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(54) LUNG DEMAND REGULATOR DEVICE AND DIAPHRAGM

(57) There is disclosed a diaphragm for a lung demand regulator device, the diaphragm comprising: a first face and a second face, the diaphragm being configured to move responsive to a pressure differential between the first and second faces; an opening extending between the first face and second face; and a non-return valve configured to control gas flow through the opening; wherein the non-return valve is biased to prevent all flow through the opening whilst the pressure differential is below a threshold and permit flow from the first face to the second face whilst the pressure differential is above a threshold. Also disclosed is a lung demand regulator device comprising a diaphragm and a breathing apparatus.

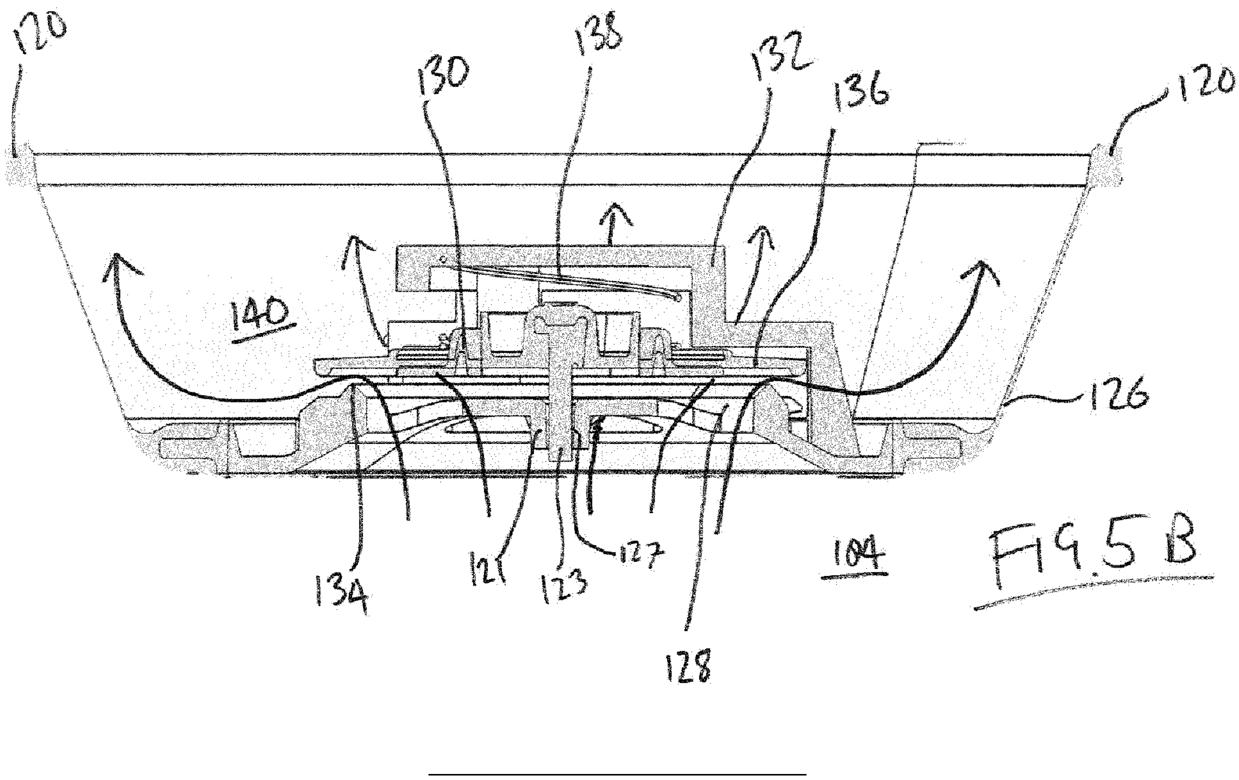

FIG.5B

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Description

[0001] This disclosure relates to breathing gas regulators for self-contained breathing apparatus for emergency services use. More particularly, the disclosure relates to diaphragms for breathing gas regulators for such breathing apparatus.

BACKGROUND

[0002] It is known to provide a flushing or purging regulator for a breathing apparatus, in which exhaled breathing gas is expelled from the mask to the ambient environment along a path which passes over the ambient side of a moveable diaphragm, so as to flush contaminants away from the diaphragm. Such flushing regulators provide a reduction in contaminant permeation through the diaphragm, as contaminants are not permitted to build up in high concentrations adjacent the diaphragm itself due to the flushing airflow.

[0003] Known flushing regulators typically divert exhaled breathing gas through a valve formed in the face mask or regulator along a dedicated ducting which flows over the outer surface of the diaphragm. An exemplary flushing regulator can be found in US Patent Publication No. 2006/0048774 A. This approach significantly increases the space envelope, bulk, and weight of the regulator. Furthermore, it also requires that the regulator be maintained in a fixed position relative to the mask, such that the regulator cannot rotate relative to the mask. These factors restrict the user's head movement which can increasing the exertion of the user and restricting their ability to work effectively.

[0004] US Patent No. 6,966,316 discloses a regulator having a diaphragm 122 comprising a purge conduit 170, which is covered by an elastomeric cover 132. The purpose of the cover 132 is to prevent foreign substances or water entering the regulator via the purge conduit 170. The regulator is maintained at a positive pressure and the cover 132 can be lifted by any pressure differential and, therefore, the positive pressure in the regulator means that there is a continuous, deliberate leakage of gas from the regulator at all times during its use. This creates various issues for the SCBA user and manufacturer. Firstly, the deliberate leakage means that it is difficult to determine when the breathing apparatus has suffered a failure and has an unintentional leak. Secondly, the continuous leakage of gas will deplete a user's gas cylinder more quickly, leaving less time for the user to be active at an emergency incident. Thirdly, this constant leakage also provides challenges in compliance with current SCBA international standards, such as NIOSH STP RCT-ASR-STP-0121 (Determination of Rated Service Time).

[0005] For at least these reasons, it will be understood that it is desirable to provide improvements to breathing gas regulators.

SUMMARY

[0006] According to a first aspect, there is provided a diaphragm for a lung demand regulator device, the diaphragm comprising: a first face and a second face, the diaphragm being configured to move responsive to a pressure differential between the first and second faces; an opening extending between the first face and second face; and a non-return valve configured to control gas flow through the opening; wherein the non-return valve is biased to prevent all flow through the opening whilst the pressure differential is below a threshold and permit flow from the first face to the second face whilst the pressure differential is above a threshold.

[0007] The non-return valve may permit gas flow through the opening from the first face to the second face and inhibit gas flow through the opening from the second face to the first face.

[0008] Where the term pressure differential is used in this disclosure, it shall mean the difference in pressure between the first face and the second face of the diaphragm. Where the term "positive" pressure differential is used in this disclosure, it shall mean a pressure differential in which the pressure at the first face of the diaphragm (i.e., the pressure inside the body of the lung demand regulator) is greater than the pressure on the second face of the diaphragm (i.e., the ambient pressure). Conversely, a "negative" pressure differential shall mean a pressure differential in which the pressure at the first face of the diaphragm (i.e., the pressure inside the body of the lung demand regulator) is less than the pressure on the second face of the diaphragm (i.e., the ambient pressure).

[0009] The threshold may be a specific pressure value, for example measured in millibars.

[0010] The threshold may be a positive, non-zero threshold. The non-return valve may remain closed at positive pressure differentials which are between zero and the threshold.

[0011] The non-return valve may be adjustable so as to adjust the threshold.

[0012] The non-return valve may be configured to open and permit flow of gas from the first face to the second face at the threshold, and open to a greater degree with increasing pressure differential values above the threshold.

[0013] The threshold may be one or more of: i) a value is that is greater than the pressure differential experienced during inhalation by the user when the diaphragm is fitted in a lung demand regulator; ii) a value is that is greater than the pressure differential experienced during latent periods between inhalation and exhalation by the user when the diaphragm is fitted in a lung demand regulator and iii) a value that is lower than the pressure differential is that experienced during exhalation by the user when the diaphragm is fitted in a lung demand regulator. The non-return valve may permit flow of gas through the opening only during exhalation by a user.

Further, the non-return valve may permit flow of gas through the opening only from the first face to the second face.

[0014] It should be understood that different designs of diaphragm and lung demand valve may have different structural configurations which affect the typical pressure differential values experienced across the diaphragm during inhalation and exhalation. However, a skilled person, once provided with the teachings of the present disclosure, shall be equipped to determine the precise value of the threshold for a particular diaphragm or lung demand regulator. The threshold may be set such that the non-return valve only permits outward flow of gas (from first face to the second face) during exhalation and not during inhalation or latent periods between inhalation and exhalation.

[0015] The threshold may be between around4 and 6 millibars. The threshold may be around 4 millibars or around 5 millibars. The pressure differential experienced during inhalation may be 0.5 to 4 millibars. The pressure differential experienced during exhalation may be 4 to 7 or 8 millibars.

[0016] The diaphragm perimeter may be substantially circular. The opening may be concentric with the diaphragm perimeter.

[0017] The diaphragm perimeter may comprise a sealing bead for sealing against the body to sealingly separate the body from the ambient environment.

[0018] The opening and the non-return valve may be configured to direct gas flow from the opening over the second face of the diaphragm.

[0019] The periphery or perimeter of the opening may form a valve seat for a sealing member of the non-return valve. The opening and the valve seat may be substantially circular.

[0020] The non-return valve may be formed integrally with the diaphragm, as a unitary component.

[0021] The diaphragm may further comprise a biasing member configured to apply a biasing force to urge a sealing member of the non-return valve into a closed position, the biasing force being of a magnitude which is overcome by a pressure force applied to the sealing member by the pressure differential at or above the threshold.

[0022] The diaphragm may comprise an adjustment apparatus for adjusting the biasing force.

[0023] The diaphragm may comprise a plurality of openings and a plurality of corresponding non-return valves.

[0024] According to a second aspect, there is provided a lung demand regulator device for use with breathing apparatus, for delivering breathable gas from a pressurised supply to a user, the lung demand regulator device comprising: a body comprising a valve member for controlling the rate of delivery of the breathable gas, a diaphragm according to the first aspect, the diaphragm having the first face exposed to internal pressure within the body and a second face exposed to ambient pressure outside the body, the diaphragm being moveable responsive to a pressure differential between its first and second faces to control the valve member; wherein the non-return valve is biased so as to prevent opening of the non-return valve and flow of gas out of the body via the opening whilst the pressure differential is that experienced during inhalation by the user and permit opening of the non-return valve and flow of gas out of the body via the opening whilst the pressure differential is that experienced during exhalation by the user.

[0025] The valve member may be configured to provide continuous breathing gas flow into the body during use so as to maintain the internal pressure greater than the ambient pressure. The internal pressure within the body may be greater than the ambient pressure outside the body at all times during use.

[0026] Continuous breathing gas flow during use should not be understood to mean that the flow rate is maintained at the same rate at all times during use. Instead, constant breathing gas flow should be understood to mean that the flow rate is above zero at all times during use, but may fluctuate.

[0027] The lung demand regulator device may further comprise a cover member arranged over the second face of the diaphragm, thereby forming a chamber between the second face of the diaphragm and the cover. The chamber may be in communication with the ambient environment.

[0028] Any aspect may comprise any combination of the features and/or limitations referred to with respect to any of the other aspects described above, except combinations of such features as are mutually exclusive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 schematically shows a breathing apparatus according to an example arrangement;

Figure 2 schematically shows a lung demand regulator device and a facemask according to an example arrangement;

Figure 3A schematically shows a cross-sectional view of the lung demand regulator device on the plane A-A shown in Figure 2;

Figure 3B schematically shows a detailed cross-sectional view of a diaphragm of the regulator and its surroundings, also on the plane A-A;

Figure 4A schematically shows a plan view of a diaphragm according to an example arrangement;

Figure 4B schematically shows the diaphragm of

Figure 4A in a first perspective view;

Figure 4C schematically shows the diaphragm of Figures 4A and 4B in a second perspective view;

Figure 5A schematically shows a diaphragm and a non-return valve thereof in a closed configuration; and

Figure 5B schematically shows the diaphragm and non-return valve of Figure 5A in an open configuration.

DETAILED DESCRIPTION OF THE DRAWINGS

[0030] With reference to **Figure 1,** an example breathing apparatus 10 is shown. The breathing apparatus 10 is a self-contained breathing apparatus (SCBA) and comprises a support frame or backplate 12, straps 14 for securing the SCBA to a user, a breathing gas cylinder 16, a face mask 18, a lung demand regulator 100 connectable to the face mask 18, and a pneumatics system 20 for delivering breathing gas from the cylinder 16 via a hose or flexible conduit 22 to the lung demand regulator 100, to thereby deliver breathing gas to the user wearing the face mask 18 on demand. The breathing apparatus 10 may further comprise other components or systems which are not shown, including but not limited to an electrical system, a monitoring system, or a communications system. The lung demand regulator device 100 may also be referred to as the regulator 100 in this disclosure for brevity.

[0031] In this illustrated arrangement, the breathing apparatus is a self-contained breathing apparatus (SCBA), but it should be understood that the lung demand regulator may also have applications in other types of breathing apparatus, such as self-contained underwater breathing apparatus (SCUBA) and emergency escape breathing apparatus.

[0032] **Figure 2** schematically shows a face mask 18 attached to the regulator 100. As shown in more detail in Figure 2, a hose 22 of the pneumatics system 20 is connected to an inlet of the regulator 100 to provide breathing gas from the cylinder 16. The pneumatics system 20 comprises a first-stage pressure reducer which reduces the pressure of the breathing air from the cylinder 16 which may be stored at several hundred bar, to an intermediate pressure for provision to the regulator 100 via the hose 22. The intermediate pressure is still too great for the breathing gas to be provided directly to the user to breathe. Therefore, the regulator 100 forms a second-stage pressure reducer which further reduces the pressure of the breathing gas to a suitable pressure for delivery to the user to breathe. In other arrangements, more than two or fewer than two pressure reducers may be provided. The face mask 18 may comprise an exhalation valve which permits exhaled gas to exit to the ambient environment.

[0033] **Figure 3A** schematically shows a cross-sectional view of the regulator 100 on the plane A-A shown in Figure 2. **Figure 3B** schematically shows a detailed cross-sectional view of diaphragm 116 of the regulator 100 and its surroundings in the regulator 100, also on the plane A-A.

[0034] The lung demand regulator device 100 comprises a body 102. The bode defines an internal chamber 104, which is configured to communicate with the mask 18 via a connection port 108 which defines a conduit 110. The body 102 contains a valve member 112 for controlling the rate of delivery of the breathable gas into the body 102. The valve member 112 can open to varying degrees in order to provide a variable rate of delivery of breathing gas. The valve member 112 is balanced such that, during use of the breathing apparatus, the valve member 112 permits a continuous flow of breathing gas into the body 102 (and thus to the conduit 110 and the interior of the mask 18) such that the internal pressure in the body 102 and the mask 18 is greater than the ambient pressure outside the body and mask. This is known as 'positive pressure' and ensures that any flow between the internal environment of the mask and regulator and the ambient environment is always in the outward direction, thereby preventing ingress of ambient gas and particulates into the breathing environment of the user.

[0035] In order to actuate the valve member 112 to control the flow of breathing gas, the regulator 100 comprises a diaphragm 116. The diaphragm 116 is flexible sheet-like member having a first face 116a exposed to internal pressure within the body 102, and specifically to the chamber 104, and a second face 116b exposed to ambient pressure outside the body 102.

[0036] Where the term pressure differential is used in this disclosure, it should be understood to mean the difference in pressure between the first face and the second face of the diaphragm. Where the term "positive" pressure differential is used, it shall mean a pressure differential in which the pressure at the first face of the diaphragm (i.e., the pressure inside the body of the lung demand regulator) is greater than the pressure on the second face of the diaphragm (i.e., the ambient pressure). Conversely, a "negative" pressure differential shall mean a pressure differential in which the pressure at the first face of the diaphragm (i.e., the pressure inside the body of the lung demand regulator) is less than the pressure on the second face of the diaphragm (i.e., the ambient pressure).

[0037] The diaphragm 116 is moveable within the body responsive to a pressure differential between its first and second faces 116a,b to control the valve member 112. Specifically, the first face 116a of the diaphragm 116 comprises a rigid contact member 117 which is contacted by a distal portion of a lever assembly 114. When the pressure differential between the first and second faces 116a,b changes, the diaphragm 116 moves, thereby also pivoting the lever assembly 114. The lever assembly 114 controls the displacement of valve member 112, thereby controlling the flow of breathing gas into the regulator 100 and mask 18.

[0038] Generally, as the diaphragm moves towards the chamber 104, it pivots the lever assembly 114 such that the valve member 112 allows greater flow of breathing gas, and as the diaphragm moves away from the chamber 104, the lever assembly 114 is pivoted in the opposing direction such that the valve member 112 allows reduced flow of breathing gas. When the user inhales, the internal pressure within the chamber 104 is reduced, and the diaphragm 116 moves inwardly towards chamber 104, pivoting the lever assembly 114 thereby opening the valve member 112 and providing breathing gas to the user during their inhalation. When the user stops inhaling, the internal pressure in the chamber 104 increases, thereby moving the diaphragm 116 outwardly with respect to the chamber 104, pivoting the lever assembly 114 in the return direction and reducing the flow of breathing gas through the valve member 112.

[0039] A spring member 115 is provided to apply a biasing force to the diaphragm 116 inwardly towards the chamber 104 (i.e., to support the force exerted on the second side 116b of the diaphragm 116 by ambient pressure). The spring member 115 has multiple purposes. Firstly, it reduces the pressure differential required in order to move the diaphragm 116, thereby reducing the effort of inhalation by the user required to actuate the valve member 112. Secondly, spring member 115 provides an opposing force to increased pressure in the chamber 104, such that the diaphragm 116 is prevented from moving outwardly to such an extent that the valve member 112 would be closed, thereby ensuring continuous flow into the regulator 100 and maintenance of positive pressure in the regulator 100 and mask 18. In this way, the valve member 112 and more generally the regulator 100 is configured to provide continuous breathing gas flow into the body 102 during use so as to maintain the internal pressure greater than the ambient pressure, and maintain positive pressure.

[0040] The regulator 100 comprises a cover member 118 which is arranged over the exterior of the body 102, and specifically over the second face 116b of the diaphragm 116. Consequently, an ambient chamber 140 is formed between the second face 116b of the diaphragm 116 and the cover member 118. The cover member comprises one or more openings (not shown) which fluidly connect the ambient chamber 140 with the ambient environment, such that the ambient chamber 140 is maintained at substantially equal pressure to the ambient pressure.

[0041] The body 102 is formed in two parts 122 and 124, which are connectable to form the body 102. The inner part 122 of the body 102 contains the valve member 112 and the lever assembly 114, comprises the connection port 108, and defines the chamber 104. The outer part 124 of the body 102 is connectable, for example by a bayonet connection or a threaded connection, to the inner part 122. At their connection, the inner and outer parts 122,124 define an annular sealing chamber 125. The diaphragm 116 is substantially circular in shape, and comprises a circular perimeter defining a sealing bead 120. The sealing bead 120 is placed in the annular sealing chamber 125 and, when the inner and outer parts 122,124 are connected, they compress the sealing bead 120 and thereby seal against the body 102. This construction sealingly separates the body, and more specifically the chamber 104, from the ambient environment and the ambient chamber 140. In the event that the diaphragm 116 requires replacement, then the outer part 124 can be disconnected from the inner part 122 in order to release the sealing bead 120 and separate the diaphragm 116 from the body 102.

[0042] Turning now to **Figures 4A, 4B, and 4C,** the diaphragm 116 shall now be described in more detail. Figures 4A and 4B show the first face 116a of the diaphragm 116 in plan and perspective view respectively, while Figure 4C shows the second face 116b of the diaphragm 116 in perspective view.

[0043] The diaphragm 116 comprises a central structure 113 comprising the contact member 117 and a non-return valve 130. In this example, the non-return valve 130 is formed integrally with the diaphragm 116, such that they form a unitary component. The central structure 113 is encircled at its periphery by a flexible membrane skirt 126. The skirt 126 is, in this example, a silicone membrane layer which is moulded to the central structure 113. The skirt 126 extends radially away from the periphery of the central structure 113 and axially out of the plane of the central structure 113 to give the diaphragm 116 a dish-like shape. The sealing bead 120 is formed at the peripheral edge of the skirt 126. The first face 116a of the diaphragm 116 is formed by a first side of the central structure 113 and the skirt 126, while the second face 116b is formed by the opposing sides of the central structure 113 and the skirt 126.

[0044] It is important to note that in Figures 4A, 4B, and 4C, the diaphragm 116 is shown in its natural resting position, i.e., when not installed in the regulator 100. In this natural position, The skirt 126 extends axially downward with respect to the central structure 113, such that the first face 116a of the diaphragm 116 in this natural state is generally convex, while and the second face 116b is generally concave. Referring back to Figure 3B, it will be appreciated that, when installed in the regulator 100, the skirt 126 of the diaphragm 116 is inverted with respect to its natural resting position, such that first face 116a is generally concave in use, while the second face 116b is generally convex. This ‘use’ configuration gives the diaphragm 116 a natural inherent bias, as the skirt 126 is naturally urged towards its un-inverted resting position, which equates to an inward bias of the diaphragm 116 while the sealing bead 120 is clamped to the body 102.

[0045] As has been established above, the diaphragm 116 configured to move responsive to a pressure differential between the first and second faces 116 a,b. In use, this movement is achieved by the flexibility of the skirt

126, which is sufficiently thin so as to move responsive to small changes in pressure differential between the chamber 104 and the ambient chamber 140. The diaphragm 116 is configured to provide flushing of its ambient-facing second face 116b and the ambient chamber 140, so as to inhibit permeation of hazardous agents through the diaphragm 116 itself.

[0046] The diaphragm 116 comprises an opening 128 which extends between the first face 116a and second face 116b. The opening 128 is generally circular in shape. In this example, the opening 128 comprises four struts 129 which extend from a perimeter of the opening to a centre of the opening 128 and form bridging support structure 121 which extends across the opening 128. When opened, the opening 128 permits flow of gas through the diaphragm 116.

[0047] Flow through the opening 128 is controlled by a non-return valve 130. Non-return valves may also or alternatively be known as check valves, or one-way valves. The non-return valve 130 is biased into a closed position in which it prevents all flow through the opening 128. The non-return valve 130 will maintain this closed position whilst the pressure differential across the diaphragm 116 is below a threshold. Once the pressure differential is above a threshold, the non-return valve will permit flow from the first face 116a through the opening to the second face 116b. In this way, the non-return valve 130 may be said to permit gas flow through the opening 128 from the first face 116a to the second face 116b when a sufficient pressure differential is present between these two faces, and inhibit or prevent gas flow through the opening 128 from the second face 116b to the first face 116a.

[0048] It will be appreciated that each specific regulator design will have different characteristics dependent upon its construction, method of operation, and shape. In practice, the biasing of the non-return valve 130 is such that, while the internal pressure in the chamber 104 is that experienced during inhalation or the latent period between breaths, the biasing force applied to the non-return valve 130 is sufficient to keep the valve closed and prevent all flow through the opening 128, even when the regulator 100 and the internal chamber 104 are at a small constant 'positive pressure' (i.e. when there is a small positive pressure differential due to positive pressure operation). Therefore, no gas flow is permitted out of the body 102 via the opening 128 during inhalation or the latent period between breaths. However, the biasing force applied to the non-return valve 130 is sufficiently small that, during exhalation, the increased pressure in the internal chamber 104 increases the pressure differential sufficiently to overcome the biasing force applied to the non-return valve 130, and thereby permit flow of gas out of the chamber 104 through the opening 128. Once exhalation ceases, the internal pressure in the chamber 104 drops, and the biasing force applied to the non-return valve 130 overcomes the pressure differential once again and closes the opening 128 to all flow. As the non-return valve 130 is only opened when a sufficient positive pressure differential is present across the diaphragm 116, flow through the opening 128 can only ever occur in the outward direction (i.e., from the first face 116a to the second face 116b).

[0049] In effect, the non-return valve 130 is configured to permit outward flow of gas through the opening 128 when the pressure differential is above a specific threshold. The threshold may be a specific pressure value, for example measured in millibars. In this specific example, the threshold may be between 4-6millibars, or more specifically around 4 millibars or 5 millibars. In this specific regulator 100, the pressure differential experienced between the first face 116a and the second face 116b during inhalation may be 0.5 to 4 millibars, while the pressure differential experienced during exhalation may be 4 to 7 or 8 millibars. Therefore, during inhalation, the pressure differential may be below the threshold, such that the opening 128 is closed by the non-return valve 130, while during exhalation, the non-return valve 130 is opened to permit outward flow of breathing gas through the opening 128.

[0050] More generally, it should be understood that the threshold may be a positive, non-zero threshold. Therefore, the non-return valve may remain closed at positive pressure differentials which are between zero and the threshold.

[0051] Turning to the specific configuration of the non-return valve 130 in the illustrated example, we refer also to **Figures 5A and 5B,** which show the diaphragm 116 in a cross-sectional view along the plane B-B shown in Figure 4A. Figure 5A shows the diaphragm 116 having the non-return valve 130 in a closed position, while Figure 5B shows the non-return valve 130 in an open position.

[0052] As can be appreciated, the opening 128 comprises a valve seat in the form of sealing edge 134 which extends around the periphery of the opening 128 on the second face 116b of the diaphragm 116. The sealing edge 134 in this example is a ridge-like annular protrusion. The non-return valve 130 comprises a sealing member. In this example, the sealing member is a sealing plate 136 which is configured to engage and contact the sealing edge 134 and form sealing contact therebetween to prevent flow of gas between the sealing edge 134 and the sealing plate 136. The sealing plate 136 comprises a locating pin 123 which extends axially with respect to the plane of the sealing plate 136 and which is received in a corresponding bore 127 of the support structure 121. Therefore, the sealing plate 136 is constrained to move linearly towards and away from the sealing edge 134 (a direction which generally corresponds to the direction of movement of the diaphragm 116 as the pressure differential changes) such that it can move into and out of contact with the sealing edge 134.

[0053] In order to provide a biasing force F to the sealing plate 136 to urge it against the sealing edge 134, and more generally to bias the non-return valve 130 into a closed position, the non-return valve 130 further comprises a biasing member 138. In this example, the biasing member is a helical spring 138, which is retained by a spring retainer 132, which provides a counteracting surface for the helical spring 138. It will be appreciated that, in order for the sealing member 136 to be lifted away from the sealing edge 134, the biasing force F must be overcome by a pressure differential across the sealing member 136 (which is effectively identical to the pressure differential between the first and second faces 116a,b of the diaphragm 116). Therefore, the magnitude of the biasing force F effectively sets the threshold of pressure differential at which the non-return valve 130 will be opened. In order for the sealing plate 136 to be lifted away from the sealing edge 134, the pressure differential must be of sufficient magnitude that the pressure force applied to the sealing plate 136 is greater than the biasing force F.

[0054] It will be understood that the non-return valve 130 may be adjustable so as to adjust the threshold. To achieve this, the biasing force F may be adjustable by an adjustment apparatus. In this example, the adjustment apparatus may be achieved by providing the spring retainer 132 with a mechanism for adjusting its height H to thereby adjust the compression of the helical spring 138. The spring retainer 132 may, for example, be threaded so as to adjust the height H by rotating the retainer 132 with respect to the diaphragm 116.

[0055] The non-return valve 130 illustrated is a lift-check valve, which is just one example of a suitable non-return valve. It will be appreciated that there are many other types of non-return or check valves which could be successfully applied in this application, such as a swing or flapper type valve, a ball valve, a duckbill valve, a butterfly valve.

[0056] Figure 5A therefore shows the diaphragm 116 and its non-return valve 130 when the pressure differential is below the threshold, and therefore the non-return valve 130 remains closed. In contrast, Figure 5B shows the diaphragm 116 and its non-return valve 130 when the pressure differential is above the threshold, and the non-return valve 130 is opened to permit gas flow through the opening 128.

[0057] The flow of gas out of the opening 128 in this position is illustrated by the arrows shown in Figure 5B. As can be appreciated, the pressure of the gas on the first face 116a of the diaphragm 116 is greater than the pressure on the second face 116b, so gas flows out of the opening 128 and over the second face 116b of the diaphragm about its entire surface, and thereby displaces any gas which had settled adjacent the second face 116b. When the diaphragm 116 is fitted in a regulator, as shown in Figure 3A and 3B, this exiting gas flows into the ambient chamber 140 and purges any settled gas in the ambient chamber 140 to into the ambient environment. Therefore, the gas in the ambient chamber 140 is continuously replaced with freshly exhaled breathing gas.

[0058] As has been described above, a flow of gas will be expelled from the opening 128 each time the user exhales. Therefore, a steady purging flow of exhaled gas will be forced through the opening 128 and into the ambient chamber 140 during use. Therefore, any contaminants that enter the ambient chamber from the ambient environment will be subject to a continuous purging flow of exhaled gas which should remove them from the ambient chamber 140.

[0059] The central, circular form of the opening may provide that exhaled gas can be expelled about the entire circumference of the opening, thereby flushing exhaled gas over the entire face of the diaphragm, and improving the flushing performance.

[0060] It should be understood that different designs of diaphragm and lung demand regulator may have different structural configurations which affect the typical pressure differential values experienced across the diaphragm during inhalation and exhalation. However, a skilled person, once provided with the teachings of the present disclosure, shall be equipped to determine the precise value of the threshold for a particular diaphragm or lung demand regulator.

[0061] It should be noted that the illustrated example is only one way in which the principles of the present disclosure could be embodied, and that other alternative constructions may be envisaged. For example, the diaphragm may be configured to comprise a comprise a plurality of smaller openings and a plurality of corresponding non-return valves, which may thereby reduce the exhalation effort required by the user, or provide multiple purging openings across the surface of the diaphragm.

[0062] Where the face mask also has an exhalation valve, the diaphragms disclosed herein effectively provide an additional exhalation valve in the diaphragm, which may lower the overall exhalation pressure and reducing the work of breathing. Alternatively, the presently disclosed diaphragms could replace the exhalation valve on the mask, thereby reducing complexity & cost.

[0063] Through the development of the presently disclosed diaphragms, it has been determined the average volume of air provided in the ambient chamber adjacent to the diaphragm is 23cc and the average amount of air expelled through the diaphragm is 444cc per minute. It should be noted that if the threshold for pressure differential were adjusted, then the average amount of expelled air may be different. Nevertheless, the amount of air expelled should greatly exceed the volume of air housed adjacent the diaphragm, meaning the contaminants in this area are effectively purged and permeation through the diaphragm is reduced, while avoiding the significant problems with previously known flushing regulators.

[0064] A further advantage of the presently disclosed diaphragms is that a non-flushing regulator can be reconfigured as a flushing regulator simply by replacement of the standard diaphragm assembly with a diaphragm as disclosed herein. The presently disclosed systems also provide improvements from a manufacturing or serviceability viewpoint, as the flushing system can be replaced by merely replacing the relatively cheap diaphragm rather than the regulator itself.

Claims

1. A diaphragm (116) for a lung demand regulator device (100), the diaphragm (116) comprising:

   a first face (116a) and a second face (116b), the diaphragm (116) being configured to move responsive to a pressure differential between the first and second faces (116a, 116b);
   an opening (128) extending between the first face (116a) and second face (116b); and
   a non-return valve (130) configured to control gas flow through the opening (128);
   wherein the non-return valve (130) is biased to prevent all flow through the opening (128) whilst the pressure differential is below a threshold and permit flow from the first face (116a) to the second face (116b) whilst the pressure differential is above a threshold.

2. A diaphragm (116) for a lung demand regulator device (100) as claimed in claim 1, wherein the threshold is a positive, non-zero threshold.

3. A diaphragm (116) for a lung demand regulator device (100) as claimed in claim 1 or 2, wherein the non-return valve (130) is adjustable so as to adjust the threshold.

4. A diaphragm (116) for a lung demand regulator device (100) as claimed in any preceding claim, wherein the threshold is one or more of:

   i) a value is that is greater than the pressure differential experienced during inhalation by the user when the diaphragm (116) is fitted in a lung demand regulator;
   ii) a value is that is greater than the pressure differential experienced during latent periods between inhalation and exhalation by the user when the diaphragm (116) is fitted in a lung demand regulator; and
   iii) a value that is lower than the pressure differential is that experienced during exhalation by the user when the diaphragm (116) is fitted in a lung demand regulator.

5. A diaphragm (116) for a lung demand regulator device (100) as claimed in any preceding claim, wherein the threshold is around 4 millibars.

6. A diaphragm (116) for a lung demand regulator device (100) as claimed in any preceding claim, wherein the diaphragm (116) perimeter is substantially circular, and wherein the opening (128) is concentric with the diaphragm perimeter.

7. A diaphragm (116) for a lung demand regulator device (100) as claimed in any preceding claim, wherein the opening (128) and the non-return valve (130) are configured to direct gas flow from the opening (128) over the second face (116b) of the diaphragm (116).

8. A diaphragm (116) for a lung demand regulator device (100) as claimed in any preceding claim, wherein a periphery of the opening (128) forms a valve seat for a sealing member of the non-return valve (130).

9. A diaphragm (116) for a lung demand regulator device (100) as claimed in any preceding claim, wherein the non-return valve (130) is formed integrally with the diaphragm (116), as a unitary component.

10. A diaphragm (116) for a lung demand regulator device (100)as claimed in any preceding claim, further comprising a biasing member configured to apply a biasing force to urge a sealing member of the non-return valve (130) into a closed position, the biasing force being of a magnitude which is overcome by a pressure force applied to the sealing member by the pressure differential at or above the threshold.

11. A diaphragm (116) for a lung demand regulator device (100) as claimed in any preceding claim, comprising a plurality of openings and a plurality of corresponding non-return valves.

12. A lung demand regulator device (100) for use with breathing apparatus (10) for delivering breathable gas from a pressurised supply to a user, the lung demand regulator device (100) comprising:

    a body (102) comprising a valve member (112) for controlling the rate of delivery of the breathable gas,
    a diaphragm (116) as claimed in any preceding claim, the diaphragm (116) having (2) the first face (116a) exposed to internal pressure within the body (102) and a second face (116b) exposed to ambient pressure outside the body (102), the diaphragm (116) being moveable relative to the body (102) responsive to a pressure differential between its first and second faces (116a, b) to control the valve member (112).

13. A lung demand regulator device (100) as claimed in claim 12, wherein the valve member (112) is configured to provide continuous breathing gas flow into the body (102) during use so as to maintain the internal pressure greater than the ambient pressure.

14. A lung demand regulator device (100) as claimed in claim 12 or 13, further comprising a cover member (118) arranged over the second face (116b) of the diaphragm (116), thereby forming a chamber (104) between the second face (116b) of the diaphragm (116) and the cover, the chamber (104) being in communication with the ambient environment.

15. A breathing apparatus (10) comprising a lung demand regulator device (100) as claimed in claim 12, 13, or 14.

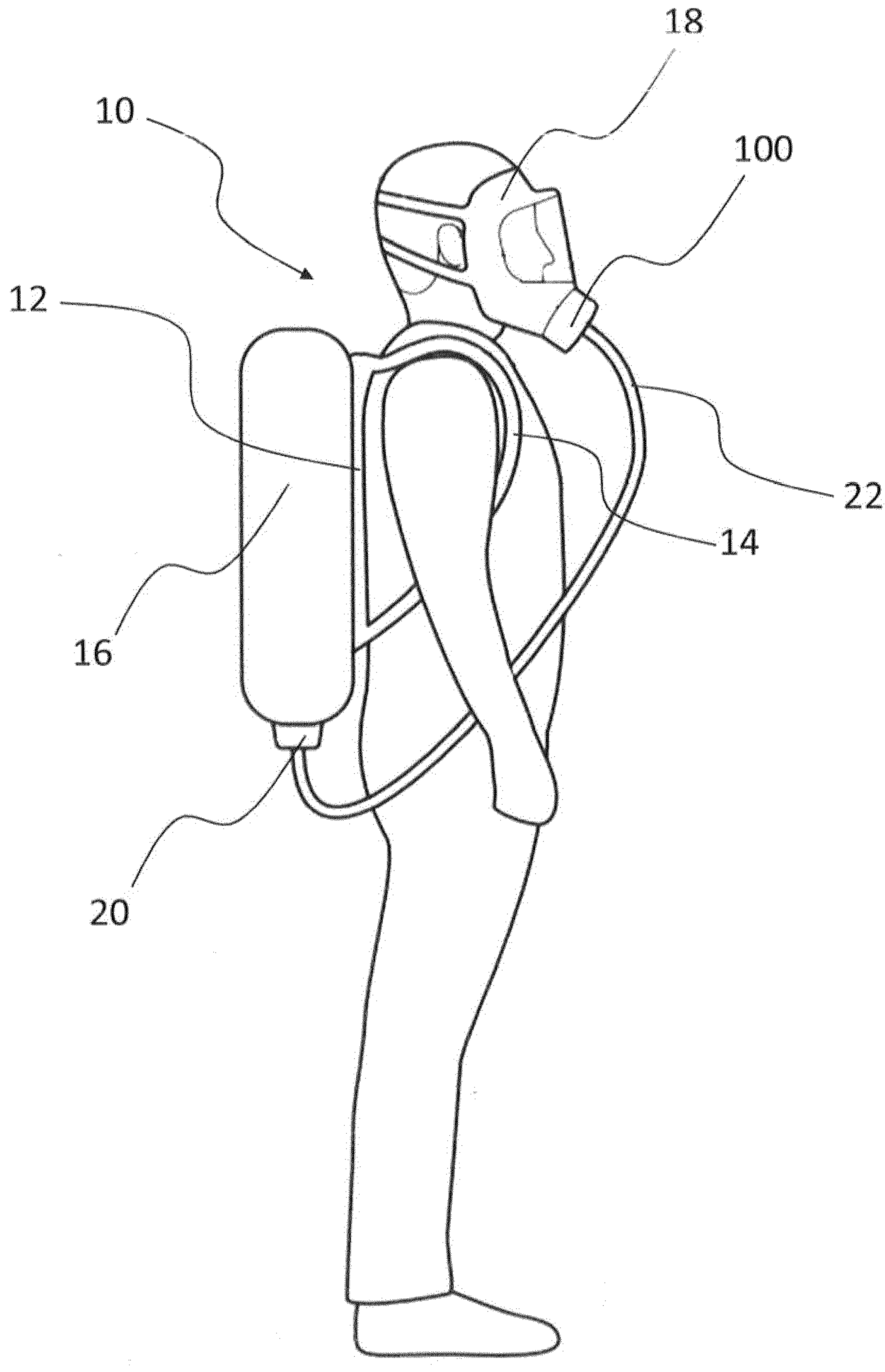

FIG. 1

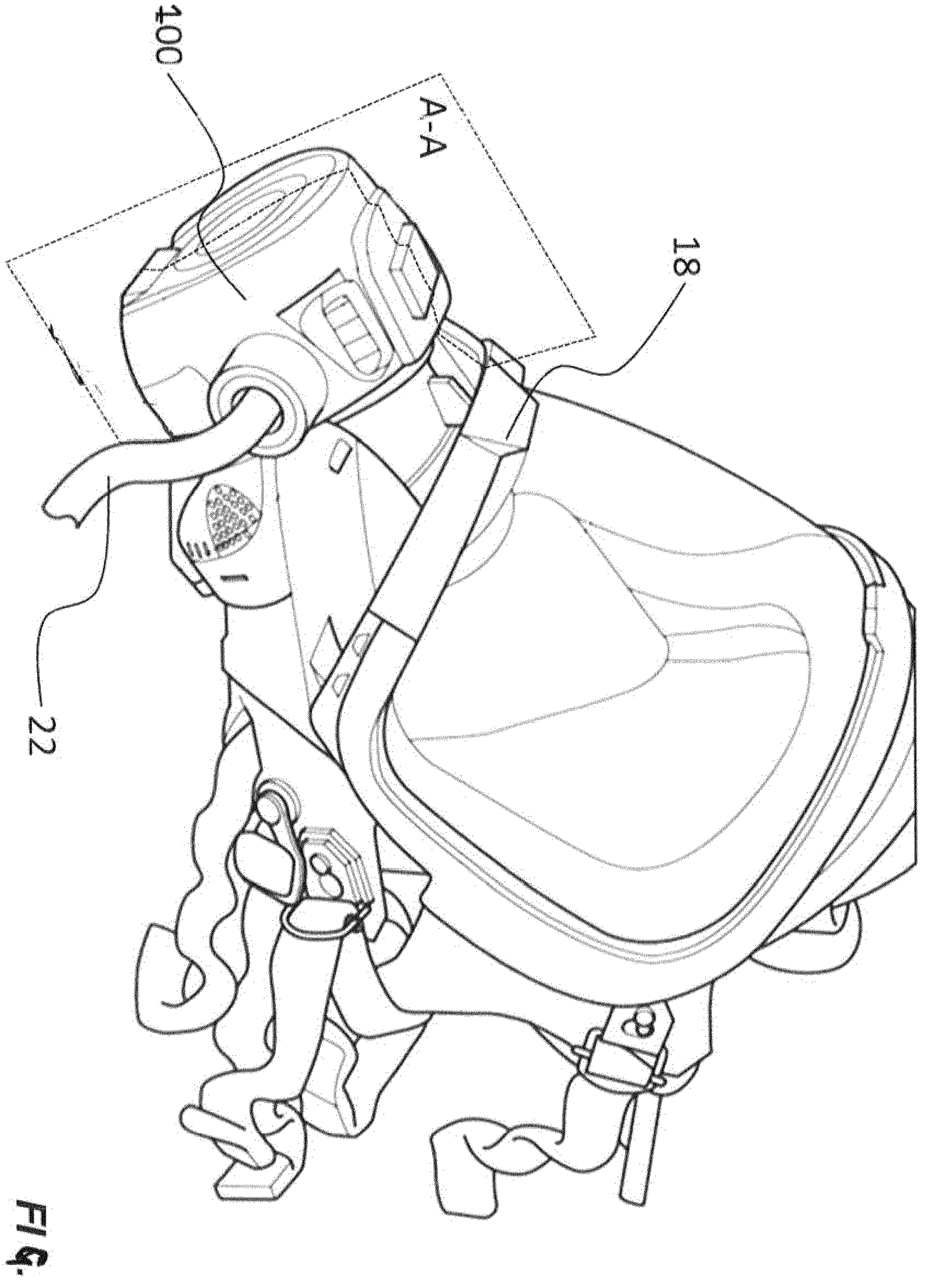

FIG. 2

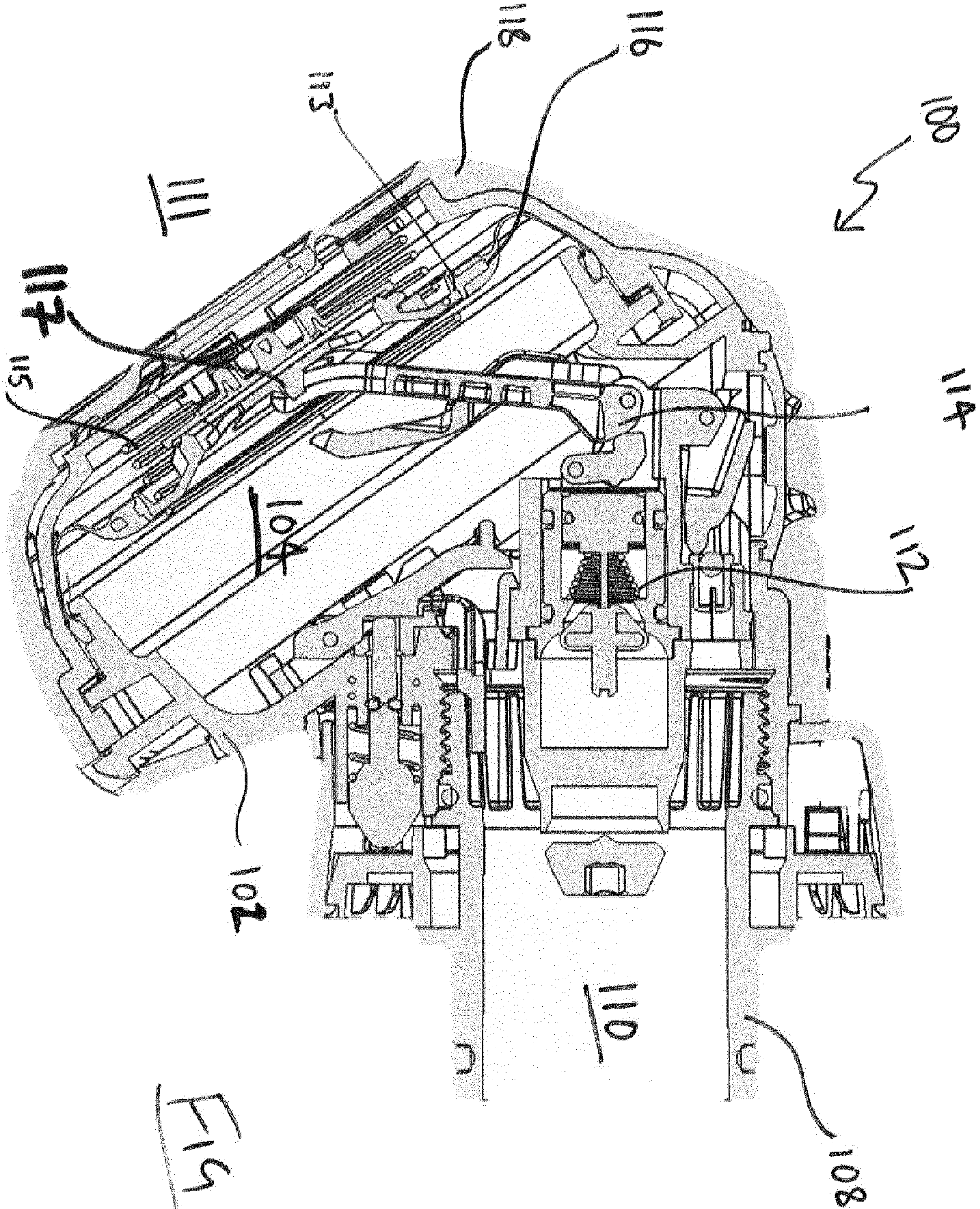

Fig 3A

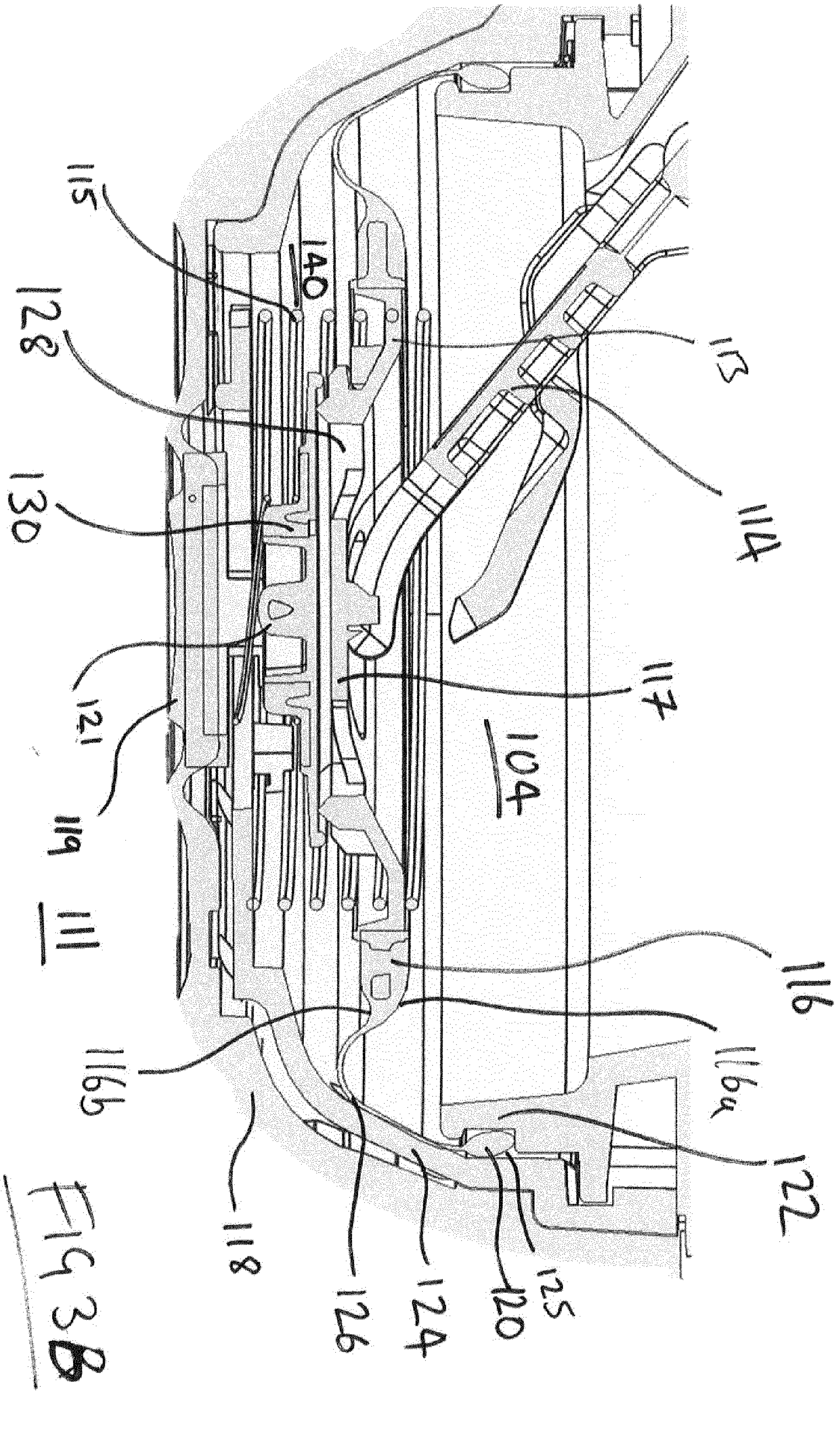
115
140
128
130
121
119
111
116b
118
126
124
120
125
122
116a
116
104
117
114
113

FIG 3B

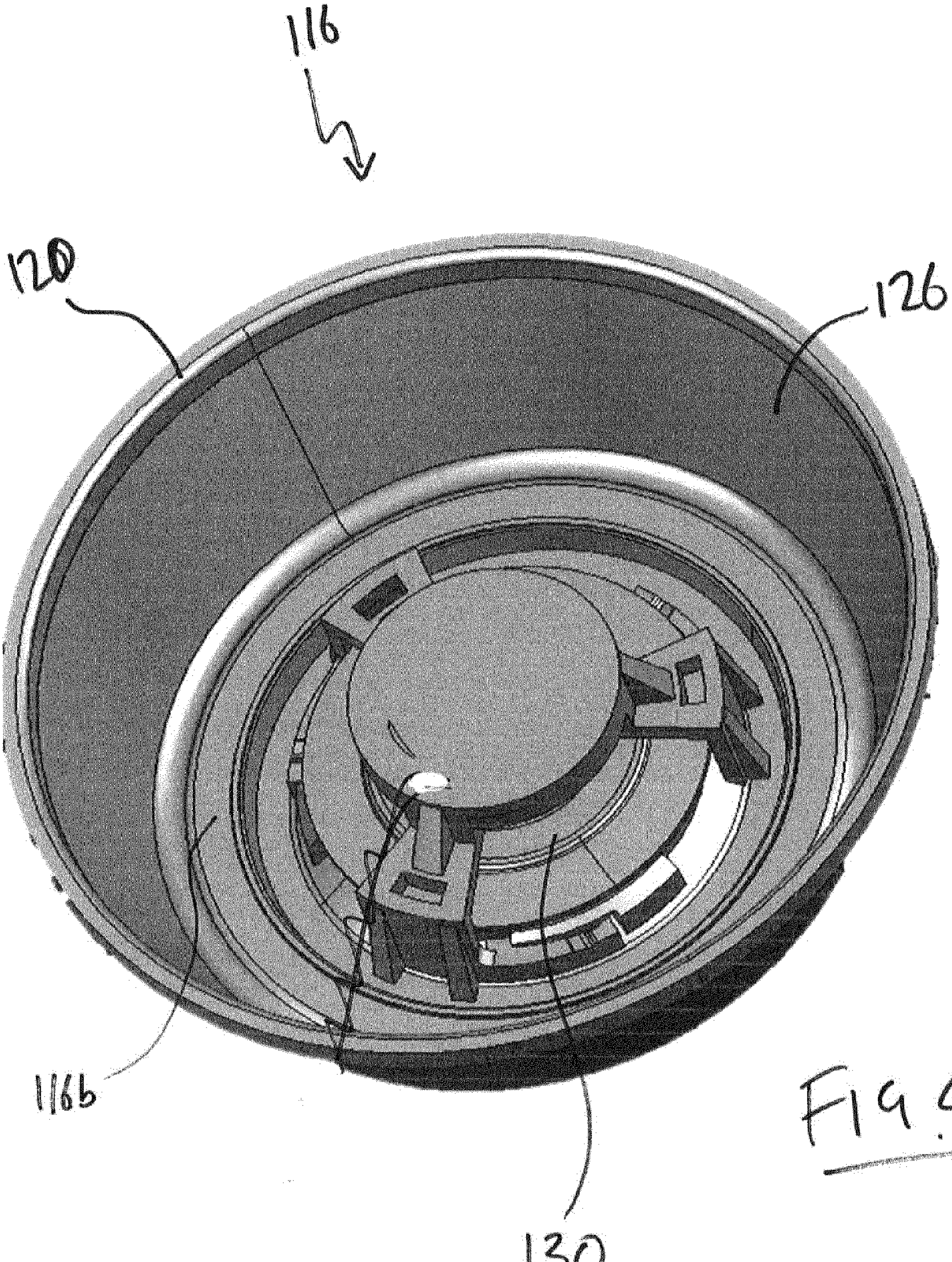

Fig.4C

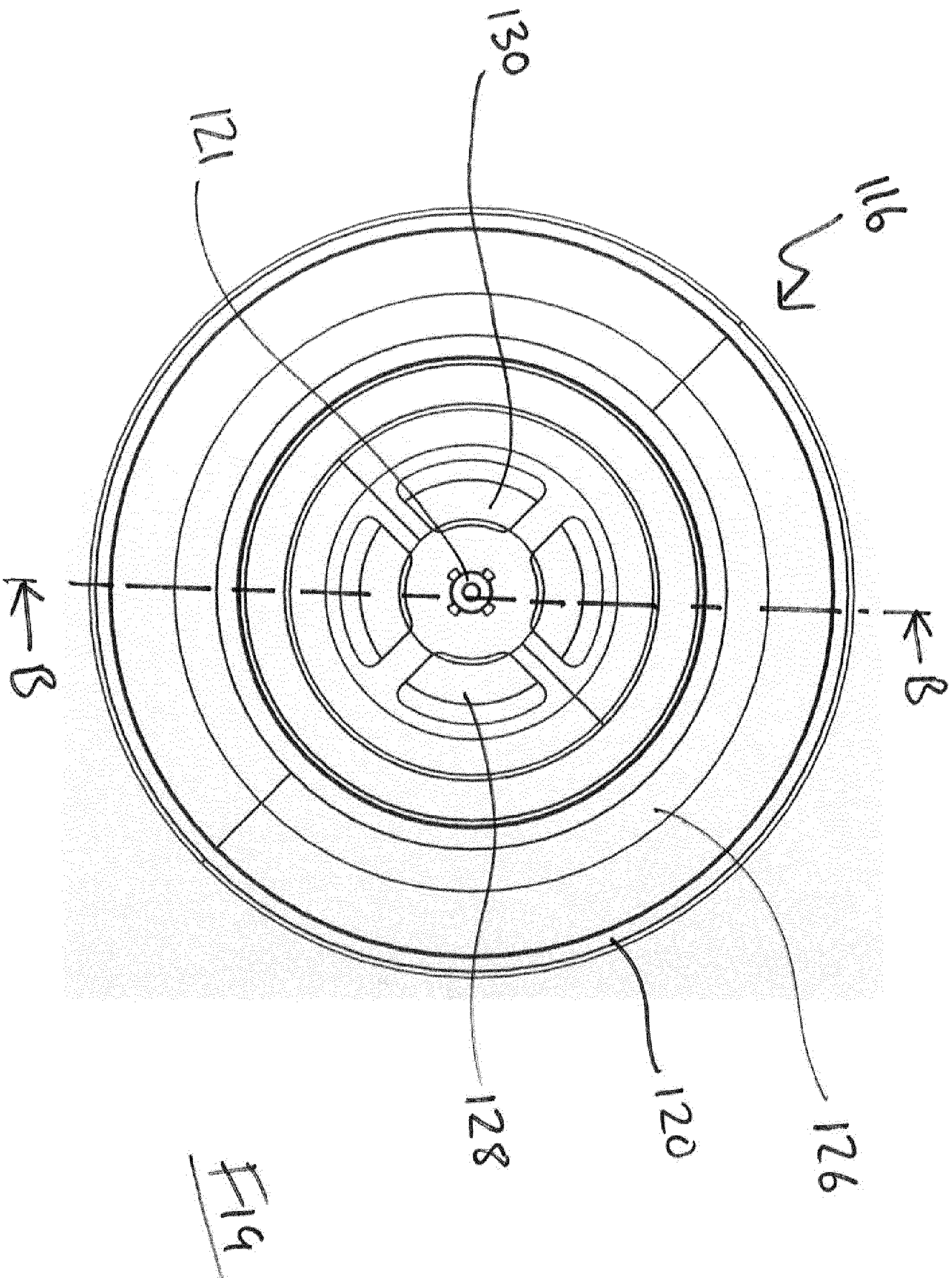

Fig 4A

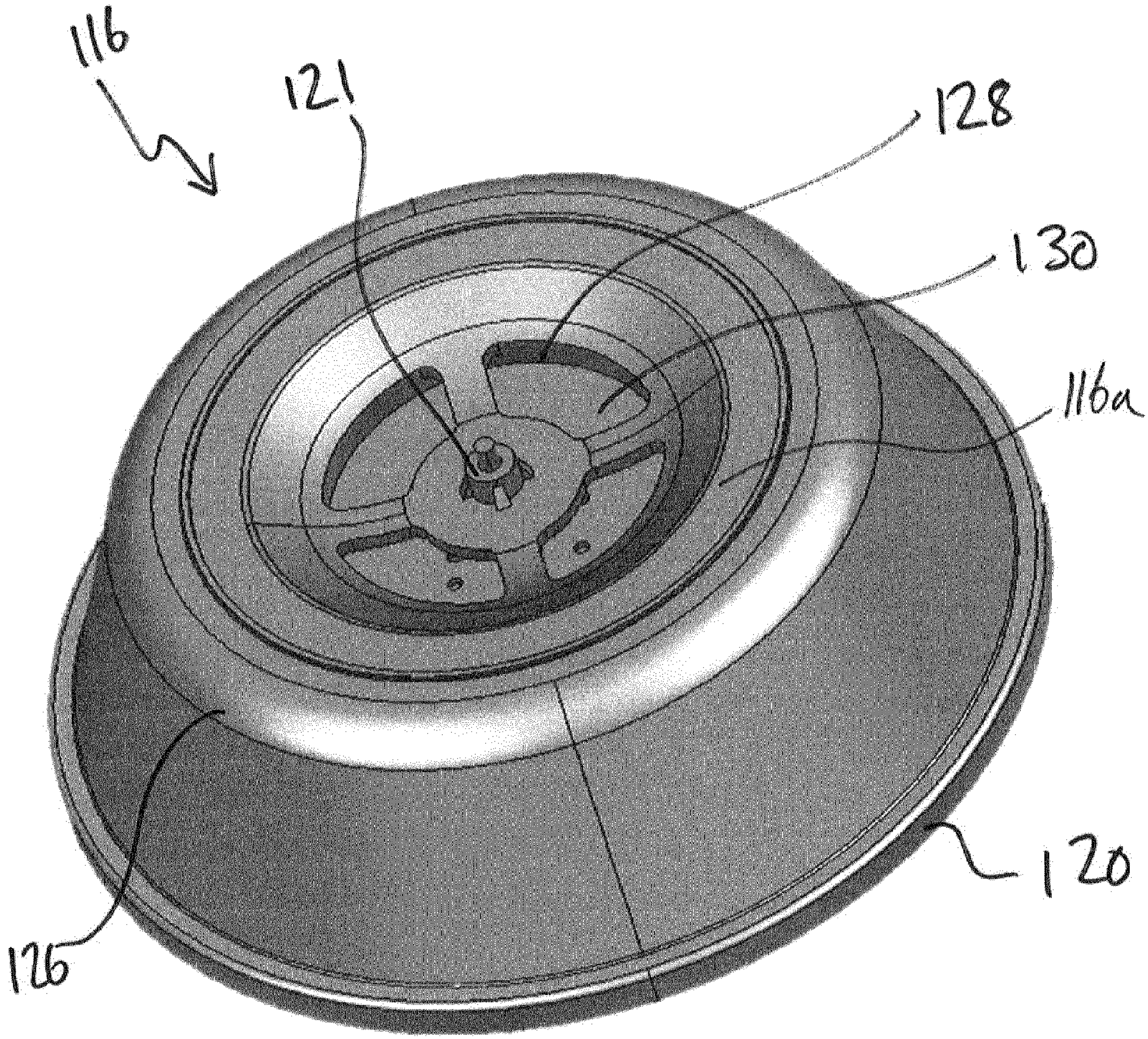

FIG.4B

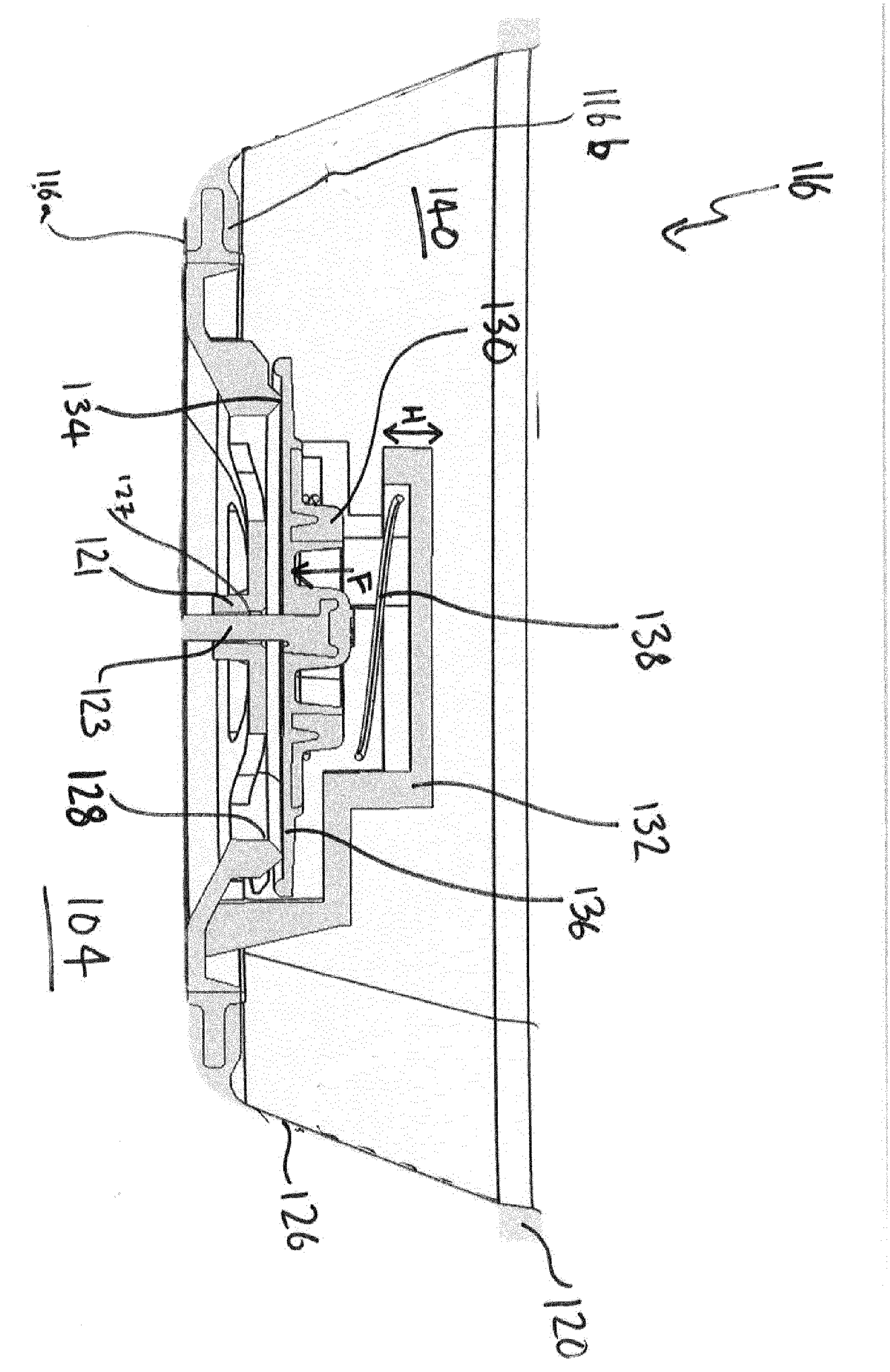
116
116b
116a
140
130
H
134
127
121
F
138
123
128
132
136
104
126
120

Fig.5A

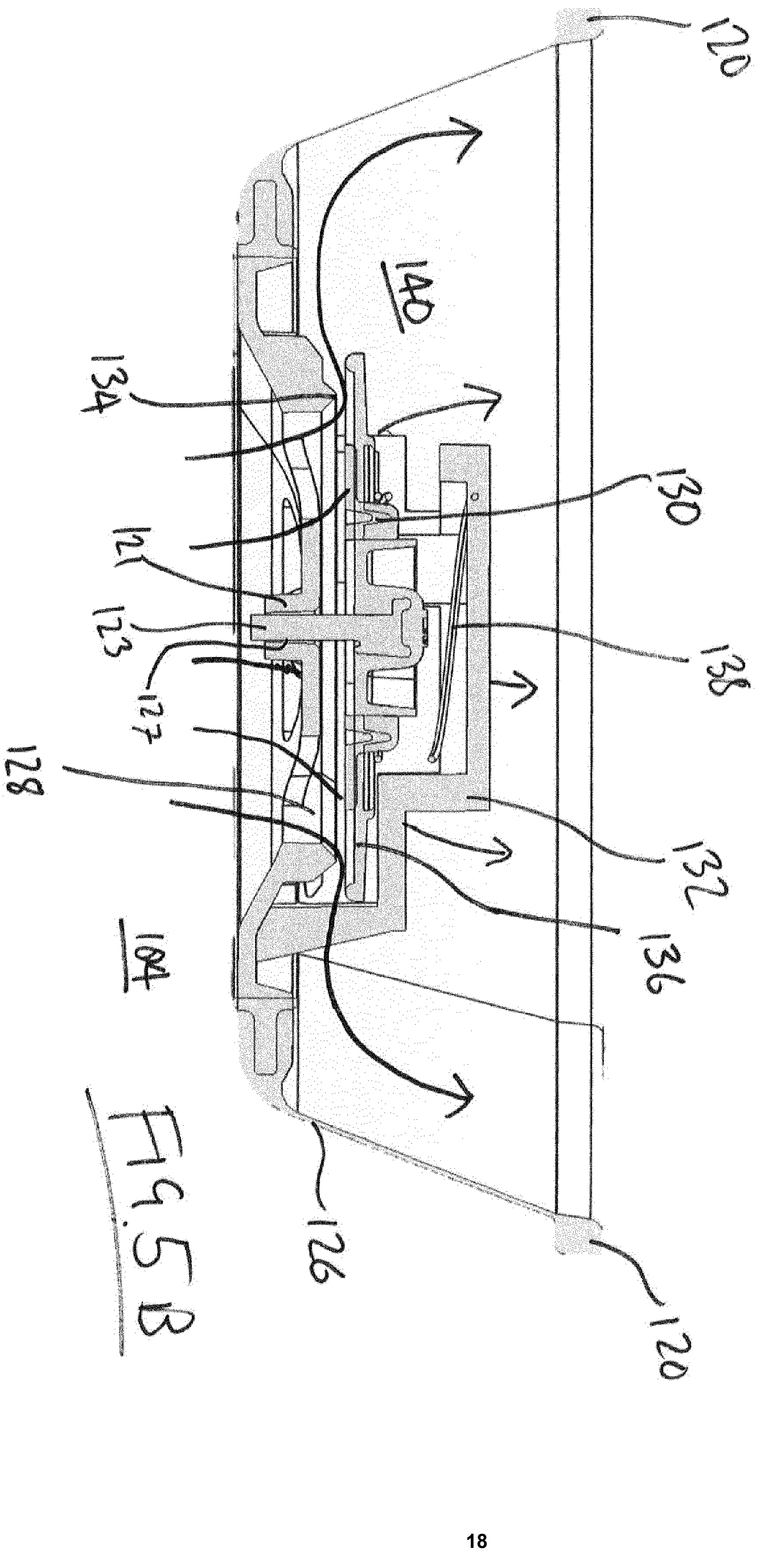

Fig. 5B

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EUROPEAN SEARCH REPORT

Application Number
EP 23 21 5528

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 A	US 4 269 216 A (SULLIVAN JOHN L ET AL) 26 May 1981 (1981-05-26) * column 1, lines 5-10 * * column 1, line 66 - column 3, line 6 * * figures 1-5 * -----	1-7,9, 10,12-15 8,11	INV. A62B7/04 A62B9/02
X A	US 6 966 316 B2 (SURVIVAIR RESPIRATORS INC [US]) 22 November 2005 (2005-11-22) * column 2, lines 35-62 * * column 3, lines 30-35 * * column 3, lines 48-58 * * column 4, lines 21-27 * * column 4, line 54 - column 6, line 48 * * column 6, line 64 - column 7, line 41 * * figures 1-9 * -----	1,2,4,5, 7-15 3,6	
X A	US 3 710 553 A (PARKER F ET AL) 16 January 1973 (1973-01-16) * column 3, lines 25-40 * * column 3, lines 54-67 * * column 4, lines 16-24 * * column 6, lines 4-53 * * figures 1-4 * -----	1-4,6, 10,12, 14,15 5,7-9, 11,13	TECHNICAL FIELDS SEARCHED (IPC) A62B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	27 May 2024	Zupancic, Gregor

CATEGORY OF CITED DOCUMENTS

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

REFERENCES CITED IN THE DESCRIPTION

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