resisting force is provided by a part of the counterbalance which is formed from a resilient material, such as a resiliently deformable plastic material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Embodiments of the invention will be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a first embodiment of a ventilation device in accordance with the present invention; Figures 2A - 2C show a second embodiment of a ventilation device in accordance with the present invention, in which the counterbalance is resiliently deformable;

Figures 3A-3C show a third embodiment of a ventilation device in accordance with the present invention;

Figures 4A-4C show a fourth embodiment of a ventilation device in accordance with the present invention;

Figures 5A-5C show a fifth embodiment of a ventilation device in accordance with the present invention, in which a spring is incorporated within a counterbalance;

Figures 6A-6C show a sixth embodiment of a ventilation device in accordance with the present invention, in which a spring is incorporated within a counterbalance.

Figures 7 shows test results on a ventilation device in accordance with the present invention.

Figures 8A-8C shows a seventh embodiment of the present invention for an acoustic ventilator device in accordance with the present invention.

Figures 9A-9C shows an eighth embodiment of a ventilation device in accordance with the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0011] The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes. Where the term "comprising" is used in the present description and claims, it does not exclude other elements or steps. Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

[0012] Figure 1 shows a first embodiment of the ventilation device. A housing 5 defines an airflow duct 4 having an inlet 1 and an outlet 2. A valve 11, 12, 13 is fitted within the airflow duct 4. The valve is mounted upon a hook-shaped support 10 which protrudes from an upper wall of the housing. The valve comprises a hooked part 11 which rests upon support 10. The valve comprises two arms which are both connected to the hooked part 11 and which are aligned in mutually different directions.

The first arm is a flap-like part 12 and the second arm is a counterbalance 13. Flap 12 is shown as having a length 1 which is substantially equal to the height of the flow duct 4 in the region where it is fitted. Although shown only in cross-section, flap 12 also extends across the full width of the airflow duct 4. Flap 12 extends upstream, towards the inlet 1. In use, flap 12 can rotate in the direction of arrow 15 to restrict the height of the airflow duct 4. Part 13 of the valve serves as a counterbalance. Flap 12 and counterbalance 13 are supported in a fixed relationship to each other, i.e. flap 12 and counterbalance 13 rotate as one unitary part about support 10. Counterbalance 13 has a suitable dimension and weight, with respect to flap 12, such that at low values of pressure difference between the inlet 1 and outlet 2 the counterbalance 13 serves to hold flap 12 in the position shown in Figure 1, with the airflow duct 4 fully open. As pressure difference increases, flap 12 rotates about support 10 in the direction of arrow 15 and the duct 4 is progressively restricted by the flap 12. A spring 14 is positioned in the uppermost corner of the housing, and lies in the path of the counterbalance 13.

[0013] As the valve rotates about support 10, counterbalance 13 is moved towards the distal end of spring 14 and makes contact with the spring. The spring 14 provides a resilient force which serves to resist movement of the counterbalance 13. At even higher values of pressure difference, flap 12 further rotates about support 10 in the direction of arrow 15, causing spring 14 to compress. Advantageously, the properties of the spring 14 cause it to exhibit a non-linear response.

[0014] Hooked part 11 of the valve is shaped to define the angular range over which the valve can move. Wall 17 of the hooked part 11 defines the rest position of the flap 12, when there is little or no pressure difference. Wall 18 of the hooked part 11 defines the maximum turning position of the flap 12, as the flap 12 rotates in the clockwise direction about support 10. Additional stops can be provided, such as protrusions extending from the wall of housing 5 in the region of the resting position of the flap 12.

[0015] Figures 2A-2C show a second embodiment of the ventilation device. As previously described for Figure 1, a housing 105 defines an airflow duct 104 having an inlet 101 and an outlet 102. A valve 111, 112, 113 is fitted within the airflow duct 104. The valve is mounted upon an upwardly pointing hook-shaped support 110 which protrudes from an upper wall of the housing. The valve comprises a hooked part 111 which rests upon support 110. The valve comprises two arms 112, 113 which are both connected to the hooked part 111 and which are aligned in mutually different directions. The first arm is a flap-like part 112 and the second arm is a counterbalance 113. In use, flap 112 can rotate in the direction of arrow 115 to restrict the width of airflow duct 104. Part 113 of the valve serves as a counterbalance. Flap 112 and counterbalance 113 are supported in a fixed relationship to each other, i.e. flap 112 and counterbalance 113 rotate

as one unitary part about support 10. Figure 2A differs in that the counterbalance 113 is formed from a resiliently deformable material. This avoids the need to provide a spring (14, Figure 1). Figures 2A - 2C show operation of the valve at increasing values of differential pressure between the inlet 101 and outlet 102. In Figure 2A, the differential pressure is low. The counterbalance 113 serves to bias the flap 112 such that it lies parallel with the wall of the airflow duct. As differential pressure increases, the flap 112 moves in direction 115, causing the flap 112 to begin to restrict the airflow duct 104. In Figure 2B, the differential pressure has caused the valve to rotate about support 110 until the distal end of counterbalance 113 presses against the upper wall of airflow duct 104. In Figure 2C, the differential pressure has caused the valve to rotate further about support 110, with the counterbalance 113 deforming (resiliently) as it is pressed against the upper wall of airflow duct 104.

[0016] Figures 3A-3C show a third embodiment of the ventilation device. This is similar to Figures 2A-2C, in that a counterbalance 213 has a resiliently deformable portion. The rotatable mounting of the valve is different to that shown in Figure 1 and Figures 2A-2C. The ventilation device has an inlet 201, an outlet 202 and a flow duct 204. The valve is rotatably supported by a socket 210 protruding from a wall of the housing. The socket has a generally annular cross-section. The annular socket has an open segment which defines end stops for controlling the angular path of the flap 212. Figure 3A shows the valve at a low (or zero) value of differential pressure, with the flap 212 pressed against one of the end stops of the socket 210. As differential pressure increases, the flap 212 moves in direction 215, causing the flap 212 to begin to restrict the airflow duct 204. In Figure 3B, the differential pressure has caused the valve to rotate about socket 210 until the distal end 216 of counterbalance 213 presses against a stop 217. In Figure 3C, increasing differential pressure has caused the valve to rotate further about socket 210, with the tip 216 of the counterbalance 213 deforming (resiliently) as it is pressed against the stop 217. It should be understood that the valve can, with increasing pressure difference, rotate between the positions shown in Figures 3B and 3C but that during this angular range of movement, the rotation is opposed by the resilient deformation of tip 216 of the counterbalance 213. The socket 210 defines an end stop which limits the angular movement of the flap and counterbalance. This serves to limit deformation of the tip 216 to within a safe operating range (i.e. to prevent permanent deformation of the tip 216. Tip 216 of the counterbalance can be co-extruded with the counterbalance, and can also be co-extruded with the flap 212.

[0017] Figures 4A-4C show a fourth embodiment of the ventilation device. This has the same rotatable socket mounting as Figures 3A-3C. In this embodiment, the counterbalance 313 carries a resilient, V-shaped, spring element 314. Figure 4A shows the valve at a low (or zero) value of differential pressure, with the flap support

pressed against one of the end stops of the socket. As differential pressure increases, the flap 212 moves in direction 215, causing the flap 212 to begin to restrict the airflow duct 204. In Figure 4B, the differential pressure has caused the valve to rotate about socket 210 until a first part of the spring 314 presses against stop 217. In Figure 4C, increasing differential pressure has caused the valve to rotate further about socket 210, with the spring 314 carried by the counterbalance 313 deforming (resiliently) as it is pressed against the stop 217, causing the two arms of the V-shaped spring 314 to press together.

[0018] Figures 5A-5C show a fifth embodiment of the ventilation device. The device has a housing which defines an airflow duct 404, an inlet 401 and an outlet 402. A valve 411, 412, 413 is rotatably mounted within the airflow duct. In common with Figure 1 and Figures 2A-2C, the valve has a hooked part 411 which rests upon an upwardly pointing hook-shaped support 410 which protrudes from an upper wall of the housing. The valve comprises, on the remote side of the hooked part 411, a counterbalance 413. The counterbalance is generally V-shaped in cross-section, with two arms mounted in fixed relationship to one another. A V-shaped spring 414 is held between the arms of the counterbalance 413. Figure 5A shows the valve at a low (or zero) value of differential pressure. As differential pressure increases, the flap 412 moves in direction 415, causing the flap 412 to begin to restrict the airflow duct. In Figure 5B, the differential pressure has caused the valve to rotate about support 410 until a first arm of the spring 414 presses against stop 417. In Figure 5C, increasing differential pressure has caused the valve to rotate further about support 410, with the arms of spring 414 having been pressed together. An end stop is defined by the counterbalance 413 pressing against the housing, and flap 412 pressing against support 410.

[0019] Figures 6A-6C show a sixth embodiment of the ventilation device. This embodiment is similar to that previously described, except that instead of the counterbalance being located within a compartment above the air duct (Figures 5A-5C), the counterbalance is positioned within the airflow duct. The device has a housing which defines an airflow duct 504, an inlet 501 and an outlet 502. A valve 511, 512, 513 is rotatably mounted within the airflow duct 504. As in Figures 5A-5C, the valve has a hooked part 511 which rests upon an upwardly pointing hook-shaped support 510 which protrudes from a wall of the housing. The valve comprises, on the remote side of the hooked part 511, a counterbalance 513. The counterbalance is generally V-shaped in cross-section, with two arms mounted in fixed relationship to one another. A V-shaped spring 514 is held between the arms of the counterbalance 513. Figure 6A shows the valve at a low (or zero) value of differential pressure. As differential pressure increases, the flap 512 moves in direction 515, causing the flap 512 to begin to restrict the airflow duct. In Figure 6B, the differential pressure has caused the

valve to rotate about support 510 until a first arm of the spring 514 presses against stop 518. In Figure 6C, increasing differential pressure has caused the valve to rotate further about support 510, with the arms of spring 514 having been further pressed together. Figures 6A-6C also show a manually-operable flap 520 which can be operated to close the air duct completely, although this is optional.

[0020] A further embodiment of the ventilation device (not shown) resembles the device shown in Figure 1, but the spring 14 is replaced by a part of the housing, such as a wall or other component of the housing, which is formed from a resilient material. In use, increasing pressure difference rotates the counterbalance 13 towards the resilient part of the housing, until the counterbalance 13 presses against the resilient part of the housing. A further increase in pressure difference causes the resilient part of the housing to be compressed.

[0021] Each of the illustrated embodiments show a counterbalance acting upon a resilient member, or a counterbalance which incorporates a resiliently deformable portion. However, this is not essential to the invention and, instead, the flap (diaphragm) can act upon a resilient member.

In Figure 1 and Figures 2A-2C, the valve has a hooked part 11 which rests upon a hooked support 10 on the housing, and part 11 is free to rotate about support 10. This arrangement has the advantages of being cheap to manufacture and easy to assemble. In Figures 3A-3C and 4A-4C the rotatable connection is achieved by a socket and pin. Any suitable alternative form of connection can be used which permits rotational movement between the valve and the housing.

[0022] The ventilation device can be fitted to a building, with the housing 5 being adapted to fit within a wall of the building, in the frame of a window, or in the window itself. Portions 51, 52 of the housing fit within the wall, frame or window, with portion 53 extending into the interior of the building and portion 54 extending outside the building. The inlet 1, 101 to the device is preferably vertically oriented, which serves to prevent ingress of water. Figure 1 shows a hooded portion 7 extending upstream of the inlet, which serves to further limit ingress of water, although this is optional, particularly where the ventilation device is fitted at low levels. A grille 3 is fitted to the outlet of the ventilation device.

[0023] In the illustrated embodiments, the counterbalance is arranged to position the valve member at an inclined position when the pressure difference has a low or zero value. This allows the exterior portion 54 of the housing surrounding the valve member to have a generally arcuate profile, which reduces the amount of material used to form this region (compared to a more rectangular profile), allows water to run off the housing and generally gives a more pleasing aesthetic appearance.

[0024] Although a housing 5 has generally been described, this can be formed from a plurality of different physical parts which can be secured together, such as

by snap fittings, screws, clips etc. For example, there can be an upper part and a lower part which, when fitted together, define the airflow duct. Parts can be formed from different materials. For example, the outermost shell of the housing can be formed from aluminium, with other parts formed in plastics materials such as PVC.

[0025] Further embodiments of the ventilation device can comprise measures to acoustically dampen the air flow. Acoustic dampening can be achieved by lining the airflow duct 4, 104, with acoustically absorbent material or by including acoustically absorbent material in the outlet 2 or grille 3; by including obstructions (or acoustically absorbent material) in the airflow duct etc. An embodiment of an acoustic device is shown in Figs. 8a to c. As previously, a housing 605 defines an airflow duct 604 having an inlet 601 and an outlet 602. A valve 611, 612, 613 is fitted within the airflow duct 604. The valve is mounted upon a hook-shaped support 610 which protrudes from an upper wall of the housing. The valve comprises a hooked part 611 which rests upon support 610. The valve comprises two arms which are both connected to the hooked part 611 and which are aligned in mutually different directions. The first arm is a flap-like part 612 and the second arm is a counterbalance 613. Flap 612 has a length "l" which is substantially equal to the height of the flow duct 604 in the region where it is fitted. Although shown only in cross-section, flap 612 also extends across the full width of the airflow duct 604. Flap 612 extends upstream, towards the inlet 601. In use, flap 612 restricts the height of the airflow duct 604 as shown progressively in Figs. 8a to c. Part 613 of the valve serves as a counterbalance. Flap 612 and counterbalance 613 are supported in a fixed relationship to each other, i.e. flap 612 and counterbalance 613 rotate as one unitary part about support 610. Counterbalance 613 preferably has a suitable dimension and weight, with respect to flap 612, such that at low values of pressure difference between the inlet 601 and outlet 602 the counterbalance 613 serves to hold flap 612 in the position shown in Figure 8, with the airflow duct 604 fully open. A spring 614 is positioned in contact with the counterweight arm 613 but not touching a part of the housing 605 (Fig. 8a). As the air pressure increase, the flap 612 rotates about support 610 and spring 614 makes contact with the part of the housing wall (Fig. 8b). The spring 614 provides a resilient force which serves to resist movement of the counterbalance 613. At even higher values of pressure difference, flap 612 further rotates about support 610 causing spring 614 to compress, Fig. 8c. Advantageously, the properties of the spring 614 cause it to exhibit a non-linear response. The spring properties should also preferably be substantially constant over the operating temperature range. For example the spring may be made of metal. To provide acoustic damping air volumes may be provided in housing 605 that can be open to the duct 604. These may be filled with sound damping material such as foam or fibres.

[0026] Another embodiment of a ventilation device is shown in Figs. 9a to 9c. As previously, a housing 705

defines an airflow duct 704 having an inlet 701 and an outlet 702. A valve 711, 712, 713 is fitted within the airflow duct 704. The valve is mounted upon a hook-shaped support 710 which protrudes from an upper wall of the housing. The valve comprises a hooked part 711 which rests upon support 710. The valve comprises two arms which are both connected to the hooked part 711 and which are aligned in mutually different directions. The first arm is a flap-like part 712 and the second arm is a counterbalance 713. Flap 712 has a length "l" which is substantially equal to the height of the flow duct 704 in the region where it is fitted. Although shown only in cross-section, flap 712 also extends across the full width of the airflow duct 604. Flap 712 extends upstream, towards the inlet 701. In use, flap 712 restricts the height of the airflow duct 704 as shown progressively in Figs. 9a to c. Part 713 of the valve serves as a counterbalance. Flap 712 and counterbalance 713 are supported in a fixed relationship to each other, i.e. flap 712 and counterbalance 713 rotate as one unitary part about support 710. Counterbalance 713 preferably has a suitable dimension and weight, with respect to flap 712, such that at low values of pressure difference between the inlet 701 and outlet 702 the counterbalance 713 serves to hold flap 712 in the position shown in Figure 9, with the airflow duct 704 fully open. A spring 714 is positioned in contact with the counterweight arm 713 but not touching a part of the housing 705 (Fig. 9a). As the air pressure increase, the flap 712 rotates about support 710 and spring 714 makes contact with the part of the housing wall (Fig. 9b). The spring 714 provides a resilient force which serves to resist movement of the counterbalance 713. At even higher values of pressure difference, flap 712 further rotates about support 710 causing spring 714 to compress (Fig. 9c). Advantageously, the properties of the spring 714 cause it to exhibit a non-linear response. The spring properties should also preferably be substantially constant over the operating temperature range, e.g. a temperature range of -20°C to +40°C. For example the spring may be made of metal.

[0027] A ventilation according to Figs. 9a to c has been tested in accordance with the Dutch test standard NEN 1087 (edition 05/1997) at varying pressure drops across the device (X axis) The flow rates (Y axis of the graph) are also shown. As can be seen the flow rate remains substantially constant over the range of pressures tested, e.g. between 4 and 7 litres/s over a pressure range of 2 to 25 Pa. The present invention provides a ventilation device with which the flow rate varies by less than $\pm 60\%$, e.g. less than $\pm 50\%$ or less than $\pm 40\%$ over a pressure drop range ratio of 5:1, preferably 10:1 (e.g. from 2 to 20 Pa).

[0028] The invention is not limited to the embodiments described herein, which may be modified or varied without departing from the scope of the invention.

Claims

1. A device for controlling the airflow through an airduct, the airduct having a housing, an inlet and an outlet, the device comprising:

- a self-regulating valve having a diaphragm, the position of the diaphragm being determined by the difference between the pressure at the inlet and the pressure at the outlet,
- the diaphragm being rotatably located on a support so that, under influence of an increasing difference in pressure, the diaphragm can rotate between a minimum rotation angle and a maximum rotation angle over an intermediate rotation angle, the intermediate angle being situated between the minimum and maximum angle,
- the diaphragm being provided with a counterbalance and
- whereby, within the angle range between the intermediate rotation angle and the maximum rotation angle, the rotation movement of the diaphragm under influence of an increasing pressure difference is counteracted by an elastic resisting force

characterised in that

the elastic resisting force is generated by contact between said counterbalance, or said diaphragm, and a resilient means and wherein the resilient means form part of, the housing.

2. The device of claim 1, wherein the support is a hinge.
3. The device according to any one of claims 1 or 2 wherein the resilient means provide substantially constant performance over a temperature range of -20°C to +40°C.
4. The device according to claim 3 wherein the substantially constant performance of the resilient means is a change of less than 20% in spring constant over the temperature range of -20°C to +40°C or 0°C to 35°C.
5. The device according to any one of claims 1 to 4 wherein the resilient means are formed of metal.
6. The device according to any previous claim, wherein the counterbalance is dimensioned so as to keep the diaphragm at the minimum rotation angle when the pressure difference has a low or zero value.
7. The device according to any previous claim, wherein the flow characteristic of the valve should be non-linear and self-limiting.
8. The device according to any previous claim, wherein

the flow rate through the device remains substantially in a range defined by between 4 and 7 litres/s over a pressure range of 2 to 25 Pa.

9. The device according to any previous claim wherein the flow rate through the device varies by less than $\pm 60\%$, less than $\pm 50\%$ or less than $\pm 40\%$ over a pressure drop range ratio of 5:1, or 10:1.

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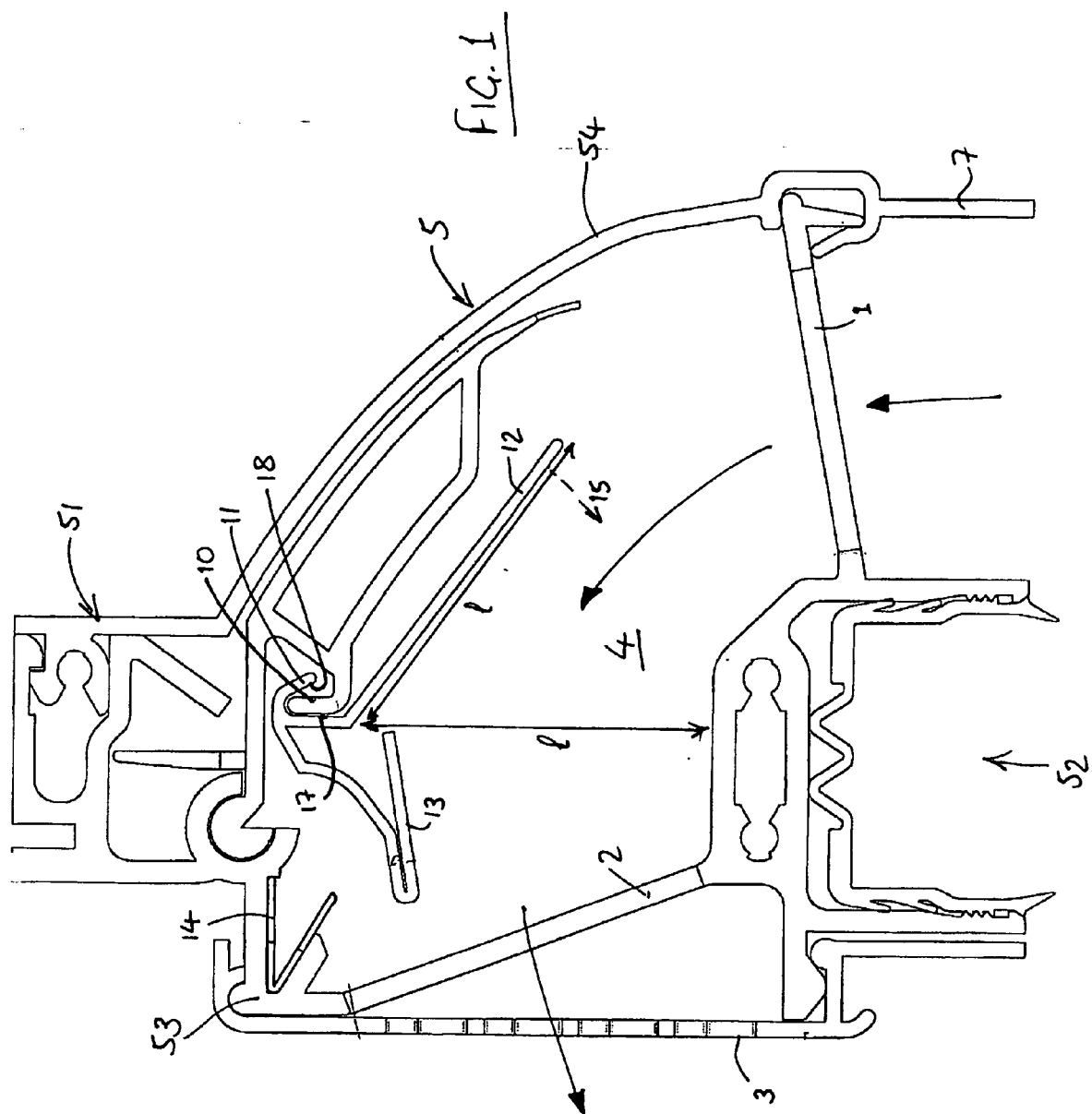
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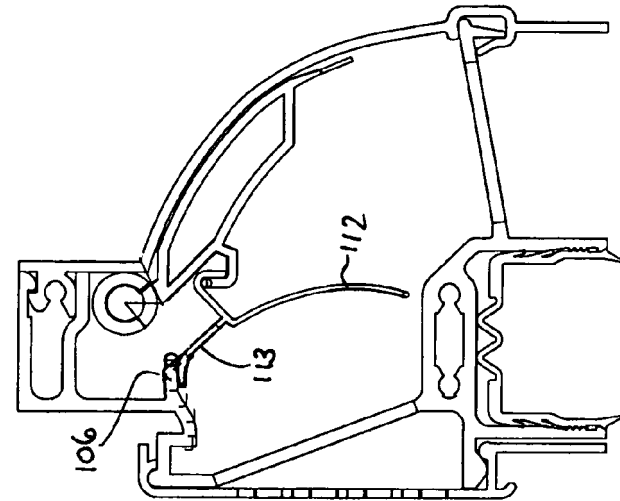


FIG. 2C

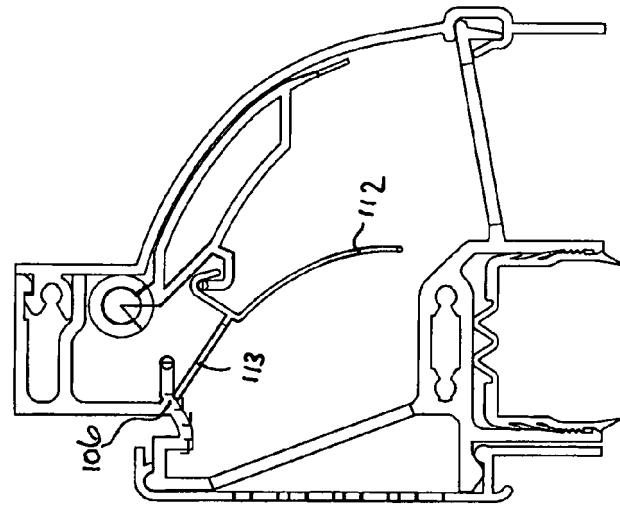


FIG. 2B

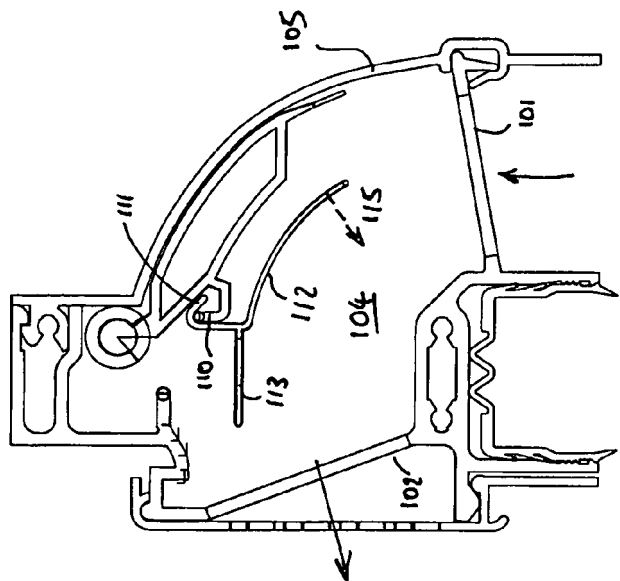
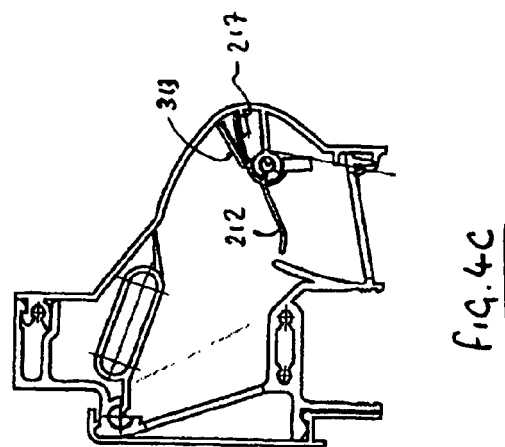
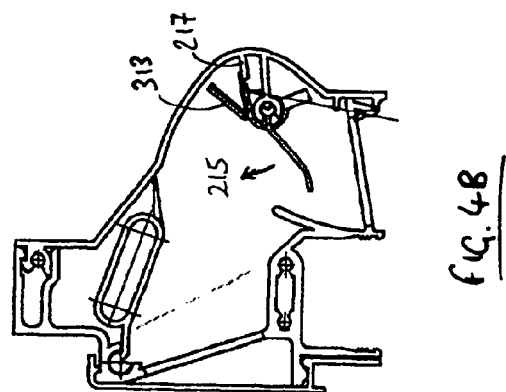
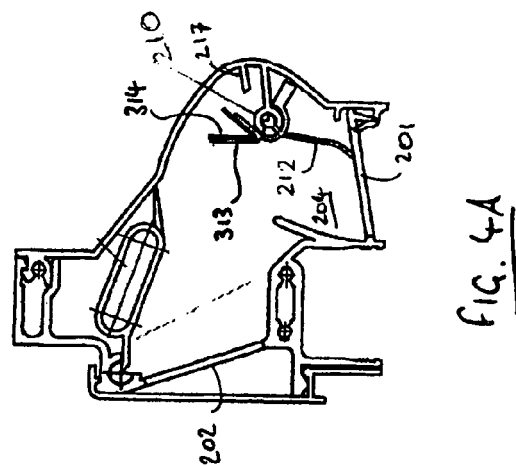
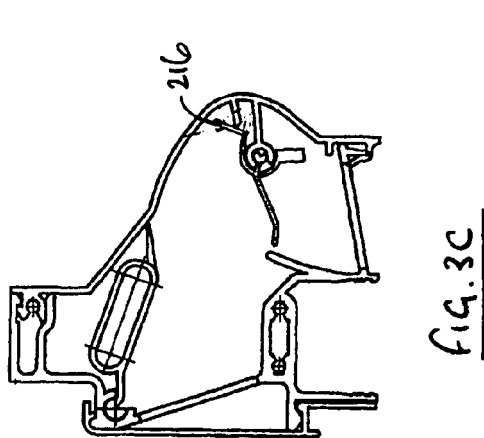
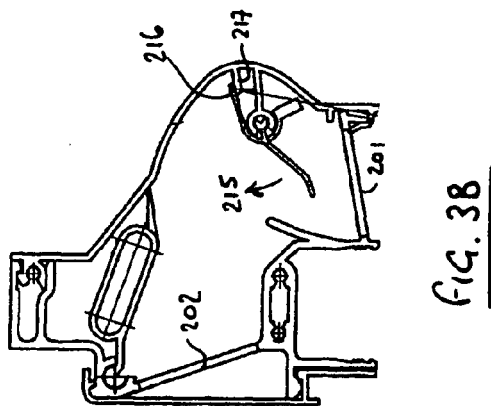
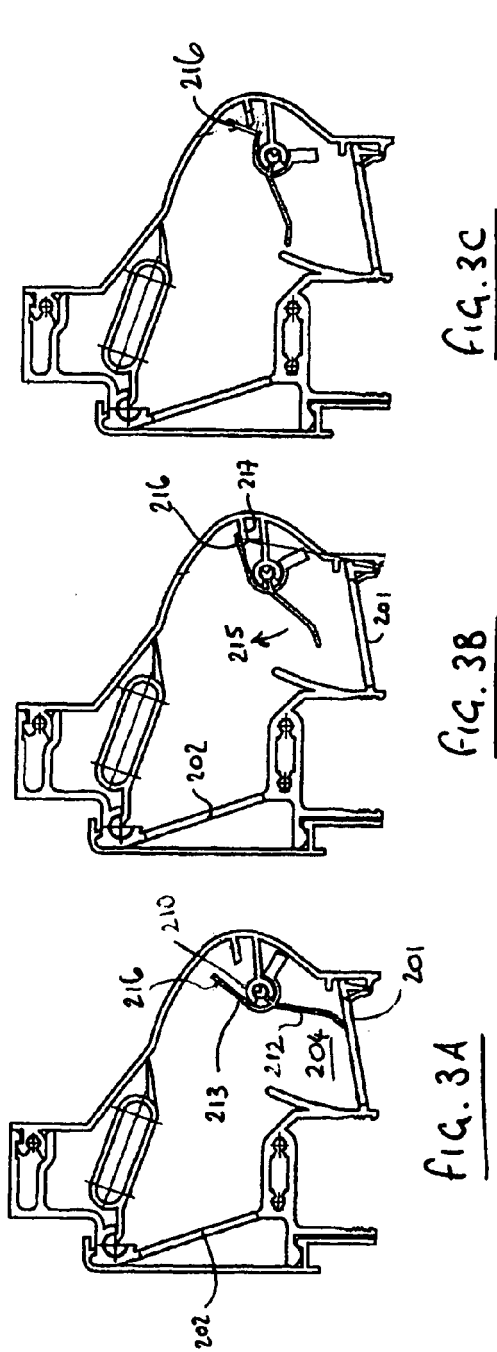


FIG. 2A



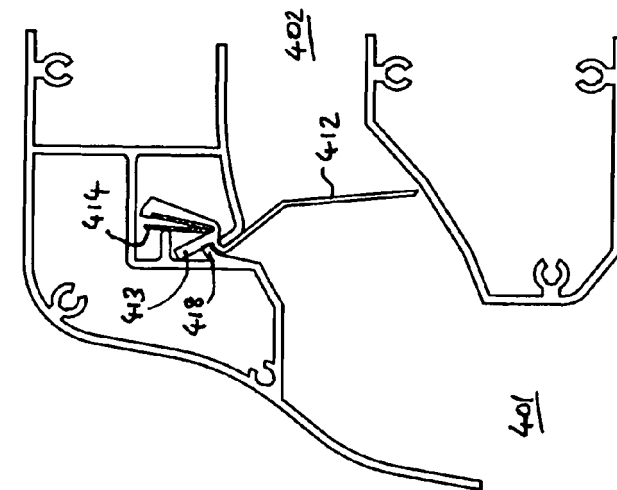


fig. 5C

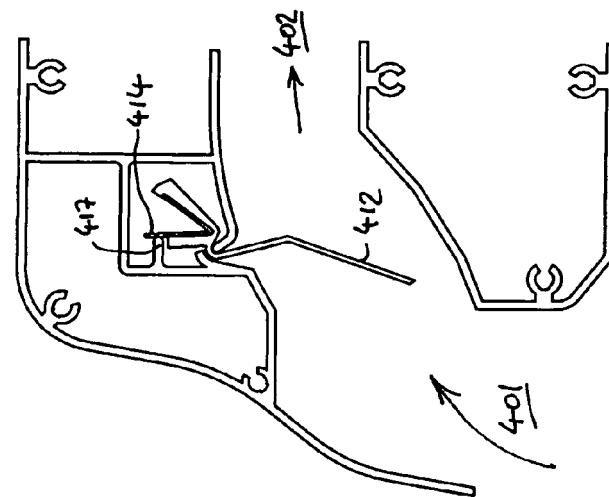


fig. 5B

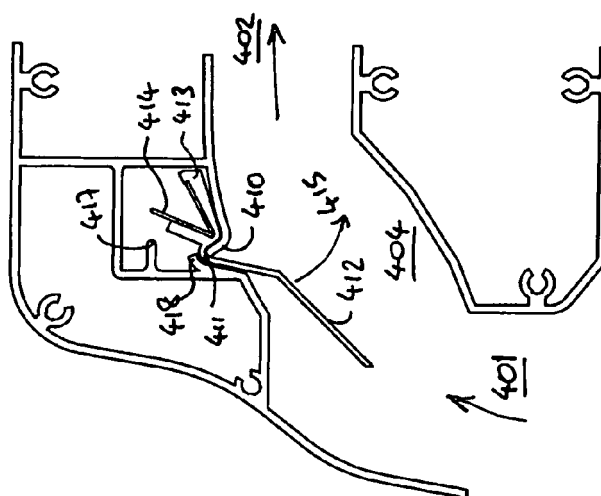


fig. 5A

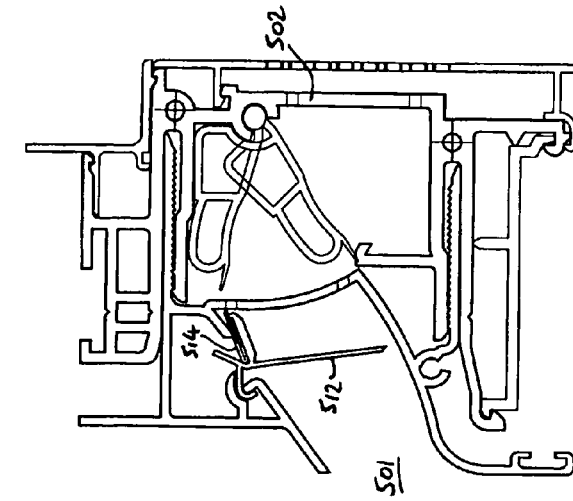


FIG. 6C

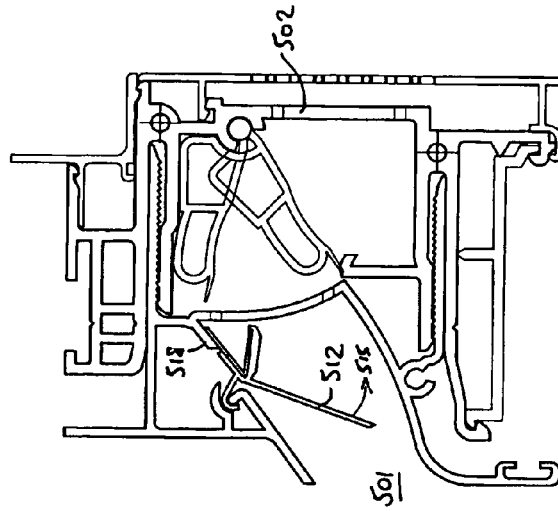


FIG. 6B

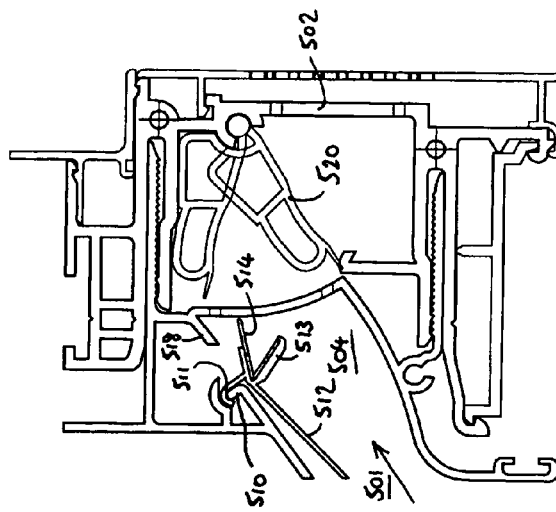


FIG. 6A

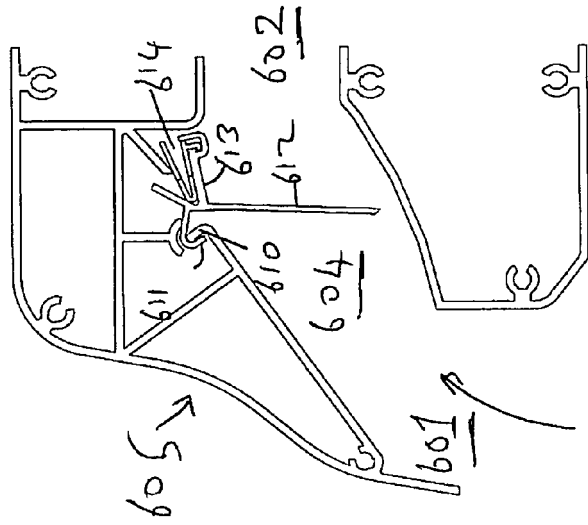


Fig. 8a

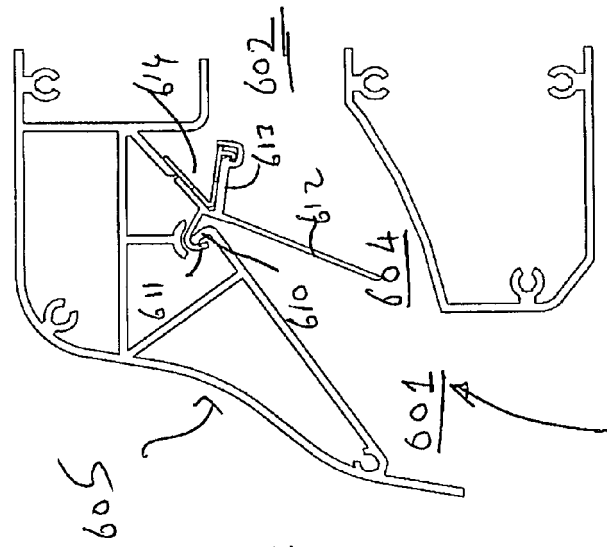


Fig. 8b

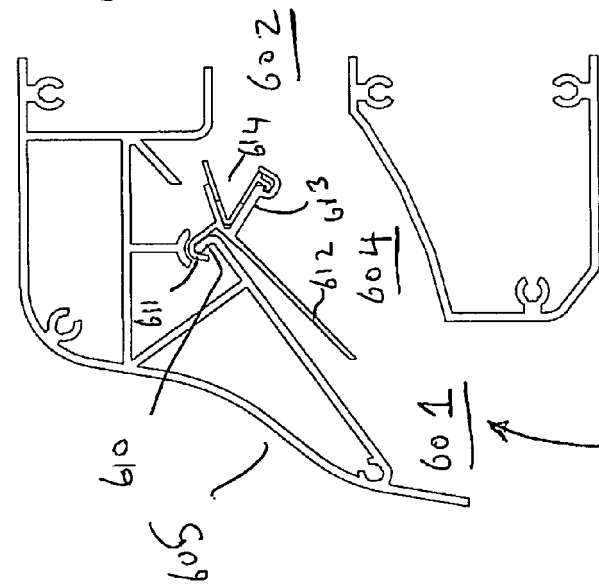


Fig. 8c

Fig. 8

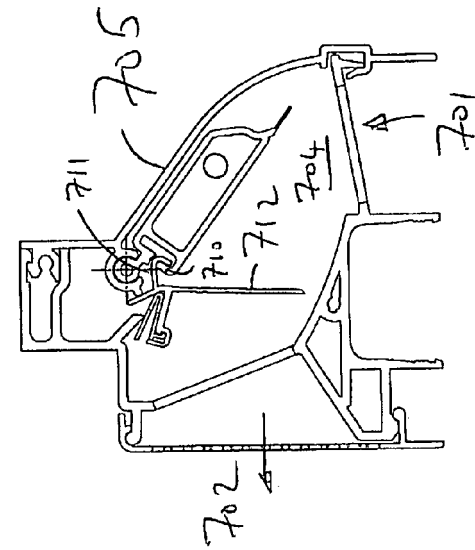


Fig 9c

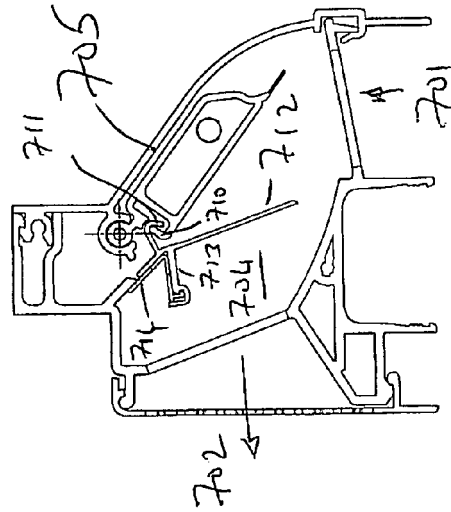


Fig 9b

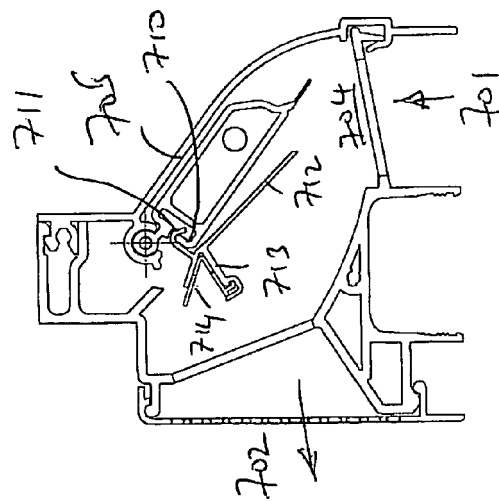


Fig 9a

Fig 9

Pressure Difference - Volume Air Flow

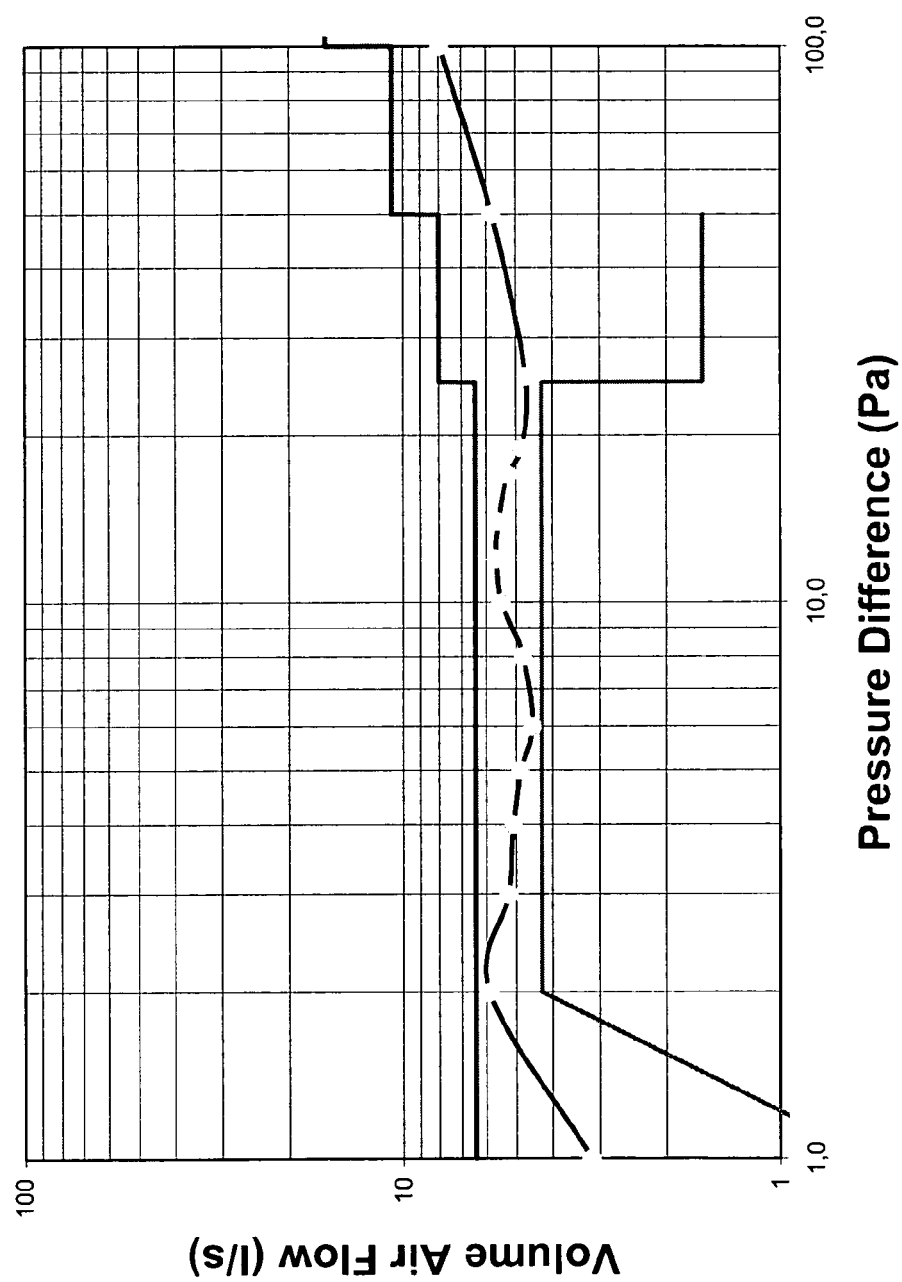


Fig. 7



EUROPEAN SEARCH REPORT

Application Number
EP 11 15 2932

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