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

(11) Publication number: **0 126 412**
A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **84105511.4**

(22) Date of filing: **15.05.84**

(51) Int. Cl.³: **A 62 B 9/02**

(30) Priority: **19.05.83 IT 2117683**

(43) Date of publication of application: **28.11.84**
Bulletin 84/48

(84) Designated Contracting States: **DE FR GB SE**

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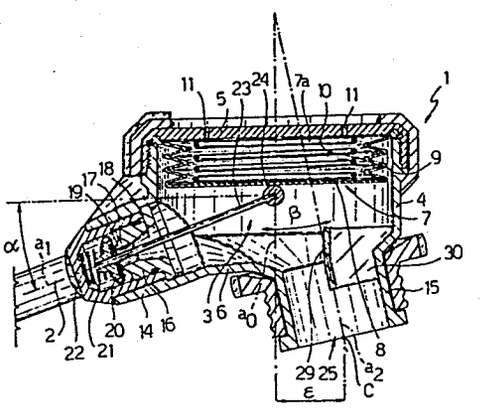
(54) Demand-valve for compressed-air breathing apparatus.

(57) What shall be described is a demand-valve (1) for delivering air into a compressed-air breathing apparatus that comprises a substantially cylindrical chamber (3), a first entry-gate (14) for admitting air into the chamber, that presents a passage-opening – controlled by intercepting-means which comprise a blocking-element (20) that is mechanically connected to a deformable membrane (7), and a second entrygate (15) predisposed for feeding-in said air. The device is characterized by the fact that, the axis (a_1) of said first entry-gate forms a first angle (α) with the bottom-surface (8) of said chamber, and that the axis (a_2) of said second exit-gate forms a second angle (β) with the lateral-surface (4) of the chamber; said two axes lying substantially on the same diametrical plane of said chamber.



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DEMAND-VALVE FOR COMPRESSED-AIR BREATHING APPARATUS

Specification

The present invention refers to an air demand-valve device of a compressed-air breathing apparatus (for open circuit compressed-air), that is apt for supplying air, at a prefixed pressure - slightly higher than atmospheric pressure, into an ambient (normally comprising an inner cavity with an anti-gas mask) of said breathing apparatus, which must result as being structurally very simple, reliable, and which must allow for a very high delivery-flow of air into the above-said ambient, and with moreover, maintaining substantially constant the ambiental-pressure itself.

A demand-valve device of the type to which the device of the invention belongs, usually comprises a chamber that communicates with a source-of-air having a mean pressure - i.e. comprised between 2 and 10 Bar., through a first-entry-gate, and with the above-said ambient, through a second-exit-gate. The passage-opening, through the first-entry-gate is controlled by intercepting-means comprising a blocking-element mechanically connected to a deformable membrane apt for defining a surface of said chamber, in such a way that - following the shifting of the membrane, the blocking-element is also shifted, for thus controlling the passage-opening. With said constructive disposition, whenever - following a pressure decrease that is verified in said ambient due to the effects of inhalation on the part of the user of the breathing apparatus, the above-said deformable membrane shifts - and the opening is effectuated of the above-mentioned blocking-element, in such a way as to allow a sufficient admission of the air-flow into said chamber for

restoring the original pressure conditions once again.

The complex - comprised by the above-said membrane and by the kinematic chain that connects it to the above-mentioned blocking-element, substantially constitutes a transducer which is apt for measuring the pressure existing inside the chamber, and for controlling - as a function of said pressure, the shifting of the blocking-element, for feeding appropriate quantities of air into the chamber.

Under the conditions described till now, the pressure existing downstream of the blocking-element is, in static terms, equal to atmospheric-pressure, and it decreases slightly during the act of inhalation - with putting the interior of the mask under vacuum. The addition of a spring - having suitable mechanical characteristics, that presses against the membrane from the outside, or else, some other device that performs the same task - allows for obtaining, in static terms, a slight overpressure, with respect to the surrounding atmosphere, downstream of the blocking-element - which, during any actual inhalation, decreases and can also change signs.

However, the air demand-valve devices of the type described, present certain drawbacks.

First and foremost, when particularly high air delivery-flows are required - as a consequence of increased and repeated inhalation on the part of the user, the air pressure existing inside said chamber - and hence, also in the ambient that communicates with the chamber itself, decreases sensibly with respect to the initial pressure. In such a situation, the respiratory efforts of the user himself, also increase -

owing to the greater difficulty had in inhaling air. Moreover, the pressure inside the mask decreases sensibly, with assuming - even in instances of the apparatus also being endowed with an overpressure spring, lower values as compared to those of atmospheric-pressure.

As a consequence of this, with the air demand-valve devices of the type described, the user is required to make non-negligible breathing efforts - and particularly, whenever greater air delivery-flows are necessary. Therefore the specified conditions of safety cannot be realized - because, in the proximity of the sealing-surface, inside the mask, the pressure can notably decrease to below that of the outside atmosphere, with thus involving risks of gases and/or vapours entering-in from the polluted surrounding ambient where the user happens to be.

The above-mentioned drawbacks depend substantially upon the fact that - apart from the atmospheric-pressure and the pressure existing inside the above-mentioned chamber, there also act, on the above-said membrane, the fluodynamic effects of the air-jet that enters into said chamber, and which - owing to the repeated surface-reflections taking place, can affect the membrane itself.

Said fluodynamic actions can have either a positive or a negative sign - and can vary considerably, besides irregularly, as a function of the air-flow delivered by the device, with also changing signs, and with resulting as being strongly resistent to static action in instances of any greater air-flows. Therefore, for obtaining these actions, a vacuum is often required - and hence, an effort on user's part, that proves to be much greater than what is foreseen by

a calculation of static-balance. It results from this that, to-date, there are many constructors who have conceived various, more or less complex, devices for eliminating any direct contact of the dynamic air-flow upon the surface of the membrane itself - for suppressing in this way, the above-described fluodynamic effect.

The aim of the present invention is to realize an air demand-valve device for a compressed-air breathing apparatus of the previously indicated type, but which will be in a condition to eliminate the above-mentioned drawbacks, and which, in particular, will be apt for supplying air - that is sensibly constant and of a better quality than the air of the surrounding atmosphere, into the ambient of the breathing apparatus, and even in those instances when the air-delivery flows may be considerably increased.

On the basis of the present invention, there has been realized an air demand-valve device for a compressed-air breathing apparatus, that is apt for supplying air, at a pre-fixed pressure, into an ambient of said breathing apparatus, said device comprising a chamber that is substantially cylindrical and a first air-entry-gate into the chamber, which substantially opens out onto the lateral surface of said chamber, and which communicates with a source of compressed-air, and which presents a passage-opening that is controlled by intercepting-means - comprising a blocking-element mechanically connected to a deformable membrance which is apt for defining a base-surface of said chamber, in such a way that - following the shifting of said membrane, the said blocking-element is also shifted for controlling said opening, the said device comprising moreover, a second exit-gate disposed on the other base-surface of said chamber,

and predisposed for feeding said air into said ambient, and being characterized by the fact that the axis of said first-entry-gate forms a second angle with the axis of said lateral surface, said two axes lying substantially on the same diametrical plane of said chamber.

Said first angle is opportunely comprised between 15° and 25°, and said second angle is comprised between 5° and 15°. Moreover, for convenience sake, the distance between said axis of said lateral surface, and the point-of-intersection of said axis of the second gate with the plane that frontally delimits the gate itself, is comprised between 20% and 35% of the diameter of said chamber.

For having a better comprehension of the device of the present invention, there will now be given, solely by way of example, the description of one particular form of realization with making reference to the attached drawings, whereby:

- FIGURE 1 represents a vertical section of the air demand-valve device of the invention;

- FIGURE 2 represents a plane view, partially in section, of the device of FIG. 1; FIGURES 3 and 4 represent sections - of a part of the air demand-valve device of Fig. 1, in two different operative positions;

- FIGURE 5 represents certain diagrams apt for illustrating the curve of the air-pressure delivered, as a function of the air-flow capacity itself, that is encountered in the device of the invention, as well as in the devices of the prior art of the same type.

First and foremost, referring to FIG. 1, the air demand-valve device of the invention - indicated in its complex whole with the reference numeral 1, is apt for being interposed between a compressed-air feeding breathing-tube 2 and an ambient (not shown) comprised, for example, by the space inside an anti-gas mask, into which breathable air has to be fed.

The device comprises a substantially cylindrical chamber 3, delimited by a lateral-wall 4 and a pair of substantially flat base-walls 5 and 6. Inside the chamber 3, there is disposed a membrane 7 which comprises a substantially flat base-wall 8 and a lateral-wall 9, that presents a plurality of corrugations apt for rendering said membrane substantially deformable in the direction of the axis of the chamber 3. With the wall 5, said membrane defines another chamber 10, which communicates with the atmosphere through one or several holes 11, made in the wall 5. For convenience sake, the device can comprise a spring 7a, disposed inside the membrane 7 and predisposed for exercising a prefixed axial-force on the flat wall 8. The device comprises moreover, a first entry-gate 14 - that is apt for putting the tube 2 into communication with the chamber 3, and which is made substantially in the lateral-wall 4 which delimits said chamber, and a second exit-gate 15 - for putting the latter into communication with the internal ambient of the mask, and which is made in the base-wall 6 that also delimits the chamber itself.

Inside the entry-gate 14, there is disposed a bush 16, provided with a pair of axial holes 17 and 18 - of which the first is cylindrical and the second conical, as well as with a seat 19 having a substantially annular form, apt for

housing the blocking-element 20 that is normally held against said seat by means of a spring 21 - interposed in-between the latter and another bush 22 that is screwed into a threaded-hole made inside the entry-gate 14 - as is clearly visible in FIG. 1.

The blocking-element 20 is made solidal with a rod 23 that goes through the holes 17 and 18, and whose extremity is provided with a stylus 24 apt for collaborating with the surface of the wall 8 of the membrane 9.

On the basis of the invention, the axis of the first entry-gate 14 - indicated with a_1 in FIG. 1, forms a first angle α with the base-surfaces that delimit the chamber 23 and, in particular, with the surface of the flat wall 8 of the deformable membrane 9. Moreover, the axis of the second exit-gate 15, indicated with a_2 in Fig. 1, forms a second angle β, with the axis a_0 of the chamber itself; the two axes, a_1 and a_2, lie substantially in the same diametrical plane of the chamber 3 - which coincides with that in the drawing of FIG. 1.

For the purpose of achieving the aims that shall be indicated further on in the text, the angles α and β are comprised respectively between 15° and 25° and between 5° and 15°. Moreover, the distance - between the axis a_0 of the chamber 13 and the intersection point C of the axis a_2 of the exit-gate 15 with the plane that frontally delimits the gate itself (and which has been indicated with ε in FIG. 1), is comprised between 20% and 35 % of the diameter of said chamber. In this manner, the opening of the outlet 25 of the exit-gate 15, results as being substantially eccentric with respect to the axis a_0 of the chamber 3 - as clearly results

in FIG. 1.

Inside the chamber 3, and in the vicinity of the lead-in of the second gate 15, there is disposed a substantially flat wall 29. The plane of said wall is substantially parallel to that of the axis a_0 and perpendicular to the plane that contains the axes a_1 and a_2 respectively, of the gates 14 and 15. Moreover, the said wall comprises, for convenience sake, a rib 30, having the function of conveying the air-flow, as well as that of acting as a stiffening.

Next, the half-opening of the conical surface - that delimits the second hole 18, downstream of the blocking-element 20, is comprised between 16° and 18°. The ratio, between the axial length of the first and second hole 17 and 18, is comprised between 0.85 and 0.45; whereas, for convenience sake, the axial lengths of the holes themselves, are comprised between 4 and 6 mm and between 7 and 9 millimeters respectively.

To end with, the ratio between the diameter of the first hole 17 and its axial length, is comprised between 0.85 and 1.32, and - for convenience sake, the diameter of the hole itself, is comprised between 5.1 and 5.3 mm.

In practical usage tests, the air demand-valve device described, has - quite surprisingly, proved to function in a very satisfactory way. It has been endeavoured to give a rational explanation, with the following considerations, which must be taken as being qualitative - since the complexity of the forms, and of the surface reflections in particular, that are for the most part curved, impede obtaining, with any precise mathematical calculus, an exact prevision of the behaviour of the device itself.

When it is inserted into the circuit of the self-breathing apparatus, there exists inside of chamber 3 - between the compressed-air feeding tube 2 and the mask of the compressed-air breathing apparatus itself, and under normal functioning conditions of the device, a pressure that is slightly higher than atmospheric-pressure - for example: a pressure that has from 30-40 mm of water-column height above said pressure. As is already known, such a pressure inside the chamber 3 - and hence, in the ambient of the compressed-air breathing-apparatus into which breathable air must be introduced, offers a greater guarantee of safety for the user - since, under such conditions, there is impeded any infiltration of gases or vapours from the polluted surrounding atmosphere wherein the user happens to be.

If it is supposed that the spring 7a is absent (a functioning condition that can be defined as "negative pressure") the membrane 9 becomes disposed in a balanced position, depending upon the pressure value that exists inside the chamber 10 - which acts on one of the surfaces of the wall 8, and the above-said pressure that exists in the chamber 3 - which acts upon the other surface of the wall itself. When the pressure inside the chamber 3 is reduced, even to a modest extent - following an inhalation, said 'balanced condition' becomes changed and the wall 8 of said membrane, shifts towards the stylus 24, determining the rotation of the rod 23 substantially in the plane of the drawing of FIG. 1, for controlling the opening of the blocking-element 20 - which substantially assumes the configuration illustrated in FIG. 3, whereby it leans just on a very restricted zone of the housing 19, with leaving free a part having prefixed dimensions, through which there is established an air-flow

entry into the chamber 3.

The addition of a spring such as 7a - having suitable mechanical characteristics, which presses against the wall 8 of the membrane 7 (or some other such device for carrying out the same task), allows for obtaining - under static conditions, a slight overpressure, with respect to the surrounding atmosphere, downstream of the blocking-element - and hence, inside of the mask; which said overpressure becomes reduced during the act of inhalation and can also change its sign. This functioning condition can also be defined as being "positive pressures".

The above-said air-flow that, given the pressure conditions inside chamber 3 and inside tube 2, realizes a true and proper supersonic expansion - enters into said chamnber through a plurality of axial deviations that are comparable, for simplicity sake, to reflections on the walls of the holes 17 and 14 - for example: according to the succession of reflections indicated with the broken-line of FIG. 3. As can clearly be seen from said broken-line, the above-said flow follows a trajectory comprised by a succession of rectilineal tracts, as a consequence of these said reflections, which do not interfere with the flat wall 8 of the membrane 9. In particular, the trajectory tract indicated with t_0, by which the above-said flow passes through chamber 3 - substantially in the transversal direction, has a slightly inclined direction with respect to the plane of the wall, in such a sense as to draw away from it, so as to strike further surfaces inside of the chamber 3 and to come out from the exit-opening 15, through the means of a series of further reflections.

A trajectory of this type, i.e. comprising a succession trajectory-tracts - none of which strike the wall 8 of the membrane 9, is the result of the form of the disposition of the various parts of the device and, in particular, of the relative position of the axes a_1 and a_2 of the gates 14 and 15, defined by the angles α and β, of the presence of the eccentricity presented by the exit-gate 25 of the gate 15 with respect to the axis a_0 (eccentricity ε), as well as by the form and the dimensions, defined previously, for the holes 14 and 17, downstream of the blocking-element 20.

It has been verified that, whenever the previously mentioned geometrical parameters are selected from the indicated ranges of values, the favourable condition - for realizing trajectories of air-flows from the entry-gate 14 to the exit-gate 15, with trajectories that never interfere with the wall 8 of the membrane 9 - is obtained not only for a particular opening angle of the blocking-element 20, but substantially for opening angles which go from zero to a maximum angle - to which correspond considerably high air-flow entries into the chamber 3, that are necessary for feeding breathable air for the user, with continuity, even under the most unfavourable operative conditions. In FIGS. 3 and 4, there have been indicated two different configurations of the membrane 9, to which correspond two diverse opening-angles of the blocking-element 20. There are also shown herein, the trajectories of the air-flows which are obtained presumably, in these two instances. As can be clearly seen, none of these comprise flow-tracts that strike the membrane 8.

It has also been verified that the first wall 29, inserted into the first position indicated inside of the chamber 3, also contributes for conveying the air-flow towards the exit-

gate 15. Moreover, said wall can constitute the end-stop limiter, for the shifting-movement of the wall 8 of the membrane 9.

Therefore, it is evident that, with the air demand-valve device of the invention, any negative fluodynamic actions on the membrane 8 generated by the air-jet entering chamber 3, is prevented, i.e. those actions which tend to take membrane towards the at-rest conditions corresponding to the null flow - and without even needing to have recourse to any costly and complex mechanisms for removing the membrane from the effects of said air-flow; but instead, it is had that, through the effects of the air-flow divergence from the membrane, as can be seen in FIGS. 3 and 4, the action of said membrane on the blocking-element 20 is amplified in such a way as to achieve a minimum lowering of the pressure (or of the overpressures) existing inside the mask for the entire field of instantaneous respiratory intensity, as necessited by human physiology (upper limit about 300 1/min). Under these conditions, an air-flow having a very high capacity can be controlled, without any particular respiratory effors on the user's part. It has been found that, under particular functioning conditions of the device, involving trajectory tracts that tend to draw away from the membrane 8 (as was shown in the instance of FIGS. 3 and 4), there is even had a suction action upon the membrane, which can favour the opening of the blocking-element whenever very high air-flows must be supplied.

In FIG. 5 there is indicated, with the curve A, the development of the pressure inside the chamber 3 as a function of the air-flows supplied. As can be seen from said curve, inside of the chamber 3 there exists a substantially

constant pressure (no matter what the flow of air supplied may be) comprised within the range that concerns those applications to which the air demand-valve device of the invention is intended. Moreover, the above-said pressure tends to become lower, only in correspondence of the upper value limit of the above-said range of values - without however, creating a depression inside the mask to which the air-breathing device itself is connected.

In the same FIG. 5, there are represented, with the curves B and C, the pressure-flow characteristics, for other known air breathing-devices of the type described. As can be seen, not only is a sensible reduction of pressure had - as soon as the air-flow introduced by the device tends to increase, but said pressure can become already negative because of the flow-values comprised within the range that concerns the viewpoint of practical applications.

In said FIGURE, the scales given on the left-hand side, relate to a functioning-configuration with "positive pressures" (obtained through the presence of the spring 7a); whereas those given on the right-hand side, relate to a functioning-configuration with "negative pressures" (obtained without the spring 7a).

The air demand-valve device of the invention - apart from its presenting the favourable properties described previously, results as also being constructively very simple - because of its being constituted of a only a few elements that can easily be constructed and which do not require any restricted working tolerances. Hence, this device results as also being very reliable - seeing that it maintains, during the course of its usage, the favourable characteristics that have been

previously described.

What results as being obvious, is that to the forms of realization described in the present invention, there can be brought about modifications and other alternative variations - both, in the form as well as in the disposition of the various parts, without this exiting in any way from the ambit of the inventive idea itself.

WHAT IS CLAIMED IS:

1. Air demand-valve device (1) for a compressed-air breathing apparatus, apt for distributing air at a pre-fixed pressure into an ambient of said compressed-air breathing apparatus, said device - that comprises a substantially cylindrical chamber (3) and a first air entry-gate (14) into the chamber, which opens out substantially upon the lateral surface of said chamber, is in communication with a source of compressed-air and presents a passage-opening controlled by intercepting-means, comprising a blocking-element (20) fixed mechanically to a deformable membrane (7) apt for defining a substantially flat base-surface (8) in said chamber, in such a way that, following the shifting of said membrane, said blocking-element is also moved for controlling said opening, the said device comprising moreover, a second gate (15) disposed on the other base-surface of said chamber and predisposed for feeding said air into said ambient, characterized by the fact that the axis (a_1) of said first-gate forms a first angle (α) with said base-surfaces (8) of said chamber and the axis (a_2) of said second-gate (15) forms a second angle (β) with the axis (a_0) of said lateral surface, said two axes lying substantially on the same diametrical plane of said chamber (3).

2. Air demand-valve device, according to CLAIM 1, characterized by the fact that said first angle is comprised between 15° and 25° and said second angle is comprised between 5° and 15°.

3. Air demand-valve device, according to CLAIMS 1 or 2, characterized by the fact that the distance (ε), between said axis (a_0) of said lateral surface and the point-of-

intersection (C) of said second-gate's axis with the plane that frontally delimits the gate itself, is comprised between 20% and 35% of the diameter of said chamber.

4. Air demand-valve device, according to one of the previous Claims, characterized by the fact that it comprises a diaphragm, disposed inside said chamber, comprising at least a flat wall (29) disposed in the vicinity of the mouth of said second-gate and on a plane that is substantially parallel to said axis (a_0) of said lateral surface and perpendicular to said plane that contains the axes of the gates (a_1, a_2).

5. Air demand-valve device, according to one of the previous Claims, wherein, downstream of said blocking-element (20), said gate comprises a first, substantially cylindrical hole (17) and a second hole (18) delimited by a conical surface, characterized by the fact that the half-opening of said conical surface is comprised between 16° and 18°.

6. Air demand-valve device, according to CLAIM 5, characterized by the fact that the ratio between the axial length of said first and second holes, is comprised between 0.85 and 0.45.

7. Air demand-valve device, according to CLAIM 4 or 5, characterized by the fact that the axial lengths, of said first and said second hole, are comprised respectively, between 4 and 6 mm. and between 7 and 9 mm.

8. Air demand-valve device, according to one of the CLAIMS from 5 to 7, characterized by the fact that the ratio - between the diameter of said first hole and its axial length,

is comprised between 0.85 and 1.32.

9. Air demand-valve device, according to CLAIM 8, characterized by the fact that the diameter of said first hole, is comprised between 5.1 and 5.3 mm.

10. Device, according to CLAIM 1, characterized by the fact that said membrane (7) comprises a substantially flat and indeformable base-surface (8), apt for defining said base-surface of said chamber, and a deformable lateral surface (9) provided with a plurality of corrugations.

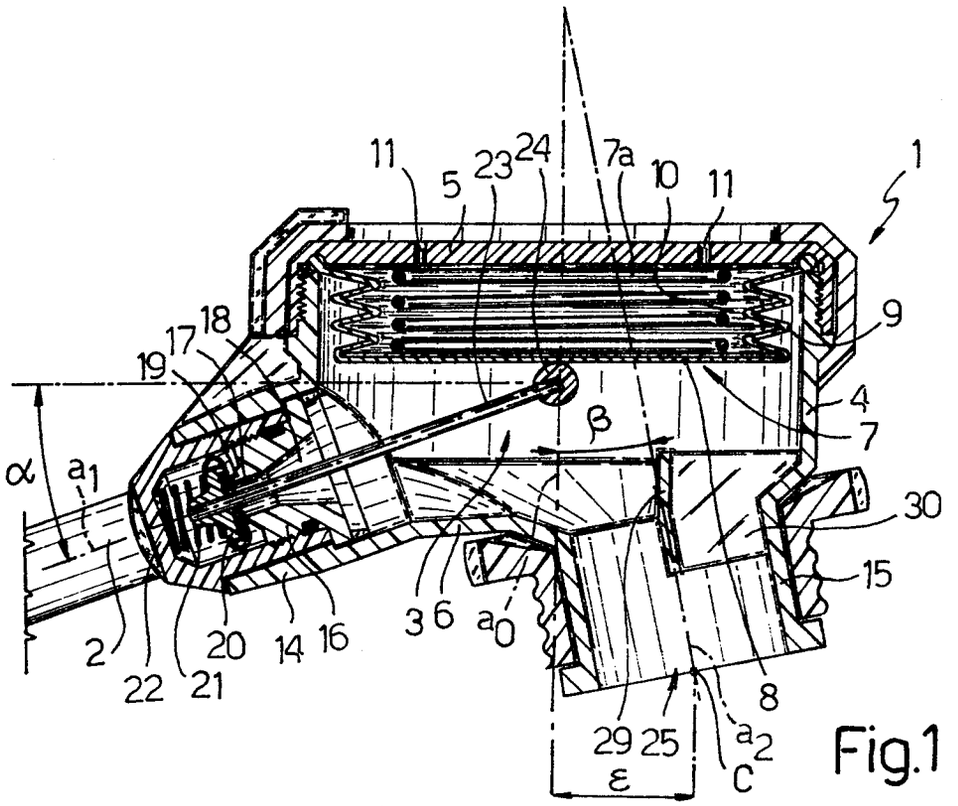
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Fig.1

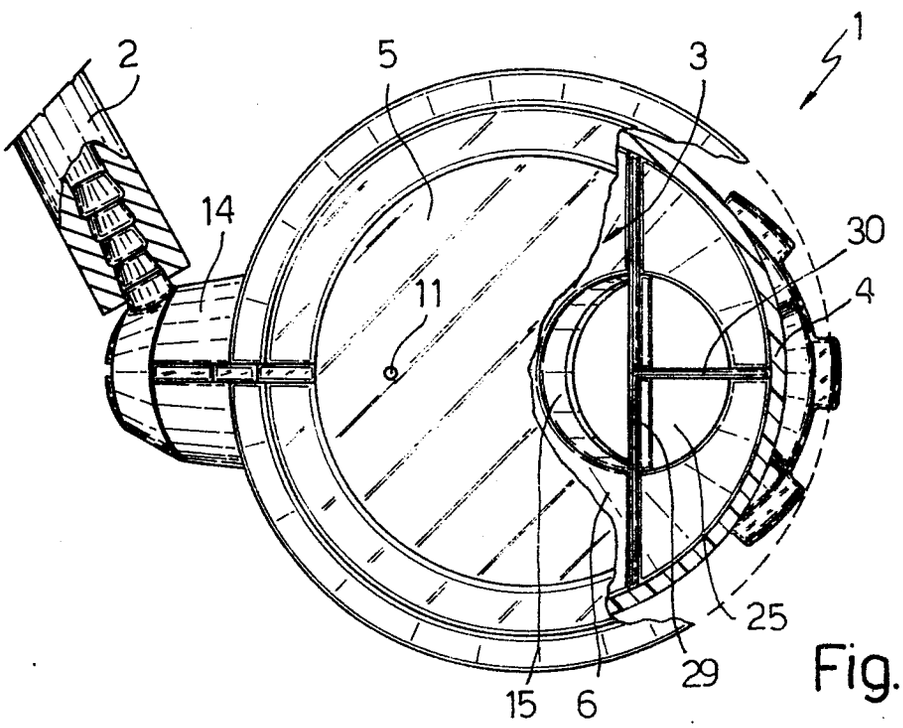
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Fig.2

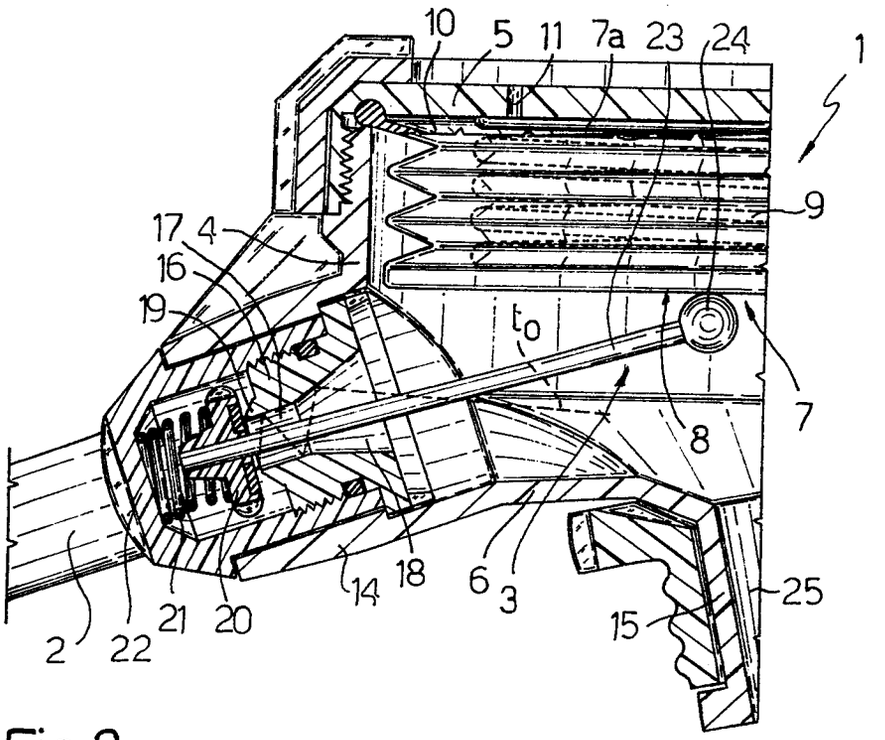
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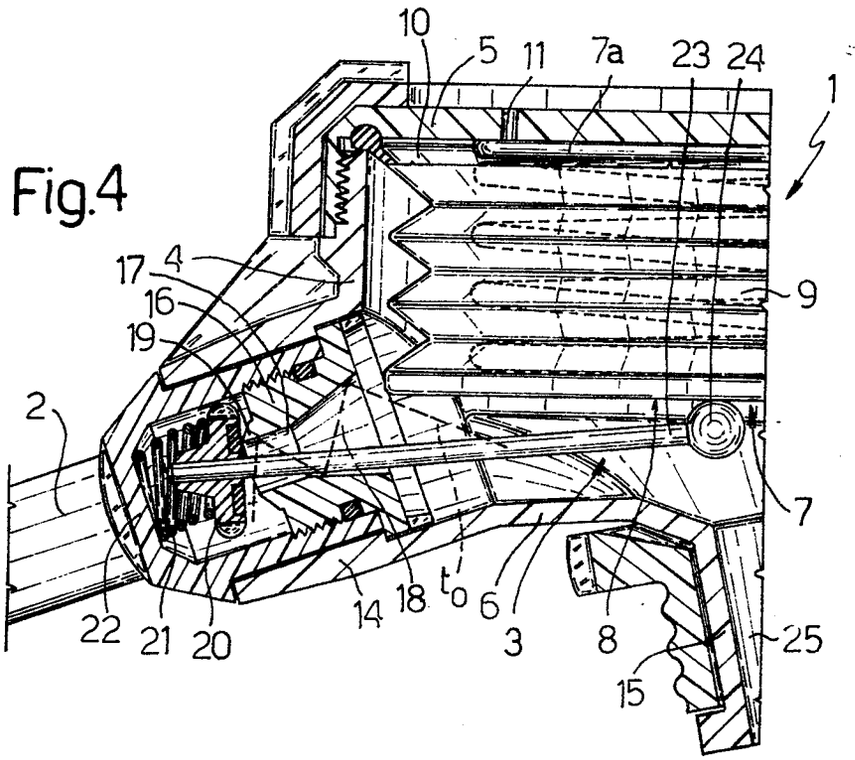
Fig.3

Fig.4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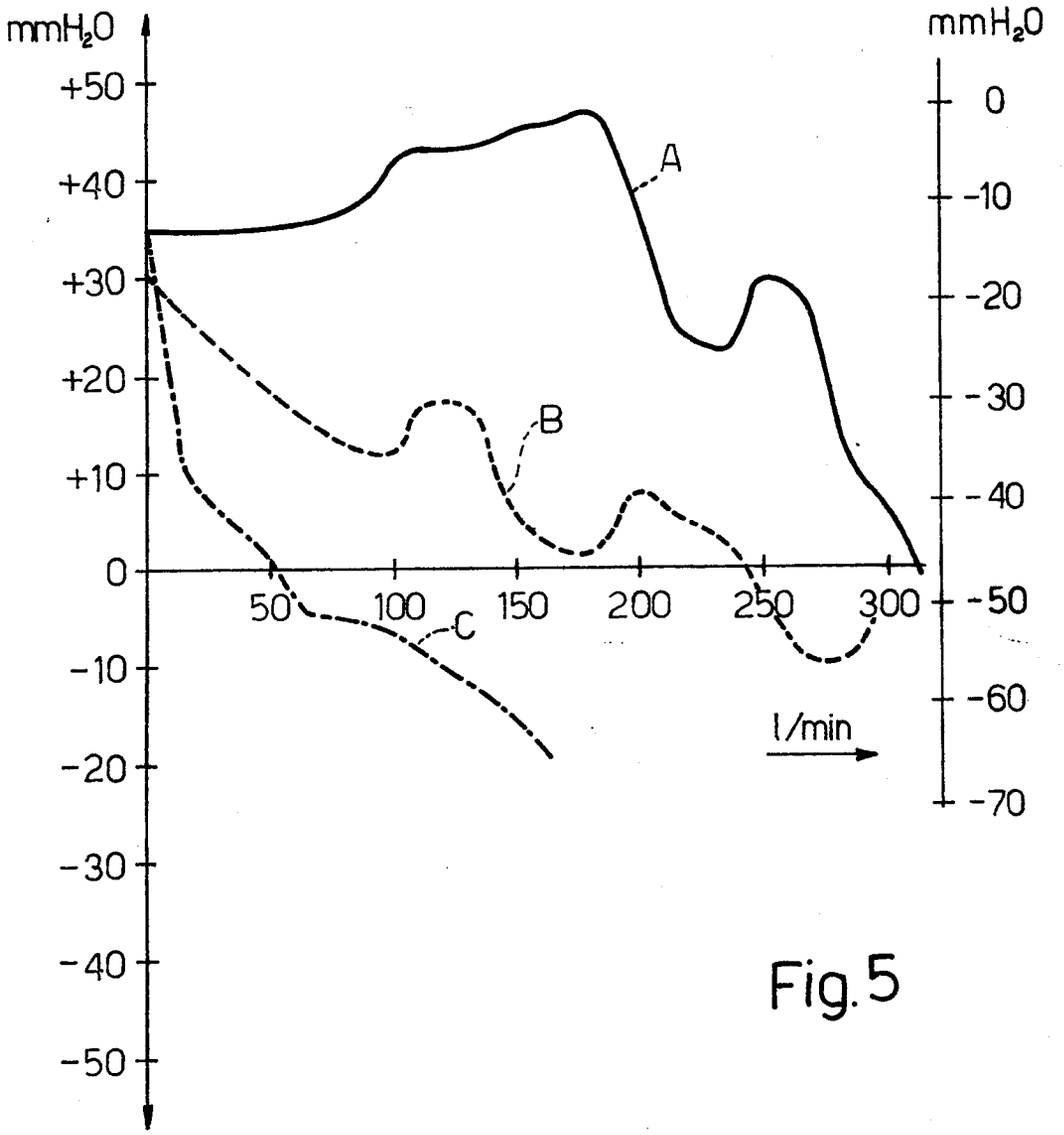
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Fig.5