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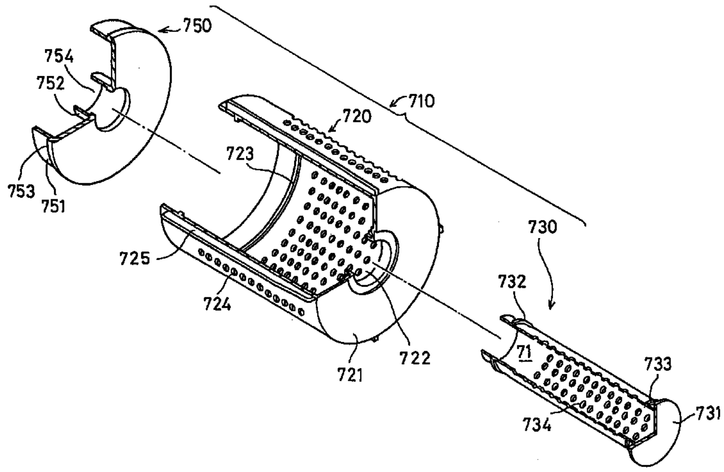
(54) CARBON DIOXIDE ADSORPTION DEVICE FOR A DIVING BREATHING DEVICE

(57) A carbon dioxide adsorbent container (710) for a diving breathing device has an external tube (720) having an end face constructed so as to form a sealed bottom, an internal tube (730) adapted to be inserted into the external tube through a bottom hole formed in the sealed bottom thereof and having an end face constructed so as to form a sealed bottom and a lid (750) adapted to be fitted into an opening in the external tube and having a fitting hole formed therein for receiving therein a leading end of the internal tube, the lid being adapted to be mounted on the external and internal tubes in a state in which it is prevented from coming off the tubes. The container (710) can be constituted by three members each having a simple construction and which are separately formed, and the respective members can easily be formed. In addition, it is possible to exchange carbon dioxide adsorbents only by mounting and dismounting this container on and from a breathing device.

Fig. 4



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Description

Technical Field

This invention relates to a carbon dioxide adsorption apparatus used in a semiclosed-circuit breathing apparatus, closed-circuit breathing apparatus or other underwater breathing apparatus.

Background Art

In a semiclosed-circuit breathing apparatus or closed-circuit breathing apparatus, exhaled air is passed through a carbon dioxide adsorption apparatus where it is regenerated and used as the gas to be inhaled. A conventional carbon dioxide adsorption apparatus must be replaced with a new one before each dive.

The replacement work involved opening the case of the carbon dioxide adsorption apparatus, removing the carbon dioxide adsorbent packed therein and repacking with new carbon dioxide adsorbent. In this work, the carbon dioxide adsorbent must be packed uniformly. If this packing work is not performed correctly, the gas passing through the carbon dioxide adsorption apparatus will pass through without the carbon dioxide being removed, so the efficiency of adsorption of carbon dioxide is decreased. Therefore, training is required for this work and it is difficult for the work to be performed quickly and easily.

In addition, even if the carbon dioxide adsorbent is packed correctly, there is a risk that during use, vibrations or the like will cause the carbon dioxide adsorbent to be compacted, resulting in gaps in the space where the carbon dioxide adsorbent is packed. If such gaps occur, ill effects such as the exhaled passing through as is without being purified may occur.

In light of these problems, the object of the present invention is to simplify the replacement work and provide a carbon dioxide adsorption apparatus in which gaps will not occur during use.

Another object of the present invention is to provide a carbon dioxide adsorbent canister suitable for use in such a carbon dioxide adsorption apparatus.

Disclosure of the Invention

In order to achieve the aforementioned objects, the carbon dioxide adsorption apparatus for underwater breathing apparatus of the present invention comprises: a hollow casing in which an opening is formed on one side, a removable cover that is attached to said opening, a removable carbon dioxide adsorbent canister that is enclosed within a sealed space formed into a compartment by the casing and cover, and carbon dioxide adsorbent packed within this carbon dioxide adsorbent canister.

The aforementioned carbon dioxide adsorbent canister comprises: an outer cylinder, one end of which forms a sealing bottom, an inner cylinder, which can be inserted from a bottom hole opened in the center of this sealing bottom of the outer cylinder, and one end of which forms a sealing bottom, and a cover that can be fit over the tip of said inner cylinder, such that the inside surface of the opening of said outer cylinder and the outside surface of said cover form a lock that prevents said cover from coming off in the removable state, thus forming a constitution in which the peripheral surface of said outer cylinder and inner cylinder becomes a gas-permeable surface.

With a canister of such constitution, the inner cylinder is inserted from the bottom hole of the outer cylinder and then carbon dioxide adsorbent is packed within the annular space formed between the outer cylinder and inner cylinder, and then the cover is fitted onto the outer cylinder and inner cylinder.

Moreover, the canister enclosed within the casing is constituted such that its cover portion is pushed toward the side in which the carbon dioxide adsorbent is packed by a coil spring or other elastic means.

With the carbon dioxide adsorption apparatus of the present invention, if carbon dioxide adsorbent canisters are prepared in advance, these can be simply placed within the casing to finish the carbon dioxide adsorbent replacement work. In addition, at the time of use, the cover is pressed in the direction of the packed carbon dioxide adsorbent. Therefore, even if the carbon dioxide adsorbent becomes compacted, the cover will move accordingly, so no gaps will be formed.

The carbon dioxide adsorbent canister of the present invention consists of the combination of three separate parts: outer cylinder, inner cylinder and cover. None of the individual parts is complex in shape so they can be simply molded from synthetic resin or the like as the raw material.

Brief Description of Drawings

Figure 1 is a perspective view of the outside of a semiclosed-circuit breathing apparatus which is an embodiment of the invention.

Figure 2 is a schematic cross-sectional view of the overall constitution of the semiclosed-circuit breathing apparatus.

Figure 3 is a schematic cross-sectional view of an enlargement of a portion of the carbon dioxide adsorption apparatus installed in a semiclosed-circuit breathing apparatus.

Figure 4 is an exploded perspective view showing the constitution of the carbon dioxide adsorbent canister that makes up the carbon dioxide adsorption apparatus of Figure 3.

Figure 5 is a cross-sectional view of the carbon dioxide adsorbent canister.

Figure 6 is a figure showing the carbon dioxide adsorbent canister, where (a) is a right-side view, (b) is a front view and (c) is a left-side view.

Figure 7 is an explanatory drawing showing the basic constitution of the water draining apparatus, where (a) shows the state at the time of exhalation, (b) shows the state at the time of inhalation, and (c) shows the state of draining water.

Figure 8 is an explanatory drawing intended to explain the operation of the water draining apparatus while the wearer is upside-down, where (a) shows the state when the water draining apparatus is not installed while (b) shows the state when the water draining apparatus is installed.

Figure 9 is an explanatory drawing that illustrates the state of the wearer while swimming.

Figure 10 is an explanatory drawing that illustrates the state of the water draining apparatus while the wearer is swimming.

Figure 11 is an explanatory drawing that illustrates the operation of the water draining apparatus while the wearer is facing upward.

Figure 12 is a drawing that illustrates the water draining apparatus mounted on the semiclosed-circuit breathing apparatus of Figure 1.

Figure 13 is a drawing that illustrates the pressure chamber of the water draining apparatus of Figure 12.

Figure 14 is an explanatory drawing that illustrates the buoyancy adjustment action of the air bag while the diver is in the upside-down diving position.

Figure 15 is a drawing that illustrates an underwater breathing apparatus with the air bag located on the side of the buoyancy compensator (BC) vest where (a) is a schematic drawing and (b) is an explanatory drawing that illustrates a diver wearing the breathing apparatus.

Figure 16 is a drawing that illustrates the fluctuation of the differential-pressure resistance of breathing in the various diving positions while diving with the apparatus of Figure 15, where (a) is an explanatory diagram for the downward-facing position, (b) is an explanatory diagram for the upside-down position, (c) is an explanatory diagram for the upright position, and (d) is an explanatory diagram for the upward-facing position.

Figure 17 is a drawing that illustrates the fluctuation of the differential-pressure resistance of breathing in the various diving positions while diving with a conventional underwater breathing apparatus, where (a) is an explanatory diagram for the downward-facing position, (b) is an explanatory diagram for the upside-down position, (c) is an explanatory diagram for the upright position, and (d) is an explanatory diagram for the upward-facing position.

Best Mode for Carrying out the Invention

A semiclosed-circuit breathing apparatus to which the present invention is applied will be explained with reference to the drawings.

(Overall Structure)

Figures 1 and 2 show a semiclosed-circuit breathing apparatus with into which the carbon dioxide adsorption apparatus of present invention is built.

First, as shown in Figure 1, the semiclosed-circuit breathing apparatus 1 of this example is equipped with a hollow housing 2 and the component parts of the device to be described later are built into this hollow housing 2. One side of this hollow housing 2 forms the back-resting surface 2a which rests against the back of the diver, and in the center of the opposing surface is formed an opening used for replacing the breathing gas cylinder, and attached to the opening is a removable cover 2b. Attached to the top edge of the hollow housing 2 is a canister 3 with a built-in horizontal carbon dioxide adsorption apparatus. This canister takes an overall cylindrical shape, and connected to its exterior on either side are two flexible hoses, an exhalation air hose 4 and an inhalation air hose 5. Connected to the ends of the exhalation air hose 4 and the inhalation air hose 5 is a mouthpiece unit 6.

We will now describe the main structural components of the apparatus 1 of this embodiment in reference to Figure 2. As shown in this figure, the inhaled/exhaled air circulation chamber 61 within the mouthpiece unit 6 communicates with the exhalation air hose 4 and inhalation air hose 5. The other ends of the exhalation air hose 4 and inhalation air hose 5 communicate with either side of the cylindrical canister 3 with a built-in carbon dioxide adsorption apparatus 7. In other words, the carbon dioxide adsorption apparatus 7 with an annular cross-section is built into the center of this canister 3 and an exhalation air passage 31 and inhalation air passage 32 are formed on either side. A breathing gas cylinder 8 is placed vertically in the center of the hollow housing 2 below the canister 3 with the built-in carbon dioxide adsorption apparatus 7, and on either side of the cylinder are placed an exhalation air bag 9 and an inhalation air bag 11. The exhalation air bag 9 communicates with the exhalation air passage 31 of the canister 3 and the inhalation air bag 11 communicates with the inhalation air passage 32 of the canister 3. Mounted on the outside surface of the exhalation air bag 9 is a water draining apparatus 130.

The breathing gas cylinder 8 is arranged such that its gas discharge outlet 81 is positioned at the bottom, and this gas discharge outlet 81 is connected via an on/off valve 82 to a regulator 83. The regulator 83 reduces the gas pressure to roughly 8 to 9 kg/cm^2. Connected to the regulator 83 are six gas supply lines, and of these, three are used for the remaining-pressure gage, the buoyancy compensator and the octopus rig (not shown). One of the remaining three lines, gas supply line 84, passes through the inhalation air passage 32 of the canister 3 with built-in carbon dioxide adsorption apparatus and through the inhalation air hose 5, extending to the interior of the mouthpiece. At an intermediate position is interposed a flow rate adjustment orifice 84a, by which the flow rate is adjusted to 4 to 5 liters/minute and supplied to the interior of the mouthpiece. Another of the lines, gas supply line 85, is a purge gas supply line used to purge water from the interior of the mouthpiece unit 6, extending to the interior of the mouthpiece unit 6 in the same manner as gas supply line 84 described above. The remaining line, gas supply line 86, is used to supply air during emergencies, and its end is positioned within the inhalation air passage 32 of canister 3.

Mounted to the end of the inhalation side of the canister 3 with built-in carbon dioxide adsorption apparatus is an auto-valve mechanism 12. This mechanism 12 controls the opening and closing of the gas supply line 86 and controls the automatic release of excess gas.

The overall flow of gas is as follows. Exhaled air from the mouthpiece 62 of the mouthpiece unit 6 passes through the exhalation air hose 4 and exhalation air passage 31 and accumulates in the exhalation air bag 9. At the time of the inhalation action, the exhaled air accumulated here is passed through the carbon dioxide adsorption apparatus 7 where carbon dioxide is removed and the air is purified and flows into the inhalation air passage 32. The exhaled air thus purified accumulates in the inhalation air bag 11 and is also supplied to the interior of the mouthpiece unit 6 via the inhalation air hose 5 for use in inhalation. Inside the mouthpiece unit 6, a constant flow of new gas for inhalation is introduced from the cylinder 8 through the gas supply line 84, so a mixture of these gases is supplied as the gas for inhalation.

(Carbon Dioxide Adsorption Apparatus)

Next, we will explain the structure of the carbon dioxide adsorption apparatus 7 in reference to Figures 3 through 6.

The carbon dioxide adsorption apparatus 7 is contained within a canister 3 which has an overall cylindrical shape. On the top and bottom of the outside surface of one side of this canister 3 are formed an exhalation air hose connector 311 and exhalation air bag connector 312, to which are connected the exhalation air hose 4 and exhalation air bag 9, respectively. On the top and bottom of the outside surface of the other side of this canister 3 are formed an inhalation air hose connector 313 and inhalation air bag connector 314, to which are connected the inhalation air hose 5 and inhalation air bag 11, respectively. Screwed into the opening on the inhalation air hose connector side of canister 3 is a hollow cylindrical cover 322 which when secured forms an airtight seal. In the peripheral wall of this cover 322 are formed many exhalation communicating holes 323. Therefore, the hollow portion of this cover functions as an exhalation air passage 31 by which the exhalation air hose 4 and exhalation air bag 9 communicate. In addition, a cylindrical communicating tube 325 penetrates the center of the disk-shaped end surface 324 of this cover 322, so the exhalation air passage 31 communicates via this communicating tube 325 with the hollow portion 71 of the carbon dioxide adsorption apparatus 7.

Screwed into the other opening of the canister 3 is a hollow bottom cover 127, onto which the auto-valve mechanism 12 is mounted, which when secured forms an air-tight seal. Between the bottom cover 127 and carbon dioxide adsorption apparatus 7 in the canister 3, the inhalation air passage 32 is formed as a compartment.

The carbon dioxide adsorbent canister 710 that forms the carbon dioxide adsorption apparatus 7 has an outer cylinder 720 and an inner cylinder 730 and the space with an annular cross section formed as a compartment between these two is packed carbon dioxide adsorbent 740. The outer cylinder 720 has one end wall that forms a sealing bottom 721 in the center of which is formed a bottom hole 722. The interior of this inner cylinder is the aforementioned hollow portion 71. Attached to the opening side of the outer cylinder and inner cylinder assembled concentrically in this manner is a disk-shaped cover 750.

This cover 750 is provided with an outer wall 751 and an inner wall 752. The tip side of the outer wall 751 is slightly thinner and thus an annular step 753 is formed on its exterior surface. In the same manner, the tip side of the inner wall 752 is also slightly thinner and thus an annular step 754 is formed on its interior surface. In opposition, on the interior surface of the opening in the tip of the outer cylinder 720 is formed an annular protrusion 723 with an inside diameter slightly smaller than the outside diameter of the root side of the outer wall of the cover, and on the exterior surface of the opening in the tip of the inner cylinder 730 is formed an annular protrusion 732 with an outside diameter slightly larger than the inside diameter of the tip side of the inner wall of the cover. In addition, an annular protrusion 733 is also formed on the exterior surface of the bottom side of the inner cylinder 730, with an outside diameter dimension slightly larger than the inside diameter of the inner wall of the bottom hole 722 of the outer cylinder.

On the other hand, many gas permeation holes 724 are formed in the exterior walls of the outer cylinder 720 excluding the bottom surface and tip opening side. In addition, four ribs 725 are formed in the axial direction at 90° increments. These ribs 725 form a passage between the interior surface of the canister 3 and the outer cylinder 720 that extends to the inhalation air passage 32. In addition, many gas permeation holes 734 are formed in the exterior walls of the inner cylinder 730 also, excluding the bottom surface and tip opening side.

The carbon dioxide adsorbent canister 710 of such structure is assembled by inserting the inner cylinder 730 through the bottom hole 722 of the outer cylinder 720, packing carbon dioxide adsorbent 740 into the annular space 760 formed as a compartment between the outer cylinder and inner cylinder, and then fitting the cover 750 onto the tips of the outer cylinder and inner cylinder. Here, the interior surface of the outer cylinder 720 and the exterior surface of the inner cylinder 730 are each wrapped with polypropylene nonwoven fabric (not shown) and the carbon dioxide adsorbent 740 is packed into the interior of the canister while wrapped with this nonwoven fabric. The nonwoven fabric prevents leakage of the fine adsorbent powder. Material other than polypropylene can be used for the nonwoven fabric, but the carbon dioxide adsorbent 740 generates heat when it adsorbs carbon dioxide, so a heat-resistant material is required.

The carbon dioxide adsorbent canister 710 thus assembled is charged into the interior of the canister 3 after opening the cover 322. A coil spring 770 in the compressed state is inserted between the cover 322 and the cover 750 of the carbon dioxide adsorbent canister 710.

In the carbon dioxide adsorption apparatus 7 of this embodiment of such structure, exhaled air passes from the exhalation air passage 31 side through the communicating tube 325 and into the hollow portion 71 of the inner cylinder 730, after which it passes through the gas permeation holes 734 of the inner cylinder and enters the carbon dioxide adsorbent 740, where it is regenerated and leaves through the gas permeation holes 724 of the outer cylinder and supplied to the inhalation air passage 32 side.

In the carbon dioxide adsorption apparatus of this embodiment, it is possible to replace the carbon dioxide adsorbent by merely replacing this carbon dioxide adsorbent canister 710. By preparing a carbon dioxide adsorbent canister 710 in advance already packed with carbon dioxide adsorbent 740, the replacement work can be performed simply. Alternatively, the cover 750 of the carbon dioxide adsorbent canister 710 can be removed and the carbon dioxide adsorbent packed therein can be replaced.

Here, the cover 750 of the carbon dioxide adsorbent canister 710 is fitted to the openings of the outer cylinder and inner cylinder such that it is prevented from coming off by means of the annular protrusions 723 and 754. Moreover, it is in a state in which movement toward the inside is possible, and in the state when charged within the canister 3 it is pressed in by means of the coil spring 770. Therefore, even if the carbon dioxide adsorbent packed inside should become compacted by means of vibration or the like during use, the compression will move the cover towards the inside and no gaps with no carbon dioxide adsorbent present will occur. Thus, even if the carbon dioxide adsorbent becomes compacted, the appropriate purification and regeneration of breathing gas will be performed constantly.

On the other hand, the carbon dioxide adsorbent canister 710 of this embodiment consists of an assembly of an outer cylinder 720, inner cylinder 730 and cover 750. Therefore, they can be easily formed in contrast to the case of the canister being formed as a single unit.

(Structure of the Water Draining Apparatus)

Next, we shall describe the water draining apparatus 130 attached to the exhalation air bag 9 of the apparatus 1 of this embodiment. This water draining apparatus 130 is related to a water draining apparatus that automatically expels water that enters the breathing air bags via the mouthpiece, by linkage with the breathing action.

First, we shall explain the background for installing this water draining apparatus 130.

As described previously, underwater breathing apparatus can generally be divided into two types: open-circuit breathing apparatus and closed-circuit or semiclosed-circuit breathing apparatus. In an open-circuit breathing apparatus, gas that has been breathed once is all expelled from the apparatus, but a closed-circuit or semiclosed-circuit breathing apparatus includes an apparatus by which gas that has been breathed can be breathed again. During dives using open-circuit breathing apparatus, the same volume of gas is breathed regardless of the ambient pressure or depth. Therefore, as the ambient pressure becomes larger the consumption of breathing gas increases. In the case in which a gas cylinder is used, namely the case in which the amount of gas that can be breathed is limited to a fixed volume, the diving time decreases as the depth increases.

In contrast, with a closed-circuit or semiclosed-circuit breathing apparatus, while compressed gas is the source of breathing air in the same manner as the open-circuit type, the same weight of gas is breathed regardless of the ambient pressure. Therefore, with the closed-circuit or semiclosed-circuit type, the consumption of breathing gas is constant regardless of depth. For this reason, the amount of breathing gas that must be carried is much less than that required for the open-circuit type, and also, by varying the mixing ratio of breathing gas, long dives to depths that cannot be reached with open-circuit apparatus become possible.

In this manner, closed-circuit or semiclosed-circuit breathing apparatus has the advantages of being lighter than open-circuit breathing apparatus and permitting longer dives to deeper depths. However, conventional closed-circuit or semiclosed-circuit breathing apparatus was developed for purposes of specialized types of diving or military use, so it provided only a minimum of safety mechanisms, and had no mechanisms for handling emergency situations that occur relatively easily. For this reason, extremely thorough training was required in order to use this type of apparatus, and thus it could not be used easily by the leisure diver.

Yet with the increase in diving aficionados, demand increased for this type of closed-circuit or semiclosed-circuit breathing apparatus that can be used for diving without the need to master complex operation. Closed-circuit breathing apparatus is equipped with oxygen concentration sensors and the like, thus requiring considerable training in its handling, control and monitoring. In contrast, semiclosed-circuit breathing apparatus has no such equipment and therefore there is no need for training in its operation, so it can be handled relatively easily by even a non-expert. This type of semiclosed-circuit breathing apparatus has become simpler than in the past, can be used easily and is extremely convenient.

The water draining apparatus 130 of this embodiment was conceived in consideration of the particulars described above and is a device for automatically expelling water that collects in the breathing air bag after entering the interior.

Next, we will describe the basic structure and operation of the water draining apparatus 130 of this embodiment.

As shown in Figure 7, the water draining apparatus 130 is attached to the outside surface 9a of the exhalation air bag 9 and is characterized in that it comprises: a pressure chamber 131 that is compressed and expanded together with the compression and expansion motion of the breathing air bag, a first water discharge line 132 that communicates between the interior and exterior of this pressure chamber, a first check valve 133, inserted within this first water discharge line 132, that permits the passage of fluid only from the interior to the exterior of the pressure chamber, a second water discharge line 134 that communicates between the bottom 9b of the breathing air bag and a portion 132a of the first water discharge line 132, which communicates between this first check valve 133 and the interior of the pressure chamber, and a second check valve 135, inserted within this second water discharge line 134, that permits the passage of fluid only from the interior of the breathing air bag to the first water discharge line 132.

Here, the external opening end 132b of the pressure chamber 131 and first water discharge line 132 is preferably positioned at roughly the height of the center G of the breathing air bag 9.

In addition, the pressure chamber 131 is attached to the outside surface 9a of the breathing air bag facing the side opposite the back of the wearer when worn, and the external opening end 132b of the first water discharge line is preferably positioned on the outside surface on the side opposite the outside surface where the pressure chamber is attached (namely, the outside surface on the side facing the back of the wearer).

On the other hand, the external opening end of the first water discharge line is preferably adjustable with respect to its position relative to the breathing air bag.

The breathing air bag 9 expands and contracts with the breathing action of the diver. As shown in Figure 7(a), at the time of exhalation, the exhaled air is taken into the air bag 9, which expands. In contrast, as shown in Figure 7(b), at the time of inhalation, the air bag 9 contracts. With the expansion and contraction action of the air bag as thus, the water draining apparatus 130 attached to its outside surface 9a undergoes pumping action, thereby expelling the water W that collects at the bottom of the air bag 9. In other words, when the pressure chamber 131 which is in the contracted state due to expansion of the air bag 9 expands with the contraction of the air bag 9, as shown in Figure 7(b), the water W that collects at the bottom of the air bag 9 is sucked out via the second water discharge line 134 and second check valve 135, and moves to the pressure chamber 131 side. Thereafter, when the pressure chamber 131 is compressed due to expansion of the air bag 9, the water that had moved here is expelled to the exterior via the first water discharge line 132.

In addition, even considering a case that does not depend on expansion or contraction of the air bag 9, when the internal pressure of the air bag 9 rises, as shown in Figure 7(c), the water W within the air bag 9 is expelled via the water discharge lines 134 and 132 due to the pressure difference.

Next, consider the case in which the internal pressure of the breathing air bag 9 becomes excessively large during use. For example, consider a diver diving in the upside-down position as shown in Figure 8. In this case, even if the air exhaust mechanism 12 is mounted on the upper-edge side of the semiclosed-circuit breathing apparatus 1, because of the positional relationship, the exhaust of air from the air exhaust mechanism 12 will not occur rapidly. As a result, as shown in Figure 8(a), the air bag 9 will be excessively inflated. However, in the present invention, the pressure chamber 131 and external opening end 132b of the water draining apparatus 130 are positioned at roughly the height of the center G of the air bag 9. For this reason, the gas within the air bag 9 is released quickly via the second water discharge line 134 and first water discharge line 132 from the external opening end 132b. Thus, as shown in Figure 8(b), excessive inflation of the air bag can be prevented even in the case of this diving position.

Next, the pressure chamber 131 of the water draining apparatus is attached to the outside surface 9a of the air bag 9 on the side opposite that of the back of the wearer, and therefore, as shown in Figure 9, the pressure chamber 131 is positioned between the outside surface 9a of the air bag 9 and the back side of the case 2 of the semiclosed-circuit breathing apparatus 1. For this reason, as shown in Figure 10, when the diver is in the swimming position, the air bag 9 is pushed against the back side of the case by buoyancy and therefore the pressure chamber 131 is put into the compressed state so its volume is reduced and it does not function well. In contrast, the external opening end 132b is positioned on the side of the back of the diver (namely, positioned below the air bag 9), so breathing gas will not be blown out from here due to the pressure difference.

On the other hand, even in the case in which the wearer is swimming in the reverse position as shown in Figure 11, when the air exhaust mechanism 12 is formed on the upper edge of the semiclosed-circuit breathing apparatus 1, the air exhaust mechanism 12 is positioned lower than the lungs of the wearer, so the exhausting of air thereby becomes difficult. However, when the water draining apparatus 130 of the present invention is provided, its external opening end 132b is close to the lungs of the wearer, so exhalation when exhausting air can be performed easily.

Moreover, when the height of the external opening end 132b of the first water discharge line can be varied relative to the air bag 9, by adjusting this height the volume of air in the air bag can be adjusted. Therefore, it is possible to prevent the generation of excess buoyancy even when diving in the upside-down position.

Next, we shall describe the specific structure of the water draining apparatus 130 attached to the exhalation air bag 9 of the apparatus 1 of this embodiment, in reference to Figures 2, 12 and 13.

The exhalation air bag 9 to which the water draining apparatus 130 is attached is an elastic bag formed from flexible raw materials, so it is able to expand and contract with the breathing action. Formed on the upper edge of the air bag 9 is a connector 91 that couples to the connector 312 formed on the canister 3 described above. Formed on the bottom edge of this air bag 9 is an opening 92.

The water draining apparatus 130 of this embodiment has a pressure chamber 131 attached to the outside surface 9a of the air bag 9 facing the side opposite the back of the wearer. This pressure chamber 131 is attached to the outside surface 9a of the air bag 9 at a position corresponding to the center of the air bag 9. As shown in Figure 13, the pressure chamber 131 consists of a bellows-shaped flexible tube 141 and on both ends of this tube are formed sealing walls 142 and 143. This can be formed as a single unit from polyethylene or other synthetic resin. One of the sealing walls 143 of the tube 141 is joined to the outside surface 9a of the air bag 9.

A connection hole 144 is formed in the peripheral surface of the pressure chamber 131 in order that the tip of a flexible tube 132a can be connected. One end of the flexible tube 132a is connected here while its other end is connected to a connection hole 145a in a three-way connection tube 145. Among the other two connection holes 145b and 145c of the three-way connection tube 145, connection hole 145b connects to one end of the flexible tube 132 via the first check valve 133. The other end of this tube 132 communicates with the external opening end 132b via check valve 147.

On the other hand, connected to the remaining connection hole 145a of the three-way connection tube 145 is one end of a second flexible tube 134 via a second check valve 135. The other end of this tube 134 is connected to an opening 92 in the bottom of the air bag 9.

Here, the first check valve 133 and check valve 147 permit the passage of fluid only toward the external opening end 132b. In addition, the second check valve 135 permits the passage of fluid only from the side of the second tube 134 toward the side of the pressure chamber 131 and external opening end 132b.

The water draining apparatus 130 of this embodiment of such structure, as explained in reference to Figure 7, permits water that collects at the bottom of the exhalation air bag 9 to be expelled to the outside via the external opening end 132b. In addition, as described in reference to Figure 7(c), when the internal pressure of the air bag 9 rises, as shown in Figure 7(c), the water that collects at the bottom can be expelled to the outside.

Moreover, in the case in which the internal pressure of the breathing air bag 9 becomes excessively large during use, for example, when a diver is diving in the upside-down position as shown in Figure 8, even if the auto-valve 12 is positioned below the air bag 9, the exhaust of air from the air auto-valve 12 will not occur rapidly. As a result, as shown in Figure 8(a), the air bag 9 will be excessively inflated. However, in this embodiment, the pressure chamber 131 and external opening end 132b of the water draining apparatus 130 are arranged at positions near the center of the air bag 2. For this reason, the gas within the air bag 9 is released quickly via the second water discharge line 134 and first water discharge line 132 from the external opening end 132b. Thus, as shown in Figure 8(b), excessive inflation of the air bag can be prevented even in the case of this diving position.

Moreover, in this embodiment, the pressure chamber 131 of the water draining apparatus is attached to the outside surface 9a of the air bag 9 on the side opposite that of the back of the wearer, and therefore, as shown in Figure 9, the pressure chamber 131 is positioned between the outside surface 9a of the air bag 9 and the back side of the case 2 of the semiclosed-circuit breathing apparatus 1. For this reason, as shown in Figure 10, when the diver is in the swimming position, the air bag 9 is pushed against the back side of the case by buoyancy and therefore the pressure chamber 131 is put into the compressed state so its volume is reduced and it does not function well. In contrast, the external opening end 132b is positioned on the side of the back of the diver (namely, positioned below the air bag 9), so breathing gas will not be blown out from here due to the pressure difference.

On the other hand, in the case in which the wearer is swimming in the reverse position as shown in Figure 11, the auto-valve 12 is positioned on the upper edge of the semiclosed-circuit breathing apparatus 1. In this case, the air exhaust mechanism 12 is positioned lower than the lungs of the wearer, so the exhausting of air thereby becomes difficult. However, when the water draining apparatus 130 of the present invention is provided, its external opening end 132b is close to the lungs of the wearer, so exhalation when exhausting air can be performed easily.

In this manner, by using the water draining apparatus 130 of this embodiment, water that collects at the bottom of the air bag 9 can be automatically expelled by linkage with the breathing action.

In addition, the water draining apparatus 130 of this embodiment also functions as an air exhausting mechanism, so excessive breathing gas can be expelled smoothly regardless of the diving position of the diver. Moreover, it has the meritorious effect of being able to suppress the increase in breathing resistance arising from the diving position.

Note that in this embodiment, the pressure chamber 131 of the water draining apparatus 130 is attached to the exhalation air bag, but it can also be attached to the inhalation air bag or to both.

Next, we shall describe the advantages of being able to move the position of the external opening end 132b of the flexible tube of the water draining apparatus 130 relative to the air bag 9 in the preferred embodiment described above.

Excessive gas in the air bag 9 is exhausted by means of the exhausting function of the auto-valve as described above. The auto-valve 12 is positioned at the upper part of the air bag between the swimming position and upright position when the swimmer is inclined forward from the horizontal. Therefore, when the air bag expands to a certain extent, the exhausting function of the auto-valve is activated. Nevertheless, when the auto-valve 12 is positioned below the air bag 9 in water, particularly in the upside-down position, the auto-valve 12 would function after the air bag 9 has expanded to its maximum to exhaust excess gas. With this, the air bag buoyancy will increase above the set buoyancy, subjecting the diver to excess buoyancy and causing the diver to begin to float up. As a countermeasure against this, the diver would need to make efforts to exhaust the gas, such as by changing his position to reduce that buoyancy.

However, by adjusting the height of the external opening end 132b of the flexible tube 132, it is possible to avoid this increase in buoyancy with a simple action. We will describe the principle of operation in reference to Figure 14. Note that areas corresponding to those in the above preferred embodiment are given the same symbols in Figure 14.

Gas introduced into the air bag 9 while the diver is in the upside-down position passes through the tube 134, check valve 135 and check valve 133 toward the external opening end 132b of tube 132. Here, the water level 901 within the air bag 9 takes the same height as the water level 902 of the tube 132.

If the introduction of gas into the air bag 9 continues, the water level within the air bag 9 drops and the water level in the tube 132 also drops accordingly. When the water level drops to the level of the external opening end 132b (indicated by the symbols 903 and 904 in the figure), gas is expelled from there into the outside. Therefore, the water level will drop no more even if the introduction of gas into the air bag continues. To wit, there will be no change in the amount of gas in the air bag 9 and therefore the buoyancy of the air bag will not increase.

Here, if the tube end 132b is moved upward while gas is continuously supplied into the interior of the air bag, the water level 901 within the air bag 9 will rise accordingly. In contrast, if the tube end 132b is lowered, the water level 901 within the air bag will drop accordingly. Therefore, buoyancy can be adjusted by changing the height of the tube end 132b. Thus, it is sufficient to secure the tube end 132b at a height position where the appropriate buoyancy is obtained.

Note that the above explanation describes an example in which the water draining apparatus is attached to a semiclosed-circuit breathing apparatus. However, the water draining apparatus can be also similarly applied to a closed-circuit breathing apparatus.

As described above, the water draining apparatus of this embodiment performs a pumping action linked to the expansion and contraction action of the air bag, thus automatically expelling water that enters the interior of the breathing apparatus and collects at the bottom of the air bag.

In addition, the pressure chamber and external open end of the water draining apparatus are arranged such that they are positioned near the center of the air bag 9, and the pressure chamber of the water draining apparatus is attached to the outside surface of the breathing air bag on the side opposite that which faces the back of the wearer, and also the external opening end is positioned on the outside surface of the air bag on the side opposite the outside surface where the pressure chamber is attached (namely the outside surface on the side facing the back of the wearer). For this reason, even considering a case that does not depend on expansion or contraction of the air bag, when the internal pressure of the air bag rises, the water within the air bag is expelled into the outside due to the pressure difference. In addition, along with functioning effectively as a discharge mechanism for excess internal breathing gas regardless of the position during swimming, it has advantages such as suppressing the increase in breathing resistance due to the swimming position.

Moreover, the height position of the external open end that communicates with the pressure chamber of the water draining apparatus is adjustable. It has the advantage of permitting this height position to be adjusted during diving in the upside-down position, thereby adjusting the set buoyancy of the air bag buoyancy.

(Arrangement of the Breathing Air Bags)

Next, we shall describe the case in which the semiclosed-circuit breathing apparatus 1 of this embodiment is attached to a buoyancy compensator (BC) vest like that used for general underwater breathing apparatus, and worn by a diver. During diving, depending on the vertical relationship with the lungs of the diver, a pressure difference arises due to water pressure during the dive. This pressure difference causes the breathing differential-pressure resistance to fluctuate. In order to reduce the breathing differential-pressure resistance, it is preferable for the air bag to be arranged at as near the same level as the lungs of the diver as possible. However, this point has conventionally not been taken into consideration. For this reason, the fluctuation in breathing resistance depending on the diving position is severe, resulting in the problem of a large load being placed on the diver.

In other words, as we shall describe with reference to Figure 17, when the diver is swimming in the downward-facing position as shown in Figure 17(a), a vertical difference arises between the center G1 of the air bag 199 and the center G3 of the lungs 200a of the diver 200. For this reason, the inhalation pressure becomes larger than the exhalation pressure by the amount of this pressure difference. In contrast, in the upside-down position as shown in (b), the difference between the air bag center G1 and the center of the lungs G3 increases, so the exhalation differential pressure increases compared to that of the downward-facing position. In addition, in the upright position as shown in (c), the center of the lungs G3 is at a position higher than the air bag center G1, so the exhalation pressure becomes large and the inhalation pressure is reduced, so there is a risk of excess inhalation. Moreover, in the upward-facing position as shown in (d), the center of the lungs G3 is at a position higher than the air bag center G1, so the exhalation pressure becomes large and the inhalation pressure is reduced.

Therefore, in an underwater breathing apparatus equipped with breathing air bags such as the apparatus 1 of this embodiment, it would be convenient if the fluctuation in the breathing differential-pressure resistance arising from changes in the diving position can be suppressed and the breathing differential-pressure resistance can be reduced as much as possible.

For this reason, the inventors focused their attention on the BC vest used to attach the main underwater breathing apparatus unit to the diver, and adopted a structure in which the breathing air bags are built into the vest. When both an exhalation air bag and inhalation air bag are provided, these air bags will be attached at positions corresponding to the left and right lungs of the diver when the vest is worn.

In this manner, by having the air bags built into the BC vest, in comparison to the conventional apparatus, the air bags are constantly at positions closer to those of the lungs of the diver regardless of which diving position is assumed. Thus, the vertical difference between the air bag center and the center of the lungs can be reduced and also the fluctuation can be suppressed. Thus, the breathing differential-pressure resistance can be reduced and the amount of fluctuation can also be reduced.

Here follows a description of the structure of a BC vest with a built-in air bag, made with reference to Figures 15 and 16.

As shown in Figure 15(a), the underwater breathing apparatus 201 consists of a main unit 210 and a BC vest 220 used to let the diver wear the main unit. The main unit 210 is the portion corresponding to the semi-closed-circuit breathing apparatus 1 described above. The figure shows the BC vest as seen from the back. The main unit 210 has the same structure as the semi-closed-circuit breathing apparatus 1 described above with the exception that the breathing air bags are not attached, and the figure shows only the canister 3 packed with carbon dioxide adsorbent used to remove carbon dioxide from exhaled air, the exhalation air tube 4 and the inhalation air tube 5 connected to the canister 3, and the mouthpiece unit 6 connected to the tips of these tubes.

The BC vest 220 consists of the vest proper 221 and a belt 222 used to permit the diver to wear this vest proper 221 along with various attachments for attaching the main unit 210. In this embodiment, in the state as when worn by the diver, the vest proper 221 contains the exhalation air bag 225 and the inhalation air bag 226 at two side areas 223 and 224 positioned in an area from either shoulder to the back. In the figure, these areas are indicated by hatching. In addition, the buoyancy bag 227 is stored in an area 228 attached around the waist of the diver.

Here, formed in the air bags 225 and 226 are connection holes 225a and 226a on the side toward the main unit 210, and these holes are open toward the back of the vest proper 221. On the other hand, formed in the canister 3 of the main unit 210 are connection holes 3a and 3b for connecting to the air bags 225 and 226. Although omitted from the figure, a connection is made with a tube from connection hole 225a of the exhalation air bag 225 to connection hole 3a of the canister 3. In addition, a connection is made with a separate tube from connection hole 226a of the inhalation air bag 226 to connection hole 3b of the canister 3.

Figure 15(b) shows the state of the diver 200 wearing the underwater breathing apparatus 201 of this embodiment of the structure described above. As shown in this figure, the air bags 225 and 226 contained in the BC vest 220 are in the state in which they are attached to areas reaching from either shoulder of the diver 200 extending toward the back.

Figure 16 shows the difference in height between the air bag center G1 and the center of the lungs G3 when the underwater breathing apparatus 201 of this embodiment is worn, in comparison to the analogous difference in height for the conventional apparatus shown in Figure 17.

As one can see from this figure, in this embodiment, the difference in height between the air bag center G1 and the center of the lungs G3 is smaller in all diving positions than that of the conventional case, and therefore the difference in water pressure is small so the breathing resistance is suppressed in comparison to the conventional case. In addition, this difference in height between the centers G1 and G3 in the various diving positions does not fluctuate so much depending on the position compared to the conventional case, but rather it is kept nearly constant. Therefore, fluctuation in the breathing resistance arising from the diving position can be suppressed.

In addition, in this embodiment, the air bags are contained within the vest, so there is no need for space to store the air bags on the side of the main unit 210, and thus the main unit 210 can be made that much more compact for an added advantage. In other words, while the volume of these air bags are normally 5 to 7 liters, there is no need to store them in the main unit, so the apparatus housing can be made more compact.

Note that the above explanation describes an example that applies to a semiclosed-circuit breathing apparatus, but it can be also similarly applied to a closed-circuit breathing apparatus or other breathing apparatus equipped with an air bag.

As described above, a structure is adopted in which the BC vest contains the breathing air bags so during diving, the vertical difference between the center of the lungs of the diver and the air bag center can be made small. In addition, the amount of fluctuation of the vertical difference between the centers due to changes in the diving position can also be suppressed. Therefore, the breathing differential-pressure resistance can be reduced compared to the conventional case in which the air bags are attached to the main unit and also fluctuations in the breathing resistance arising due to changes in the diving position can be suppressed. Moreover, there is also the advantage that the main unit can be made more compact because there is no need for space in the main unit for attaching the air bags.

Industrial Applicability

As explained in the foregoing, the carbon dioxide adsorption apparatus for underwater breathing apparatus of the present invention comprises: a hollow casing in which an opening is formed on one side, a removable cover that is attached to said opening, a removable carbon dioxide adsorbent canister that is enclosed within a sealed space formed into a compartment by the casing and cover, and carbon dioxide adsorbent packed within this carbon dioxide adsorbent canister. Thus, if carbon dioxide adsorbent canisters are prepared in advance, these can be simply placed within the casing to perform the work of replacing the carbon dioxide adsorbent conveniently.

The carbon dioxide adsorbent canister of the present invention consists of the combination of three separate parts: outer cylinder, inner cylinder and cover. Therefore, none of the individual parts is complex in shape so they can be simply molded from synthetic resin or the like as the raw material.

Moreover, the cover of the carbon dioxide adsorbent canister is attached such that it is pushed toward the side in which the carbon dioxide adsorbent is packed by a coil spring or other elastic means. Therefore, even if the carbon dioxide adsorbent becomes further compacted due to vibrations during usage, the cover will move accordingly, so no gaps will be formed. Therefore, there is the advantage that no gaps with no carbon dioxide adsorbent present will form.

Claims

1. In an underwater breathing apparatus constituted such that exhaled air recovered from a mouthpiece unit is passed through a carbon dioxide adsorption apparatus and regenerated, and a mixture of said regenerated gas and a constant flow of new gas for inhalation supplied from a breathing gas cylinder is supplied to said mouthpiece unit as the gas for inhalation,

    an improved carbon dioxide adsorption apparatus for underwater breathing apparatus characterized in that:
    said carbon dioxide adsorption apparatus comprises:
    a hollow casing in which an opening is formed on one side,
    a removable cover that is attached to said opening,
    a removable carbon dioxide adsorbent canister that is enclosed within a sealed space formed into a compartment by the casing and cover, and
    carbon dioxide adsorbent packed within this carbon dioxide adsorbent canister; and,
    said carbon dioxide adsorbent canister comprises:
    an outer cylinder, one end of which forms a sealing bottom,
    an inner cylinder, which can be inserted from a bottom hole opened in the center of this sealing bottom of the outer cylinder, and one end of which forms a sealing bottom, and
    a cover that can be fit over the tip of said inner cylinder,
    such that the inside surface of the opening of said outer cylinder and the outside surface of said cover form a lock that prevents said cover from coming off in the removable state, thus forming a constitution in which the peripheral surface of said outer cylinder and inner cylinder becomes a gas-permeable surface; and,
    the inner cylinder is inserted from the bottom hole of the outer cylinder and then carbon dioxide adsorbent is packed within the annular space formed between the outer cylinder and inner cylinder, and then the cover is fitted onto the outer cylinder and inner cylinder, thereby constituting said carbon dioxide adsorbent canister, and moreover, the cover of said carbon dioxide adsorbent canister is pushed toward the side in which the carbon dioxide adsorbent is packed by a coil spring or other elastic means.

2. A carbon dioxide adsorbent canister characterized in that it is provided with the constitution described in claim 1.

Fig. 1

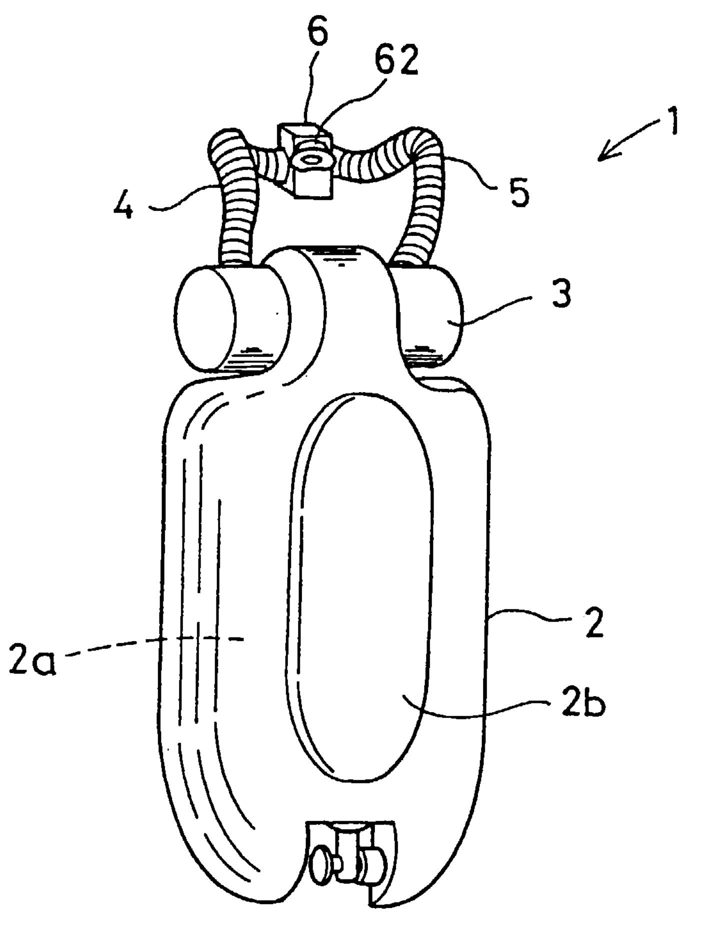


Fig. 2

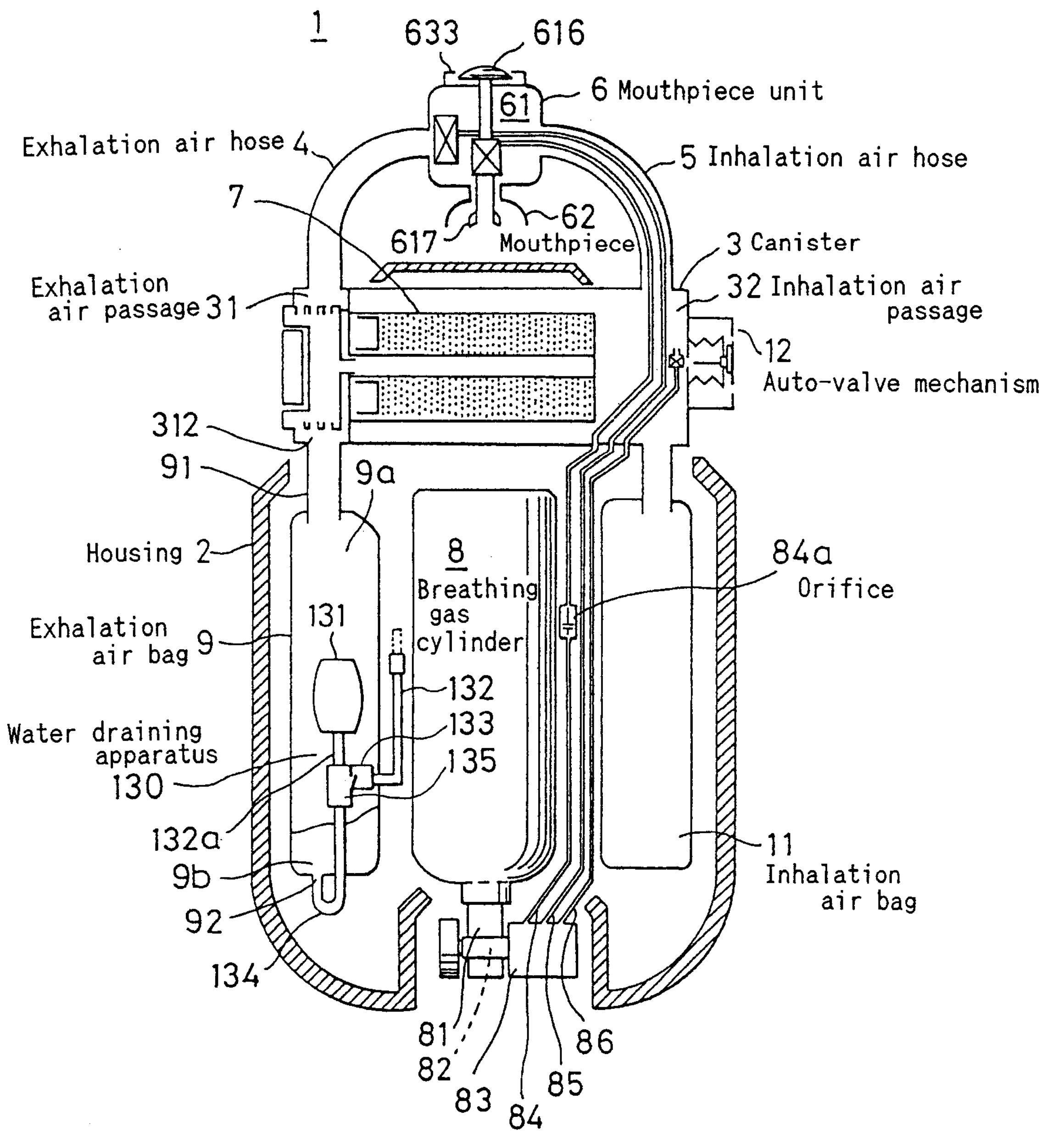

1
633
616
6 Mouthpiece unit
61
Exhalation air hose 4
5 Inhalation air hose
7
617
62
Mouthpiece
3 Canister
Exhalation air passage 31
32 Inhalation air passage
12
Auto-valve mechanism
312
91
9a
Housing 2
8
Breathing gas cylinder
84a
Orifice
Exhalation air bag 9
131
132
133
Water draining apparatus
130
135
132a
9b
92
134
11
Inhalation air bag
81
82
83
84
85
86

Fig. 3

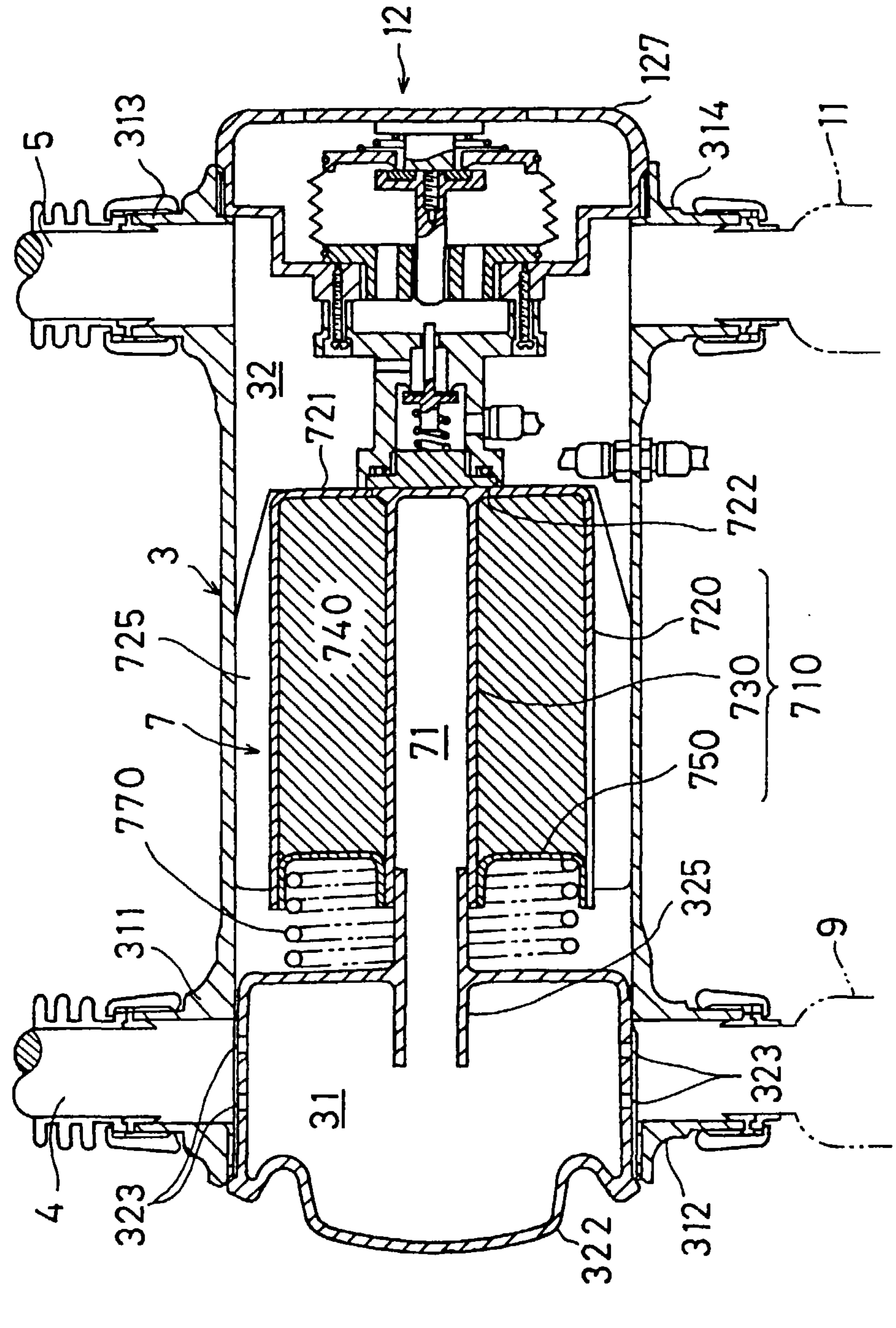

12
127
5
313
314
11
32
721
722
3
725
740
720
730
710
7
71
750
770
311
325
9
323
31
4
312
322

Fig. 4

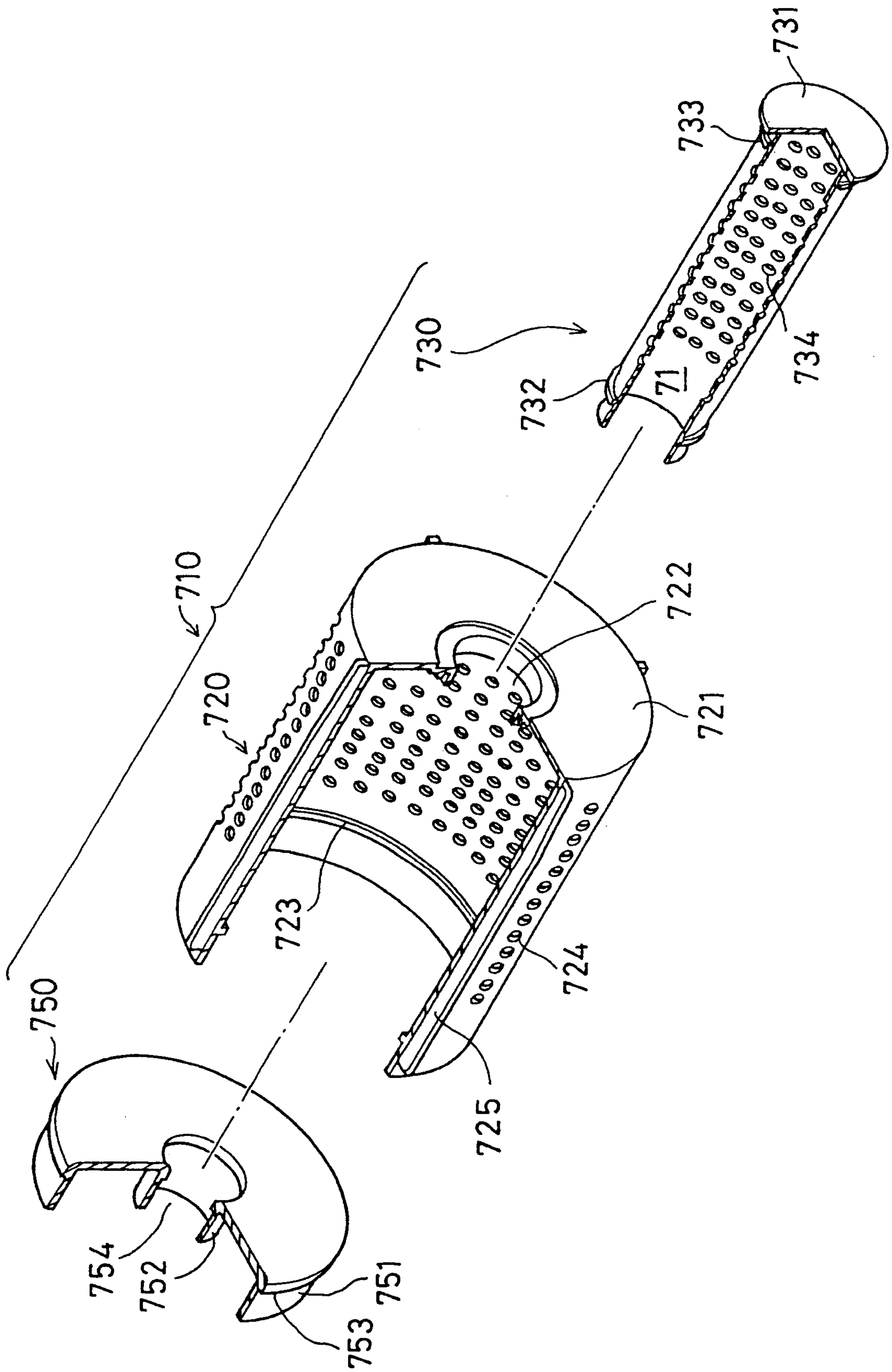
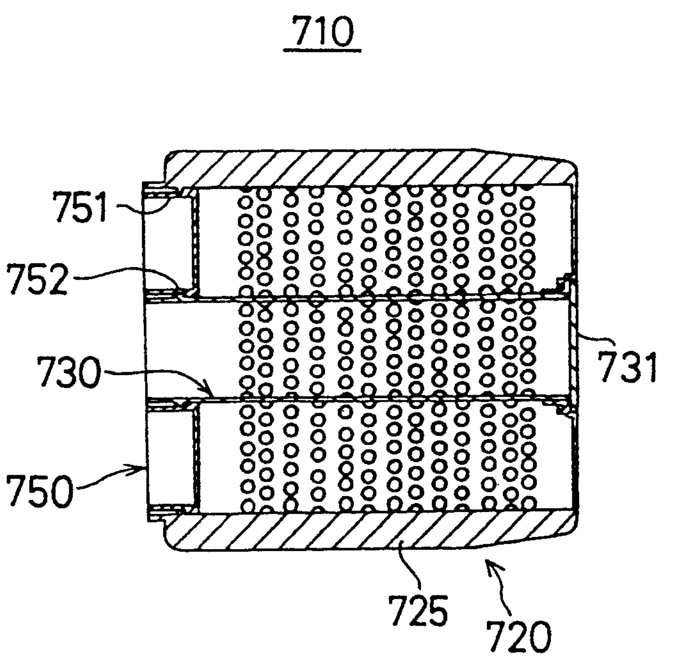

731
733
730
734
732
71
710
722
720
721
723
724
750
725
754
752
751
753

Fig. 5



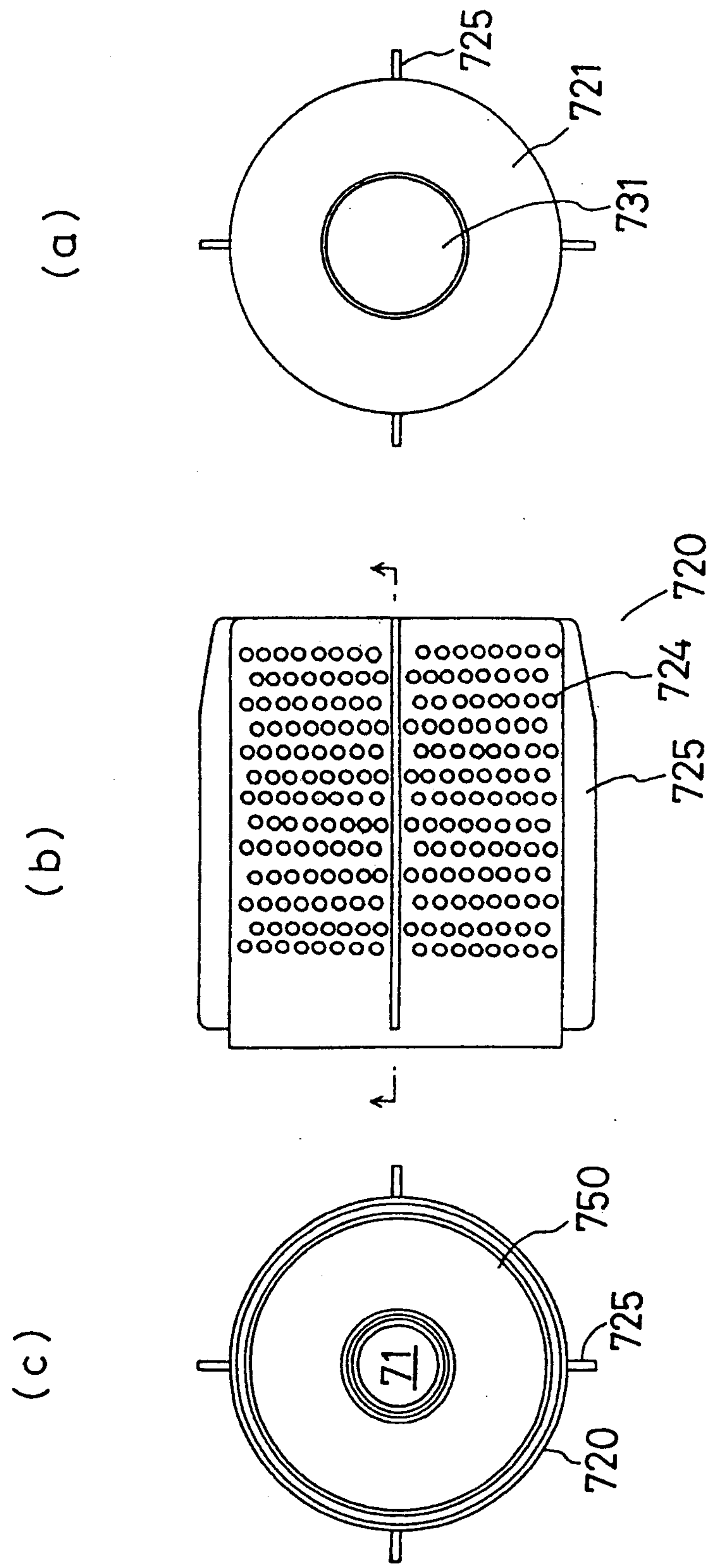
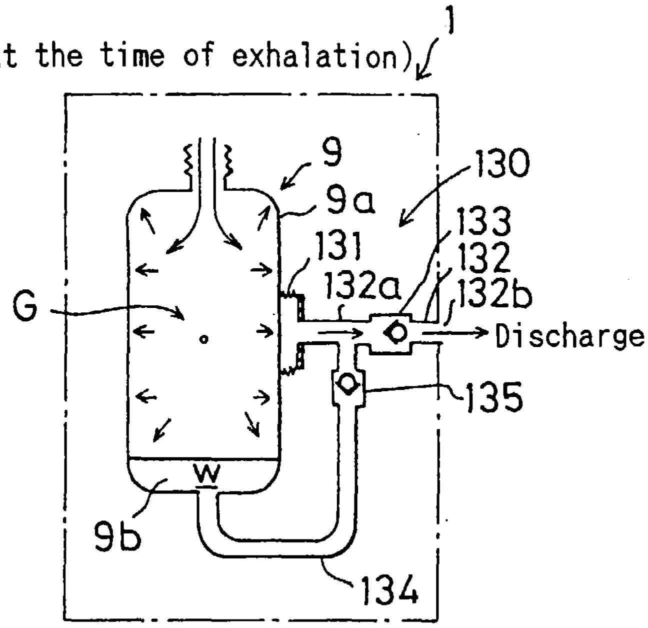


Fig. 6

Fig. 7

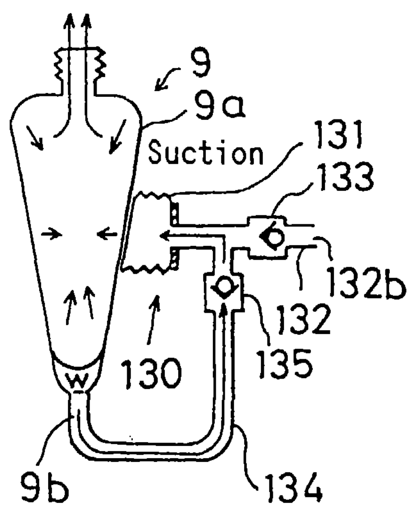
(a)

(At the time of exhalation)



(b)

(At the time of inhalation)



(c)

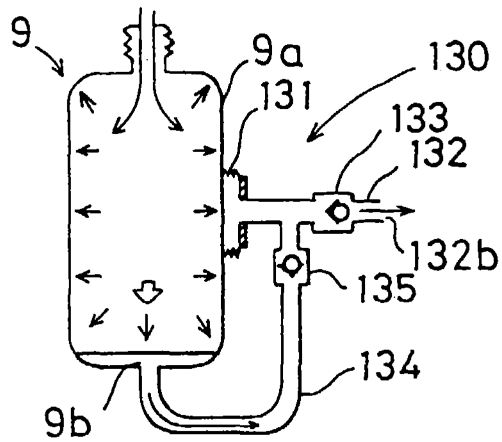


Fig. 8

(a)

(b)

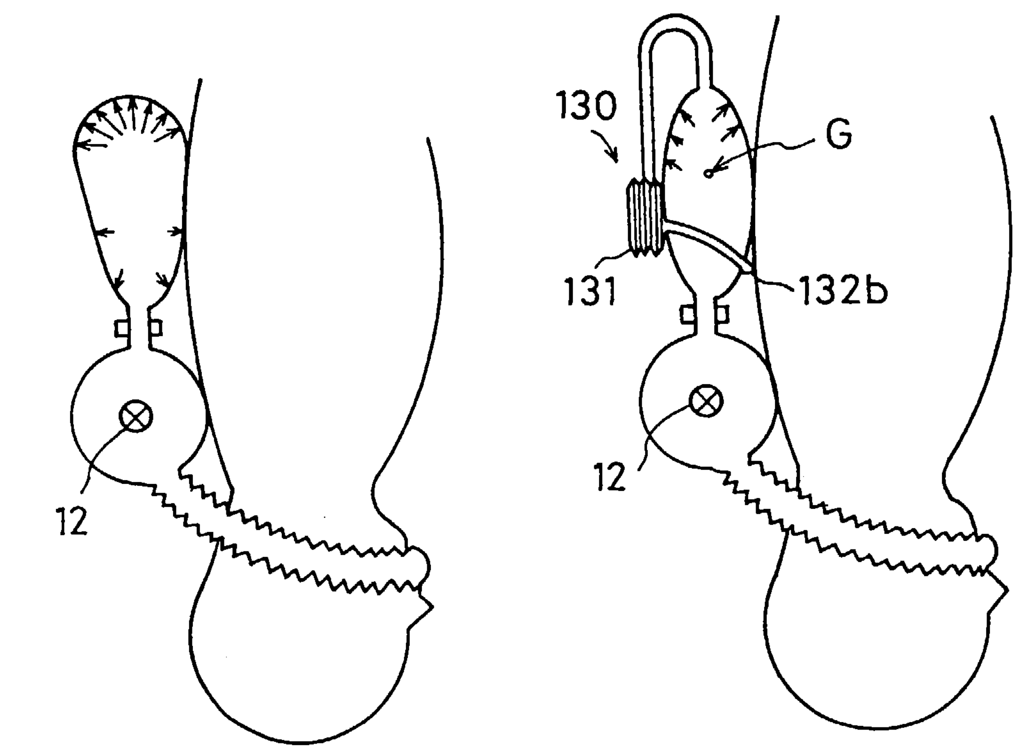


Fig. 9

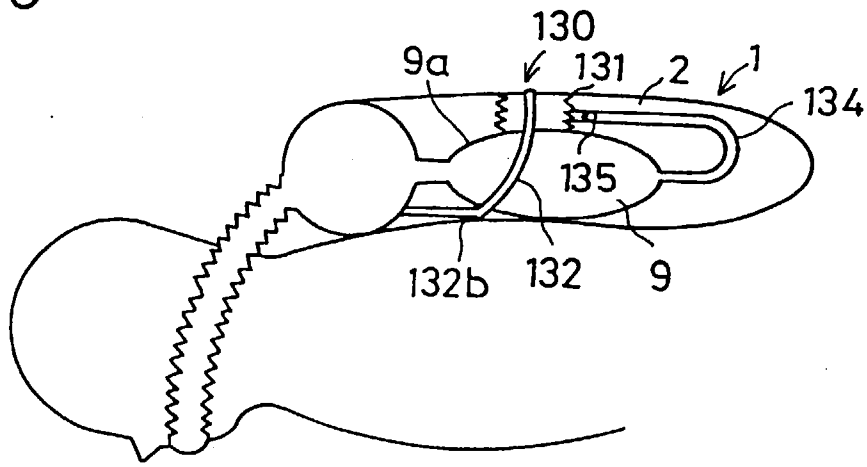


Fig. 10

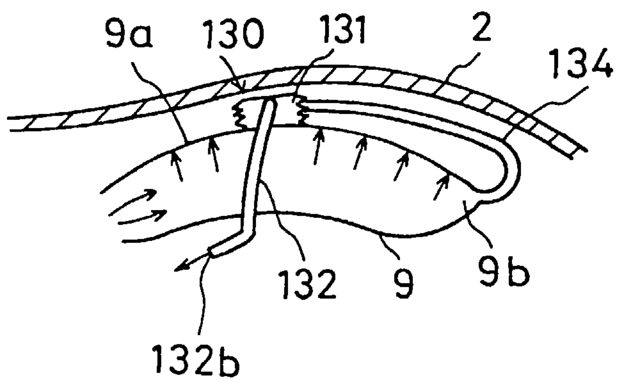


Fig. 11

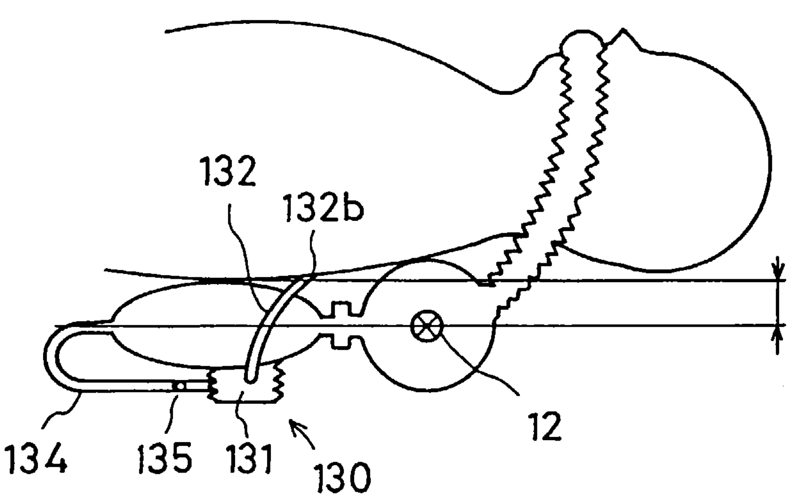


Fig. 12

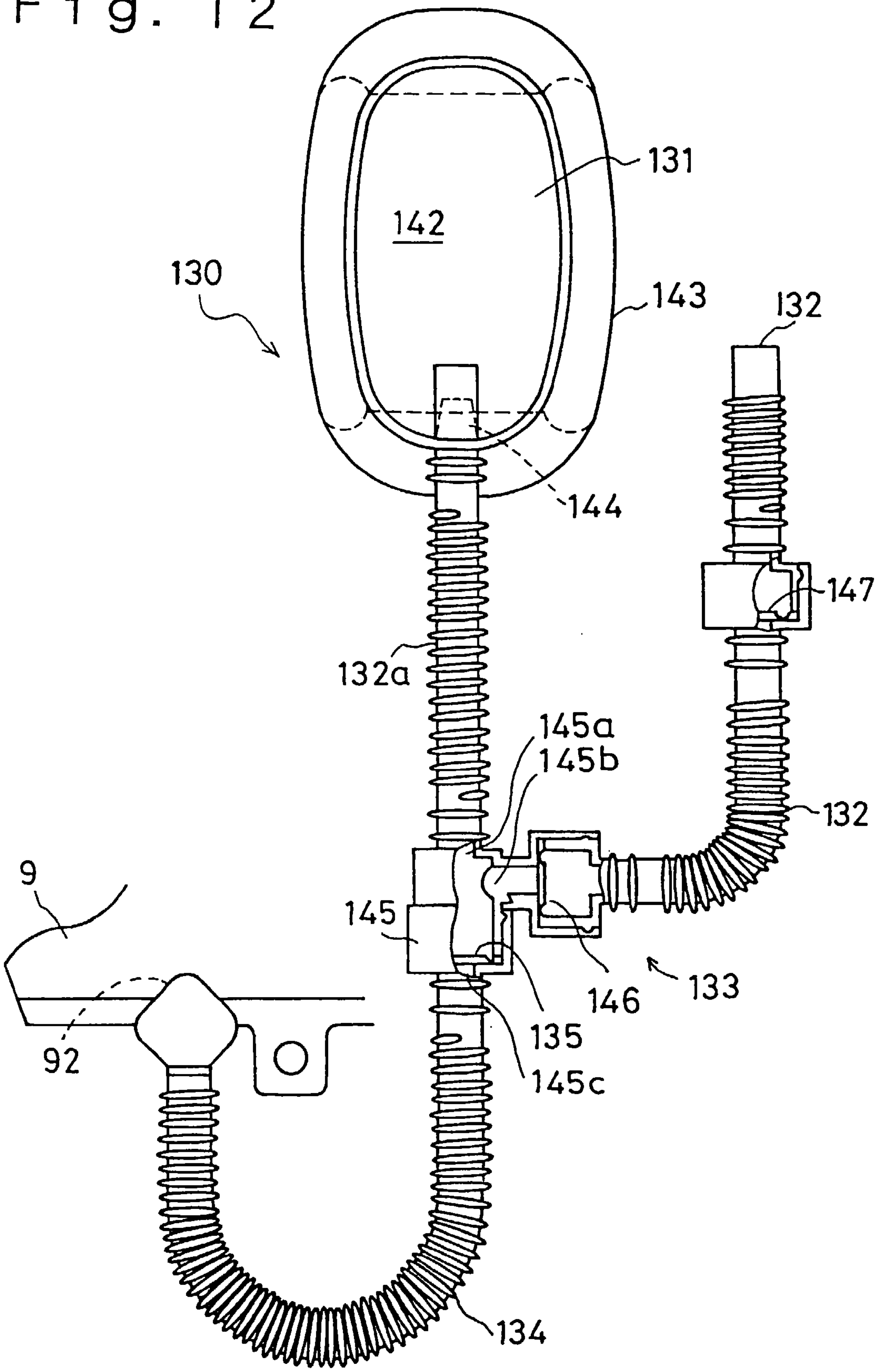

131
142
130
143
132
144
147
132a
145a
145b
132
9
145
133
146
92
135
145c
134

Fig. 13

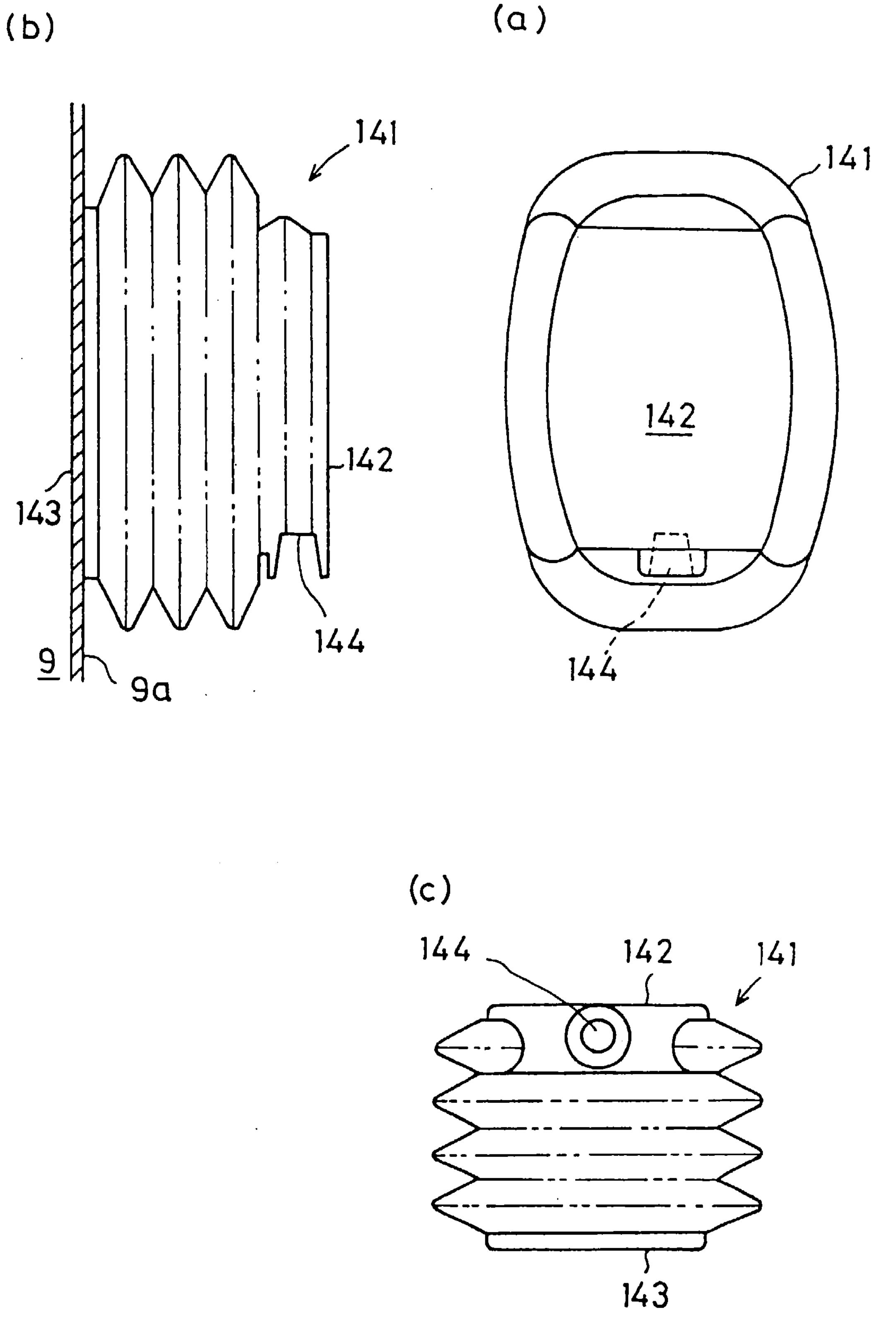


Fig. 14

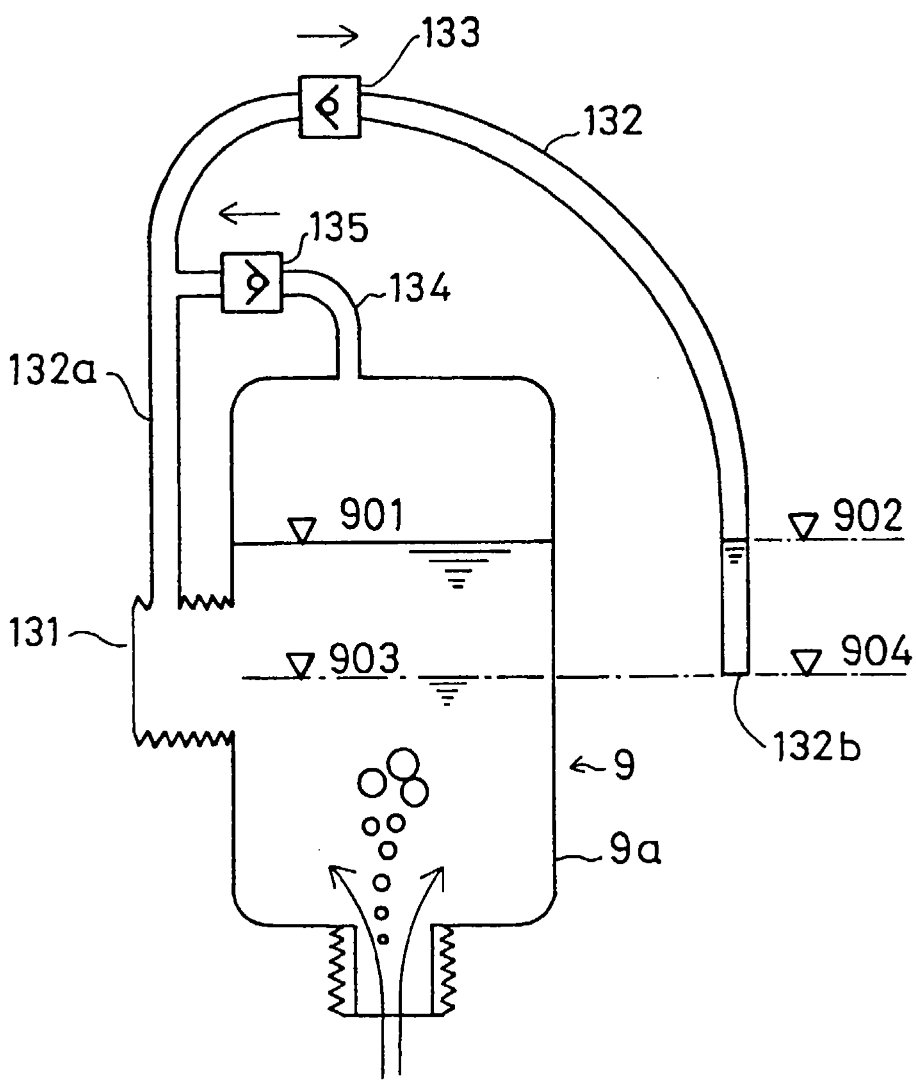
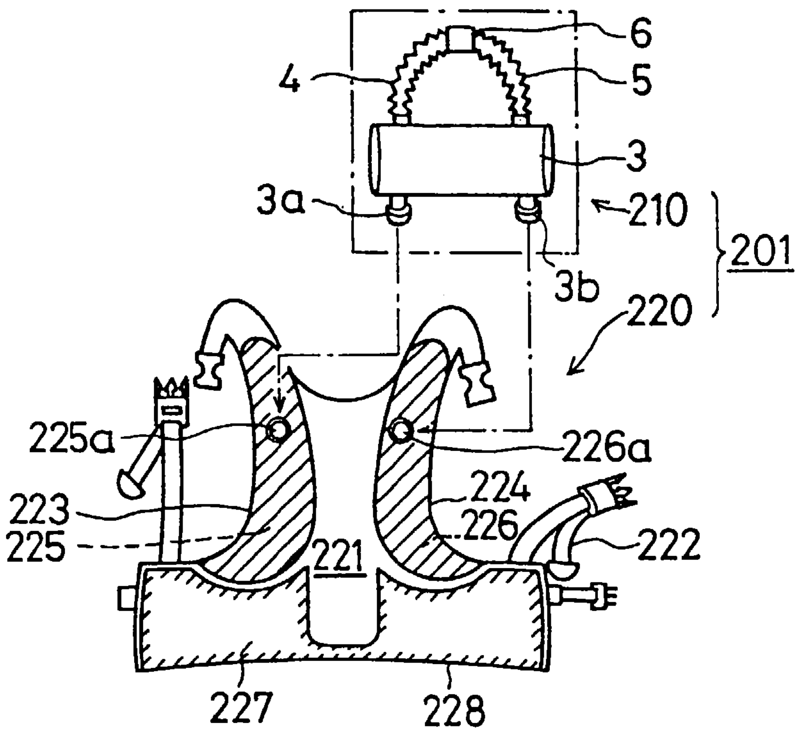


Fig. 15

(a)


6
4
5
3
3a
210
201
3b
220
225a
226a
224
223
226
225
221
222
227
228

(b)

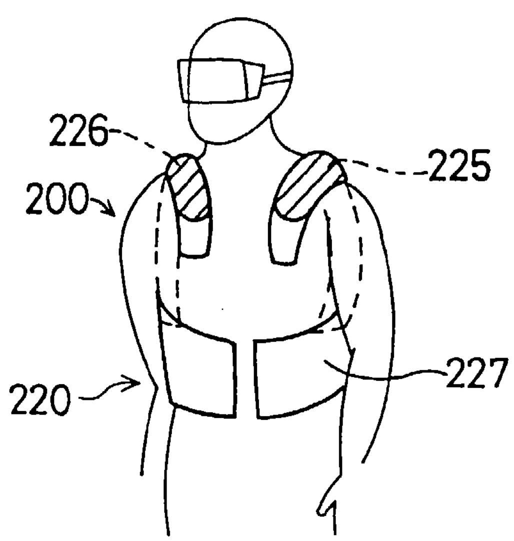
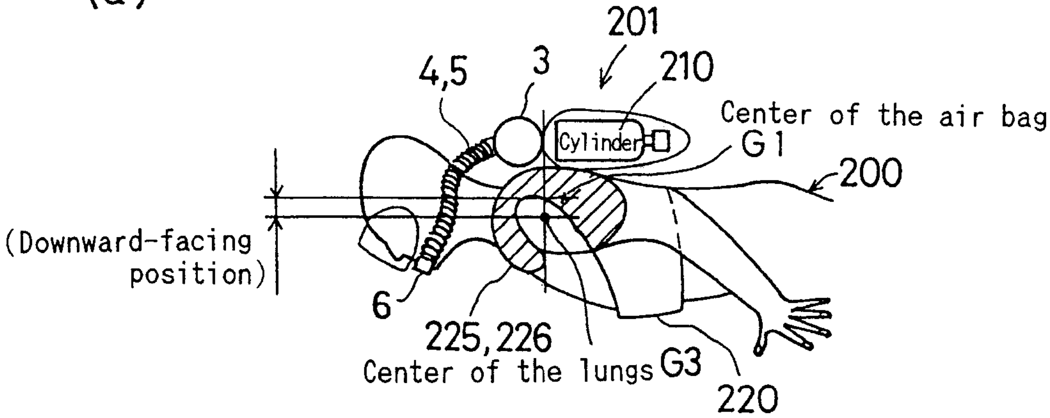
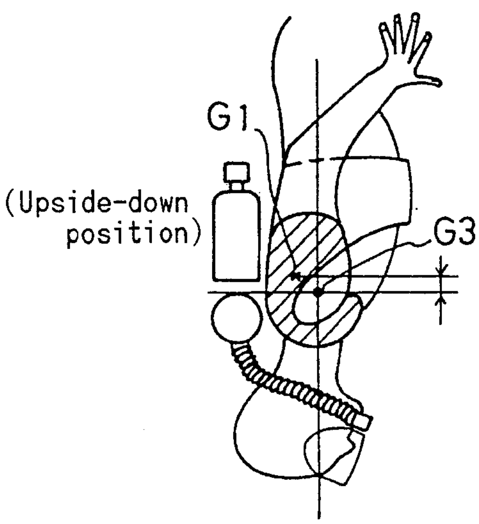

226
225
200
227
220

Fig. 16

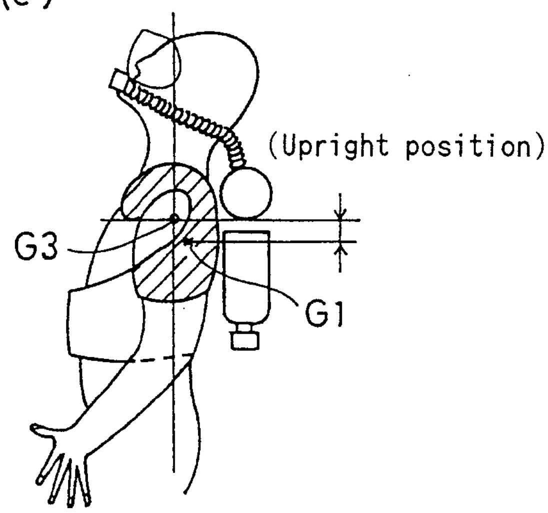
(a)


201
4,5
3
210
Cylinder
Center of the air bag
G1
200
(Downward-facing position)
6
225,226
Center of the lungs
G3
220

(b)


G1
(Upside-down position)
G3

(c)


(Upright position)
G3
G1

(d)

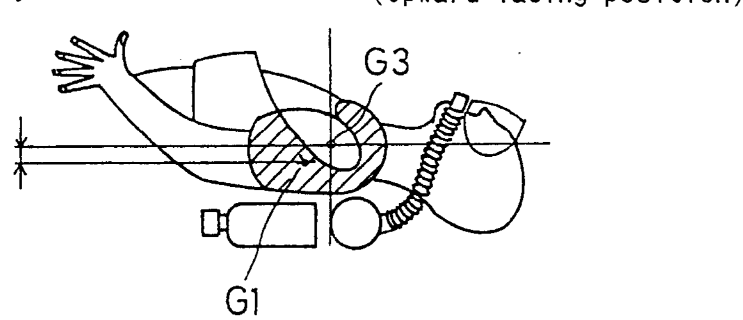
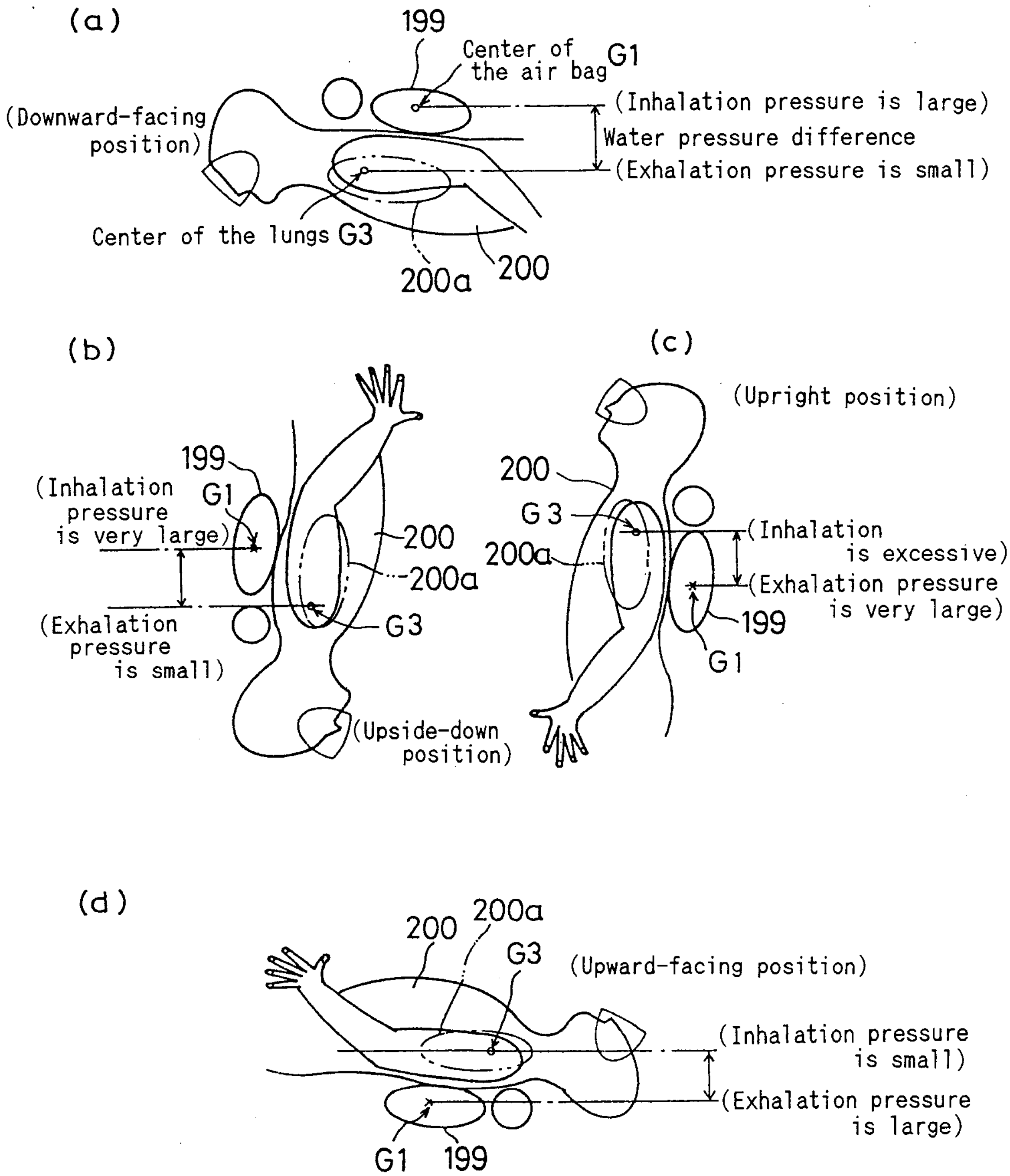

(Upward-facing position)
G3
G1

Fig. 17


(a)
199
Center of the air bag G1
(Downward-facing position)
(Inhalation pressure is large)
Water pressure difference
(Exhalation pressure is small)
Center of the lungs G3
200a
200
(b)
199
(Inhalation pressure is very large)
G1
200
200a
G3
(Exhalation pressure is small)
(Upside-down position)
(c)
(Upright position)
200
G3
200a
(Inhalation is excessive)
(Exhalation pressure is very large)
199
G1
(d)
200
200a
G3
(Upward-facing position)
(Inhalation pressure is small)
(Exhalation pressure is large)
G1
199

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP95/01558

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl[6] B63C11/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl[6] B63C11/18-11/24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1926 - 1995
Kokai Jitsuyo Shinan Koho 1971 - 1995

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP, 7-101388, A (Grand Bleu Inc.), April 18, 1995 (18. 04. 95), Line 49, left column, page 8 to line 16, left column, page 9 & WO, 9509762, A1 & AU, 9458235, A	1, 2
A	JP, 7-25384, A (Zexel Corp.), January 27, 1995 (27. 01. 95)(Family: none)	1, 2
A	JP, 6-171590, A (Grand Bleu Inc.), June 21, 1994 (21. 06. 94)(Family: none)	1, 2
A	JP, 3-124999, U (Nippon Sanyaku K.K.), December 18, 1991 (18. 12. 91)(Family: none)	1, 2
A	JP, 54-3000, U (Asahi Senken K.K.), January 10, 1979 (10. 01. 79)(Family: none)	1, 2
A	JP, 53-99799, U (Asahi Senken K.K.), August 12, 1978 (12. 08. 78)(Family: none)	1, 2

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
October 4, 1995 (04. 10. 95)	October 31, 1995 (31. 10. 95)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP95/01558

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 50-108797, A (Terens Barinton Porl), August 27, 1975 (27. 08. 75) & AU, 7406482, A1	1, 2
A	JP, 50-43920, Y2 (Asahi Senken K.K.), December 15, 1975 (15. 12. 75) (Family: none)	1, 2
EX	JP, 7-215288, A (Grand Bleu Inc.), August 15, 1995 (15. 08. 95), Lines 1 to 34, left column, page 2 (Family: none)	1, 2

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