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(54) **Valve**

Ventil

Valve

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(73) Proprietor: **Maquet Critical Care AB**
171 95 Solna (SE)

(72) Inventor: **Höglund, Kasper**
144 63 Rönninge (SE)

(74) Representative: **Stein, Jan Anders Lennart et al**
Albihns Stockholm AB,
Box 5581
114 85 Stockholm (SE)

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Description

[0001] The present invention relates to a valve and in particular to one connectable to a common flow path for inspiration and expiration gas in a patient ventilation system to provide separate the flows paths of the inspiration and expiration gases.

[0002] Known patient ventilation systems, such as respirators, ventilators and anaesthetic delivery systems, have associated with them tubing circuits. These tubing circuits commonly include an inspiration gas line for delivering breathing gas from the ventilation system to a patient and an expiration gas line for taking expired gas from the patient to the air or other expiration gas receiving facility. In common usage the tubing circuit may need to be frequently removed for cleaning or replacement, perhaps on a daily basis, in order to minimise the possibility of bacterial growth within the circuit which could infect the patient. Additionally, long lengths of flexible tubing in an inspiration arm and a separate expiration arm makes the determination of the patient's tidal volume and lung-thorax compliance difficult since the tubing tends to expand and contract radially in response to pressure variations during a breathing cycle. Patient comfort needs also to be considered and some patients, especially "home-care" patients, wish to move around in their "care environment" and obviously the smaller the amount of tubing the easier and more comfortable it will be for them as they move. It is therefore desirable to minimise the length and the number of tubes within the circuit.

[0003] This may be achieved by providing a common flow path for the inspiration and the expiration gases which therefore replaces two gas lines with only one for a part of the tubing circuit. In order to be able to do this a valve arrangement is required that is able to separate inspiration and expiration gas flows in order to prevent the patient re-breathing expired gases or to enable the inspiration gas and the expiration gas to be treated separately within the ventilation system.

[0004] One known valve which is used in ventilation systems to achieve this result is disclosed in US 5,002,050. This valve comprises a valve body having an inlet for inspiration gas, an outlet for expiration gas and a common inlet/outlet for connecting the valve to the airway of a patient. Concentrically arranged inner and outer gas flow conduits are also provided, each having one end connected to the common inlet/outlet via a common gas flow passage and having their other ends respectively connected to the inlet and the outlet. A differential area valving means is located towards the end of the inner conduit and arranged so that inspiration gas always impinges on its larger surface area. This inspiration gas provides operational control of the valve so that its opening and closing is dependent on the pressure exerted by the inspiration gas on the valving means The valving means is slidable along the common axis of the valve in response to the flow of pressurised inspiration gas through the valve to seal the end of the common gas flow passage and block gas communication between the valve outlet and the common passage. When the pressure exerted on the differential area valving means by the expiration gas exceeds that exerted by the inspiration gas the valving means slides in the opposite direction to unblock the end of the common passage way and permit egress of expiration gas past the valving means, into the outer conduit and out of the valve through the outlet. Further check valves are also provided in attachment to the differential area valving means which permit only a unidirectional flow through the valving means.

[0005] However, this arrangement is mechanically complex and the seal itself is made over a relatively small area which is the end of a pipe so that small particles may prevent a proper seal being formed. Moreover, once fabricated, and the differential area of the valving means set, the operation of the valve is controllable mainly by varying the relative pressures of inspiration and expiration gas acting on the different areas. Thus, the operation of the valve is controlled basically by varying the amount of gas within the inspiration line of the tubing circuit. This line has a relatively large volume, compared with that of the valve, and this leads to a relatively slow response of the valve to inspiration gas changes.

[0006] A further known valve is disclosed in US 5,538,002 and comprises a pair of concentric tubes arranged to form a narrow channel therebetween through which breathing gas is supplied to a patient. The inner tube is arranged to connect the respiratory system of the patient to the outside and an inflatable cuff is disposed within the inner channel to expand and seal against itself as breathing gas passes through the outer, narrow channel. A disadvantage with this "self-sealing" arrangement is that a relatively poor gas seal may be formed. This is because if the cuff is substantially fully expanded to form the seal then the region of contact between the two surfaces is small and if the cuff is less expanded wrinkles may form in the contacting surfaces which can lead to a poor seal or to the surfaces being separable at low pressures.

[0007] US 3,995,643 describes an intra-tracheal tube device for use with respiratory ventilation equipment for providing respiratory support by assisting in the administration of air, oxygen or other gases into the patient's lungs. When connected to a ventilator the device is inserted into the trachea of the patient to enable inspiratory gas such as oxygen to be inhaled by the patient while providing an airway seal (occlusion) to prevent leakage of the oxygen out of the patient while the gas is being administered. This is done by using an occlusion cuff that is formed as a parachute or canopy and made of flexible material for making a seal between the outer surface of the occlusion and the inner surface of a tracheal passage wall. The canopy is comprises an inflatable, annular chamber formed in the body which can be inflated from an external air source in order to extend the canopy outward from the tube to contact to seal against the tracheal wall. One disadvantage is that the device is not self-con-

taining in that it cannot operate independently outside the body since the cuff operates to block flow by contacting the trachea. It is known that there can be risks for medical problems resulting from intra-tracheal tubes inserted for prolonged periods and from inflatable cuffs contacting the trachea. Thus it is desirable to use a gas-blocking valve device that is operable independently outside the patient's body.

[0008] It is an aim of the present invention to provide a constructionally simple valve, useable in patient ventilation systems, in which a relatively large sealing area can be provided and in which operation of the valving means can be done substantially independently of the relative pressures of the inspiration and expiration gases within the tubing circuit.

[0009] This is achieved by a valve according to and characterised by claim 1. Thus, by providing a valving means in the form of an inflatable cuff that seals between overlapping regions of the outer surface of an inner pipe and the inner surface of an outer pipe which are arranged to be substantially parallel to, preferably co-axial with one another, a seal may be formed across a large area of the external surface of the cuff. Additionally, by having the inside of the cuff connectable with an external pressurised fluid source then the opening and closing of the valve need not rely on any of the inspiration gas or the expiration gas. Moreover, the valve is of a relatively simple construction with the valving means comprising of only one moving part i.e. the inflatable cuff.

[0010] Usefully the degree of inflation of the cuff is controllable to provide a variable area flow restriction which may be used, for example, to provide for a Positive End Expiratory Pressure (PEEP) valve useable in a ventilation system to regulate the exhaled gas flow to keep the lungs under a positive pressure throughout the expiratory phase of a patient's breathing cycle. Such PEEP ventilator operating modes are well known in the art but are achieved here in a novel manner. Additionally or alternatively, the variable area flow restriction may be used in conjunction with a differential pressure flow meter so that the size of the inflated cuff is varied in order to maintain the linearity of the meter over a large dynamic flow range. The operating principles of variable area flow restriction flow meters are well known in the art and are described, for example in US 4,938,077 and US 4,006,634.

[0011] Usefully, the cuff may be formed integral with the valve, attached to one or other of the inner and the outer pipe so as to provide a unitary design. This may be achieved, for example, by locating the cuff on the outer surface of the inner passage so that it inflates to seal against the inner surface of the outer passage.

[0012] These and other objects and advantages of the present invention will be more clearly understood upon consideration of the following description of exemplifying embodiments and of.the accompanying figures, of which:

Figure 1 shows a sectional view of an embodiment of a valve of the present invention.

Figure 2 shows a schematic representation of a tubing circuit of a patient ventilation system including the valve of the present invention.

Figure 3 shows an alternative embodiment of the valve according to the present invention.

[0013] Considering now Figure 1, a valve 1 is shown to comprise, in this example, two body sections 2,3 which when interfitted, together form co-axially arranged outer 4 and inner 5 fluid flow passages and a common flow passage 6 through the valve 1. An inflatable cuff 7 is secured about its periphery to the external surface of the inner flow passage 5, for example by using a suitable bonding agent. A further fluid passage 8 is a formed within the body section 2 and is connectable to a source of pressurised fluid (not shown) for inflating the cuff 7 to block the outer flow passage 4, as illustrated in Figure 1. Connection pieces 11,12 are formed on the body sections 2,3 respectively and are provided to facilitate the external connection of the valve 1 to fluid flow conduits (for example the tubing section 14 shown connected to the common flow passage 6).

[0014] The body section 2 is also provided with apertures 9 which, when the two body sections 2,3 are interfitted, are in fluid communication with the inner passage 4 of the valve 1. These apertures 9 thus provide for fluid communication external of the valve 1 and are co-operatively disposed with the cuff 7 so that, when expanded, the cuff 7 can block fluid flow to and from the apertures 9 to control fluid flow through the valve 1.

[0015] In the present example, a flow restriction 13 is located within the common flow passage 6 and flow channels 15 are provided in pressure communication with the common flow passage 6 either side of the flow restriction 13. These channels are connectable to a standard differential pressure flow meter 16 to provide flow measurements for fluid travelling in both directions within the valve 1 i.e. into and out of the common flow passage 6.

[0016] As shown in Figure 1, the valve 1 is configured with the connection piece 11 acting as an inlet for fluid flow through inner flow passage 5 and in to the common flow passage 6. The apertures 9 then act as outlets for fluid flowing from the common flow passage 6 and through the outer passage 4. Pressurised fluid flows through the fluid passage 8 to the cuff 7 to inflate it and seal the outer passage 4 when fluid flows through the valve 1 from the inner passage 5. To reverse the direction of flow through the valve 1 the cuff 7 is deflated by removing the pressurised fluid therefrom and fluid can flow from the common flow passage 6 to the apertures 9.

[0017] As shown in Figure 2, one use of the valve of the present invention, such as the embodiment shown in Figure 1, is to control the flow of respiration gases (the flow directions of which are shown in Figure 2 by the arrows) within a tubing circuit of a patient ventilation sys-

tem, such as might include a ventilator or a respirator, as further described below.

[0018] The valve 1 is connected between connected between the lungs of a patient 17 and a known patient ventilation system 18 to control the flow of gas between the patient 17 and the ventilation system 18. An inspiration gas line 19 passes from the ventilation system 18 and seals in a gas tight connection to the connection piece 11 of the inner gas passage 5. An expiration gas line 20 passes from the ventilation system 18 and is connected in a gas tight seal with the body section 2 to enclose the outlet apertures 9. The inspiration line 19 and the expiration line 20 are configured concentrically for at least part of their lengths proximal the valve 1. A small bore lumen tubing 21 connects the cuff passage 8 with a pressurised gas source 22. This gas source 22 is preferably one of a gas harmless to humans in order to minimise harm to the patient in case of its unexpected leakage into the valve 1. The gas source 22 is operatively inked to the ventilator system 18 so that supply of the pressurised gas to the cuff 7 can be timed with an operating cycle of the ventilation system 18, for example inflation of the cuff 7 may be triggered at the onset of the mechanical assisted inspiration phase of a patient's breathing cycle.

[0019] The common flow passage 6 of the valve 1 is connected in a gas tight seal with a common flow conduit 14, which may be an inlet to a face mask (not shown) or an endotracheal tube, through which both inspiration gas to the lungs 17 and expiration gas from the lungs 17 alternately flows.

[0020] In use, the ventilation system 18 outputs a volume of inspiration gas into the inspiration tubing 19 during an inspiration phase of the patient and also triggers the supply of pressurised gas from the source 22 to inflate the cuff 7 and block the outer passage 4 and prevent gas flow through the apertures 9. The volume of inspiration gas therefore passes through the valve 1 from the inlet connection 11, through the inner passage 5 and to the common gas flow conduit 14. From the conduit 14 the inspiration gas is delivered into the lungs 17. During an expiration phase of the patient's breathing cycle valving means (not shown) within the ventilation system 18 closes to prevent supply of inspiration gas to the inner passage 5. The gas within the cuff 7 is removed, to be vented to the atmosphere or recovered for re-use by the source 22, and the outer passage 4 is unblocked as the cuff 7 deflates. Expiration gas passing from the lungs 17 into the common flow passage 6 of the valve 1 can flow through the outer passage 4, through the apertures 9 and into the expiration gas line 20 from where it is recovered by the ventilation system 18. Thus the cuff 7 acts as a valving means to block and unblock the outer passage 4 of the valve 1 as it respectively inflates and deflates during the breathing cycle of the patient. Additionally, or alternatively, by controlling the manner in which the cuff 7 is deflated a variable area flow restriction in the expiration gas path may be provided. This may be used to control the expiration pressure of the patient while the exhaled gas passes the partially deflated cuff 7 and so provides a PEEP mode of ventilation therapy.

[0021] Figure 3 shows a further embodiment of the valve of the present invention. Similar to the valve of Figure 1, the valve 31 comprises two body sections 32,33 which, when interfitted, form inner 35 and outer 34 fluid passages. The body portion 32 is provided with apertures 39 which in the assembled valve 31 provide fluid communication between the outer flow passage 34 and external of the valve 31. Different to Figure 1 is that the body sections 32,33 are of lengths such that no common flow passage is formed within the valve 31. Instead the body section 33 is connectable directly to a common flow passage 314. Sealed about the external surface of the inner flow passage 35 is an inflatable cuff 37. The inflation and deflation of the cuff 37 is controlled by a pressurised gas source (not shown) which is connectable to the fluid passage 38. Ports 315 are provided in pressure communication with the outer flow passage 34, one either side of the cuff 37. A differential pressure flow meter 316 is connectable to the ports 315. The inflation of the cuff 7 is controlled to vary size the flow restriction it forms when partially inflated so as to provide a more linear response across the dynamic range of the meter 316.

[0022] It will be appreciated by those skilled in the art that the valves described above are only to serve as examples of a valve according to the present invention. Non-inventive modifications may be made to the valves described above while remaining within the scope of the invention as defined by the present Claim 1. For example, the inner conduit may be adapted to carry the expiration gas and the outer the inspiration the inspiration gas; or the inflatable cuff may be fixedly located against the inner wall of the outer flow passage so as to seal against the outer wall of the inner flow passage when inflated; or the two part body may be formed as a single part, for example by using plastic injection moulding techniques in its construction. Moreover, a one-way valve may be placed within the flow passage not to be sealed by the cuff to prevent a reverse flow through that passage instead of relying on existing valves normally present within the ventilation system, as are used in the above examples.

Claims

1. A valve (1,31) comprising a substantially parallel arrangement of inner (5,35) and outer (4,34) fluid flow passages for conducting fluid through the valve to and from a common flow conduit (14,314), each passage in a different direction; and a cuff inflatable to control the flow of fluid through the valve (1,31) **characterised in that** an interfitted two body section forming a co-axially arranged outer (4, 34) and inner (5,35) fluid flow passages and a common flow passage through the valve such that the cuff (7,37) is inflatable to form a fluid-tight seal against one or oth-

er of facing surfaces of the inner (5,35) and the outer (4,34) flow passages to block flow through the outer (4,34) passage.

2. A valve as claimed in claim 1 **characterised in that** the cuff (7,37) is inflatable to form the seal against the outer (4,34) fluid flow passage.

3. A valve as claimed in Claim 1 or Claim 2 **characterised in that** the inner (5) and outer (4) fluid flow passages are of differing lengths selected so that the outer passage(4) extends beyond the inner passage (5) to form a common flow passage (6) connectable with the common flow conduit (14).

4. A valve as claimed in any preceding claim **characterised in that** a further fluid flow passage (8,38) is provided in fluid isolation from the inner (5,35) and outer (4,34) passages and disposed to conduct a pressurised fluid to and from internal the cuff (7,37) from external the valve (1,31) to control its inflation.

5. A valve as claimed in any preceding claim **characterised in that** the cuff (37) is inflatable to provide a variable area flow restriction to flow through the outer (34) fluid flow passage.

6. A valve as claimed in claim 5 **characterised in that** there is further provided a differential pressure flow meter (316) arranged for pressure communication with flowing fluid in the outer passage (34) either side of the variable area flow restriction (37) along the direction of flow and adapted to measure a pressure difference developed on either side of the variable area flow restriction (37) and to determine the flow through the passage (34) therefrom.

7. A ventilation system tubing circuit comprising an inspiration gas line (19) having a first end connectable with a source of inspiration gas (18); an expiration gas line (20) having a first end connectable with an expiration gas receiving facility (18) and a common gas line (14) having a first end connectable to a patient's airway (17) **characterised in that** the circuit additionally comprises a valve (1) as claimed in any preceding claim in which the inner fluid flow passage (5) is connected to a second end of one or other of the inspiration line (19) or the expiration line (20); and the outer fluid flow passage (4) is connected to a second end of the other of the expiration line (20) or the inspiration line (19) to conduct respiration gases through the valve (1) to and from the common gas line (14).

8. A ventilation system as claimed in claim 7 when dependent on claim 5 or claim 6 **characterised in that** the cuff (7) is controllably inflatable to provide a Positive End Expiratory Pressure (PEEP).

Patentansprüche

1. Ventil (1, 31), umfassend eine im Wesentlichen parallele Anordnung aus einem inneren Fluiddurchflusskanal (5, 35) und einem äußeren Fluiddurchflusskanal (4, 34) zum Leiten von Fluid durch das Ventil hin zu und aus einer gemeinsamen Durchflussleitung (14, 314), wobei das Fluid in jedem Kanal in eine andere Richtung fließt, sowie eine aufblasbare Manschette, um den Fluidfluss durch das Ventil (1, 31) zu steuern, **dadurch gekennzeichnet, dass** ein Abschnitt aus zwei ineinander gesteckten Gehäusen einen äußeren Fluiddurchflusskanal (4, 34) und einen inneren Fluiddurchflusskanal (5, 35), die koaxial zueinander angeordnet sind, und einen gemeinsamen Durchflusskanal durch das Ventil bildet, derart dass die Manschette (7, 37) aufblasbar ist, um eine fluiddichte Abdichtung gegen die eine oder die andere von gegenüberliegenden Flächen des inneren Durchflusskanals (5, 35) und des äußeren Durchflusskanals (4, 34) zu bilden, um den Fluss durch den äußeren Kanal (4, 34) zu blockieren.

2. Ventil nach Anspruch 1, **dadurch gekennzeichnet, dass** die Manschette (7, 37) aufblasbar ist, um die Abdichtung gegen den äußeren Fluiddurchflusskanal (4, 34) zu bilden.

3. Ventil nach Anspruch 1 oder Anspruch 2, **dadurch gekennzeichnet, dass** der innere Fluiddurchflusskanal (5) und der äußere Fluiddurchflusskanal (4) unterschiedliche Längen haben, die so gewählt sind, dass sich der äußere Kanal (4) über den inneren Kanal (5) hinaus erstreckt, um einen gemeinsamen Durchflusskanal (6) auszubilden, der mit der gemeinsamen Durchflussleitung (14) verbindbar ist.

4. Ventil nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** ein weiterer Fluiddurchflusskanal (8, 38) mit Fluid-Isolierung zum inneren Kanal (5, 35) und zum äußeren Kanal (4, 34) vorgesehen und so angeordnet ist, dass er ein Druckfluid ins Innere und aus dem Inneren der Manschette (7, 37) von außerhalb des Ventils (1,31) leitet, um deren Aufblasen zu steuern.

5. Ventil nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Manschette (37) aufblasbar ist, um eine Durchflussbegrenzung mit variabler Fläche gegenüber einem Durchfluss durch den äußeren Fluiddurchflusskanal (34) vorzusehen.

6. Ventil nach Anspruch 5, **dadurch gekennzeichnet, dass** ferner ein Differentialdruck-Durchflussmesser (316) vorgesehen ist, der so angeordnet ist, dass er in Druckverbindung mit in dem äußeren Kanal (34) fließenden Fluid zu beiden Seiten der Durchflussbe-

schränkung (37) mit veränderliche Fläche entlang der Fließrichtung steht und dazu geeignet ist, eine Druckdifferenz zu messen, die sich auf beiden Seiten der Durchflussbeschränkung (37) mit veränderlicher Fläche entwickelt hat, und daraus den Durchfluss durch den Kanal (34) zu bestimmen.

7. Leitungskreis für ein Ventilationssystem, umfassend eine Inspirationsgasleitung (19) mit einem ersten Ende, das mit einer Inspirationsgasquelle (22) verbunden werden kann, eine Exspirationsgasleitung (20) mit einem ersten Ende, das mit einer Exspirationsgas-Aufnahmevorrichtung (18) verbunden werden kann, sowie eine gemeinsame Gasleitung (14) mit einem ersten Ende, das mit einem Atemweg (17) eines Patienten verbunden werden kann, **dadurch gekennzeichnet, dass** der Kreis zusätzlich ein Ventil (1) nach einem der vorhergehenden Ansprüche umfasst, in dem der innere Fluiddurchflusskanal (5) mit einem zweiten Ende entweder der Inspirationsgasleitung (19) oder der Exspirationsgasleitung (20) verbunden ist, und der äußere Fluiddurchflusskanal (4) entsprechend mit einem zweiten Ende des jeweils anderen von Exspirationsleitung (20) oder der Inspirationsleitung (19) verbunden ist, um Respirationsgase durch das Ventil (1) hin zu bzw. aus der gemeinsamen Gasleitung (14) zu leiten.

8. Ventilationssystem nach Anspruch 7 in Abhängigkeit von Anspruch 5 oder Anspruch 6, **dadurch gekennzeichnet, dass** die Manschette (7) kontrollierbar aufgeblasen werden kann, um einen positiven endexspiratorischen Druck (PEEP) vorzusehen.

Revendications

1. Valve (1,31) comprenant un agencement sensiblement parallèle de passages de courant de fluide intérieur (5,35) et extérieur (4, 34) pour faire passer dans la valve du fluide allant et provenant d'un conduit (14,314) de courant commun, chaque passage étant dans une direction différente ; et un coussin gonflable pour régler le courant de fluide passant dans la valve (1,31), **caractérisée en ce qu'** une section à deux corps adaptés entre eux forme des passages de courant de fluide coaxiaux extérieur (4,34) et intérieur (5,35) et un passage commun de courant dans la valve, de sorte que le coussin (7,37) est gonflable pour former un joint étanche au fluide contre l'une ou l'autre des surfaces en regard des passages de courant intérieur (5,35) et extérieur (4,34) pour arrêter le courant dans le passage (4,34) extérieur.

2. Valve suivant la revendication 1, **caractérisée en ce que** le coussin (7,37) est gonflable pour former le joint contre le passage de courant de fluide extérieur (4,34).

3. Valve suivant la revendication 1 ou la revendication 2, **caractérisée en ce que** les passages de courant de fluide intérieur (5) et extérieur (4) ont une longueur différente choisie de façon à ce que le passage (4) extérieur s'étende au-delà du passage (5) intérieur pour former un passage (6) de courant commun pouvant être relié au conduit (14) de courant commun.

4. Valve suivant l'une quelconque des revendications précédentes, **caractérisée en ce qu'**un autre passage (8,38) de courant de fluide est prévu en étant isolé du point de vue des fluides des passages intérieur (5,35) et extérieur (4,34) et est disposé de manière à conduire un fluide sous pression allant et provenant de l'intérieur du coussin (7,37) à partir de l'extérieur de la valve (1,31) pour régler son gonflage.

5. Valve suivant l'une quelconque des revendications précédentes, **caractérisée en ce que** le coussin (37) est gonflable pour donner un étranglement variable du courant passant dans le passage du courant de fluide extérieur (34).

6. Valve suivant la revendication 5, **caractérisée en ce qu'**il est prévu en outre un débit-mètre (316) à pression différentielle, disposé de manière à avoir une communication de pression avec le fluide passant dans le passage (34) extérieur de chaque côté de l'étranglement (37) variable du courant le long de la direction du courant et conçu pour mesurer une différence de pression développée de part et d'autre de l'étranglement (37) variable de courant et pour déterminer le courant en passant dans le passage (34).

7. Circuit de canalisation de système de ventilation, comprenant une ligne (19) de gaz d'inspiration ayant une première extrémité pouvant être reliée à une source de gaz (18) d'inspiration ; une ligne (20) de gaz d'expiration ayant une première extrémité pouvant être reliée par un équipement (18) recevant du gaz d'expiration et une ligne (14) de gaz commune ayant une première extrémité pouvant être reliée aux voies aériennes (17) du patient, **caractérisé en ce que** le circuit comprend en outre, une valve (1) telle que revendiquée suivant l'une quelconque des revendications précédentes, dans lequel le passage (5) de courant de fluide intérieur est relié à une deuxième extrémité de l'une ou de l'autre de la ligne (19) d'inspiration ou de la ligne (20) d'expiration ; et le passage (4) de courant de fluide de courant extérieur est relié à une deuxième extrémité de l'autre de la ligne (20) d'expiration ou de la ligne (19) d'inspiration pour faire passer des gaz de respiration dans la valve (1) vers la ligne (14) de gaz commune et à

partir de celle-ci.

8. Système de ventilation suivant la revendication 7, lorsqu'elle dépend de la revendication 5 ou de la revendication 6, **caractérisé en ce que** le coussin (7) peut être gonflé de manière réglable pour donner une pression positive de fin d'expiration (PEEP).

Fig. 1

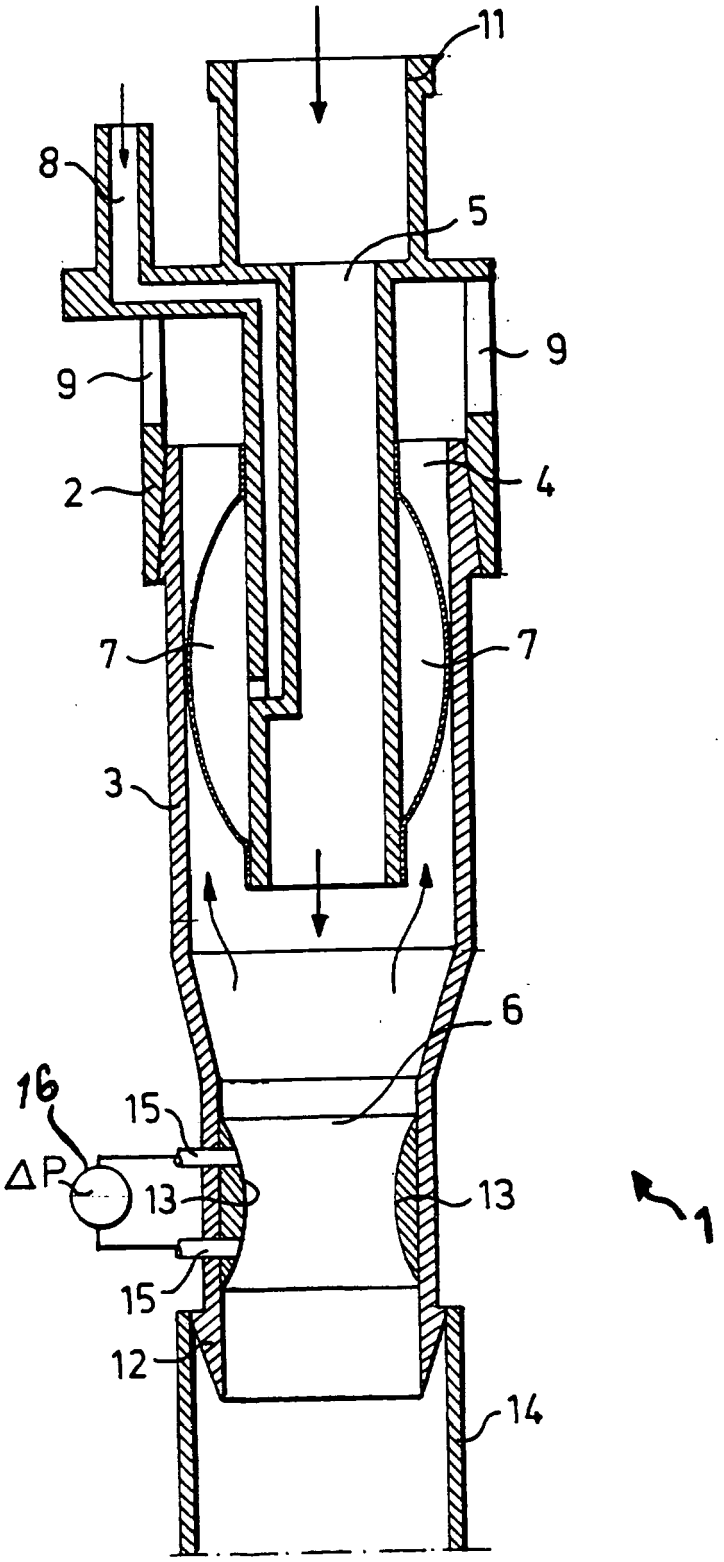


Fig. 2

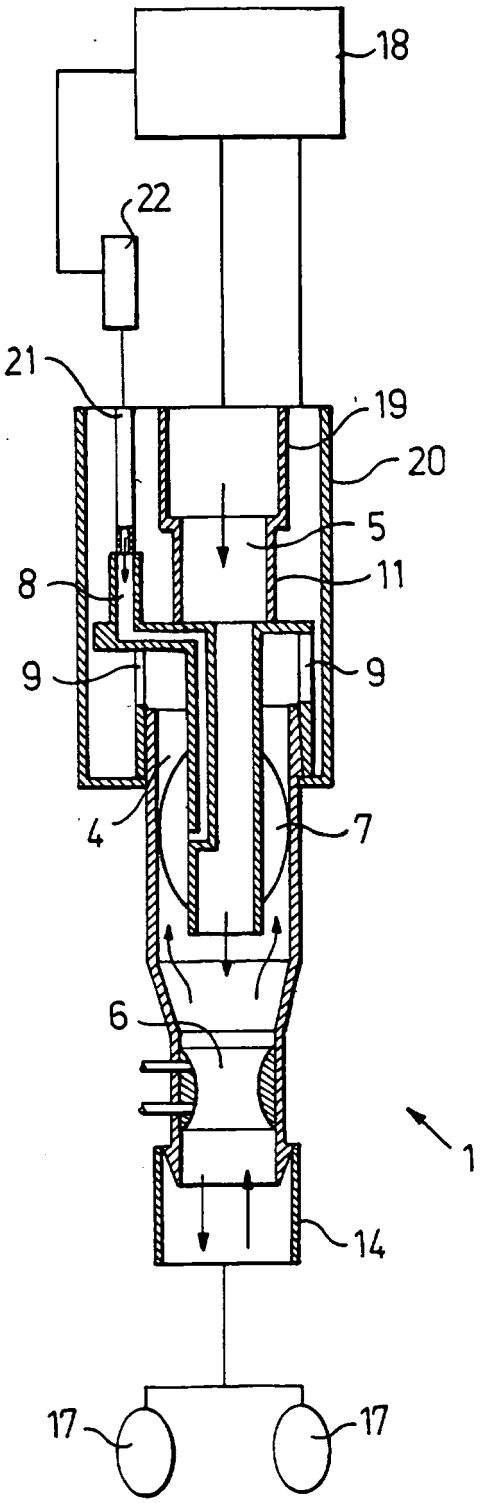
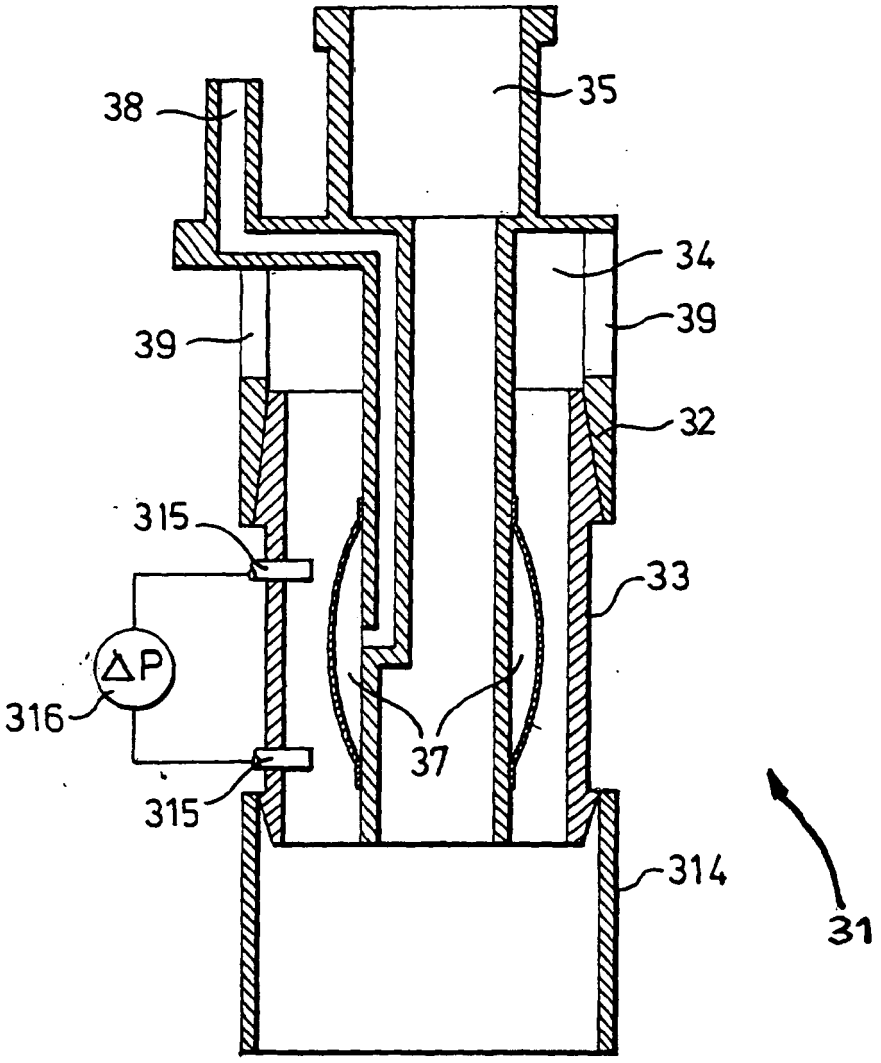


Fig. 3



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- US 5538002 A **[0006]**
- US 3995643 A **[0007]**
- US 4938077 A **[0010]**
- US 4006634 A **[0010]**