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(56) Documents Cited:
GB 2072526 A EP 3313487 A1
EP 2145644 A1 WO 2016/097669 A1
WO 2013/001216 A1 WO 2007/025336 A1
US 6098621 A US 4110419 A

(58) Field of Search:
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(54) Title of the Invention: Gas conservation apparatus

Abstract Title: A gas reservoir for supplying a gas to a subject comprising a wall with gas inlet and outlet having respective gas conduits

(57) Apparatus 22 for supplying a gas to a subject, comprising a reservoir 100 with a wall 102 to hold a volume of gas, the wall having an inlet 126b and conduit 122 for receiving gas to be supplied to the subject and an outlet 128b and conduit 124 for supplying gas from the reservoir to the subject. The inlet and outlet are disposed such that gas enters the reservoir through the inlet before passing to the outlet. In a first aspect, the flow of gas through the inlet draws gas from the second conduit through the outlet when the gas in the second conduit is subjected to a back pressure. In a second aspect the gas conduits are arranged to allow heat exchange between gas in the conduits. In a third aspect the reservoir wall is tapered from a first end 100a comprising the inlet/outlet to a second end 100b.

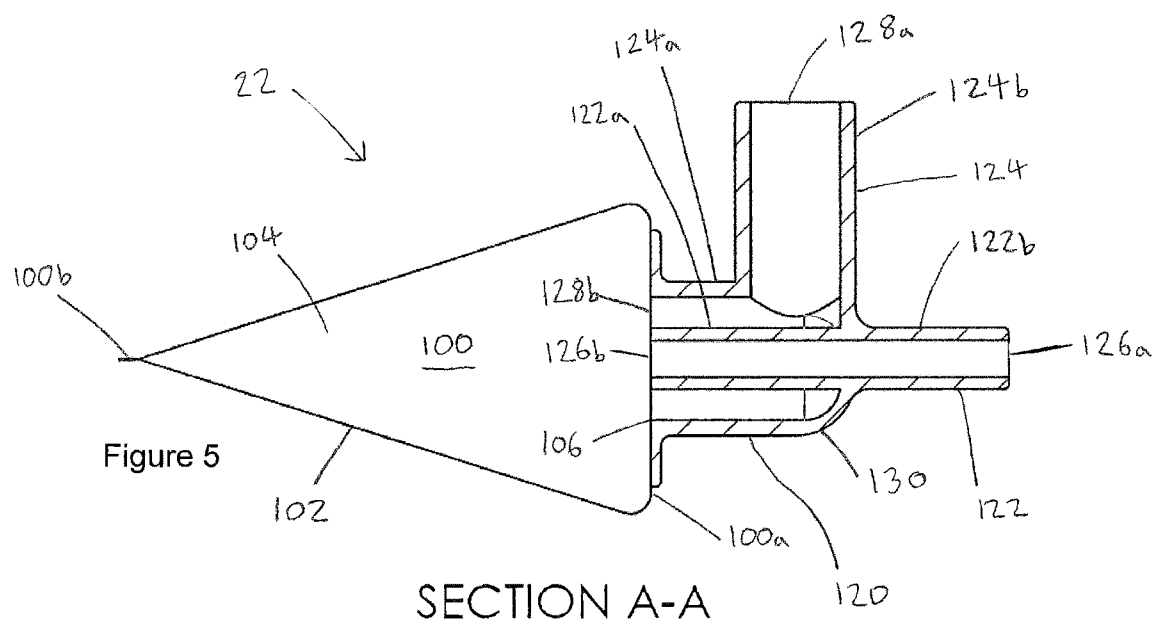


Figure 5

SECTION A-A

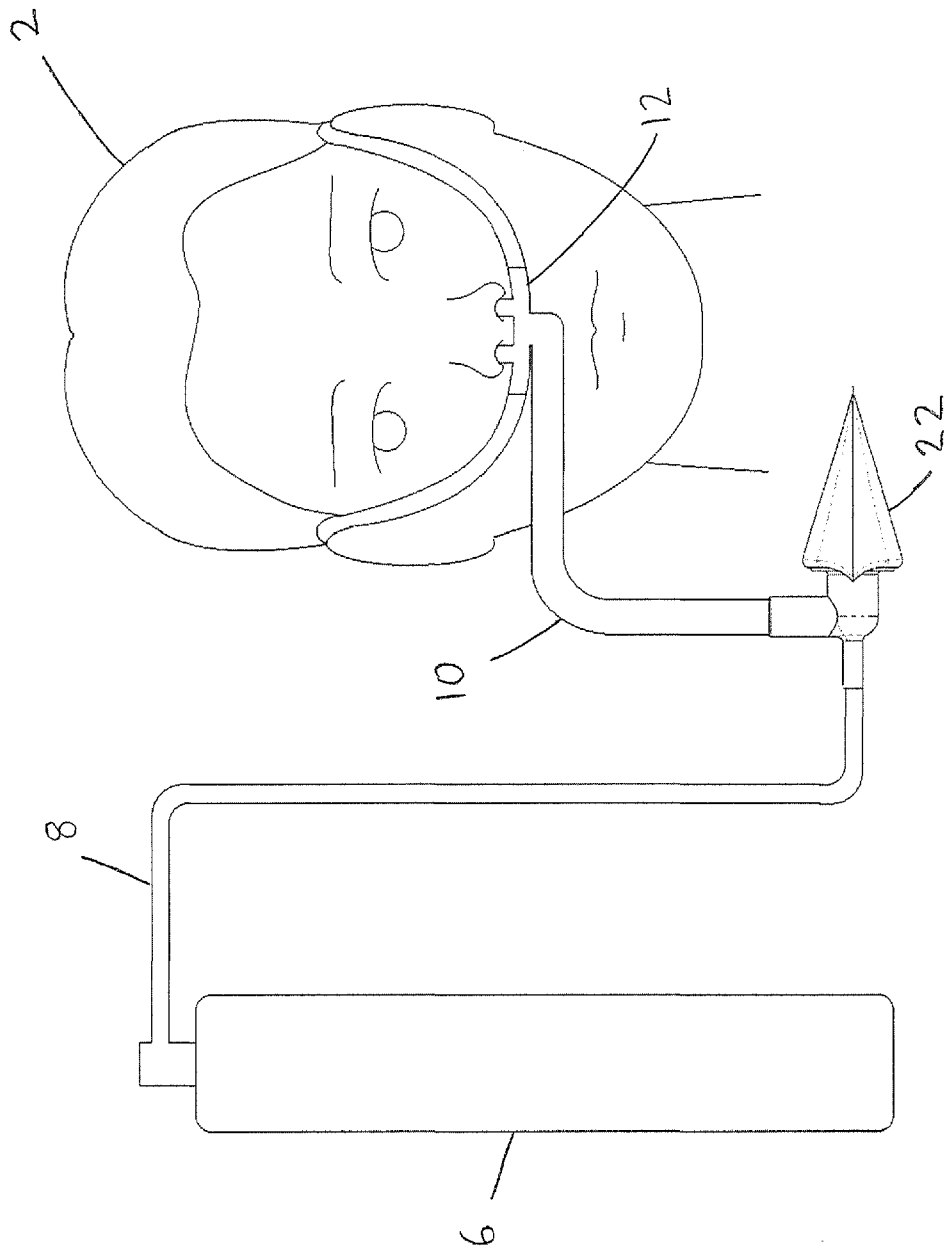


Figure 1

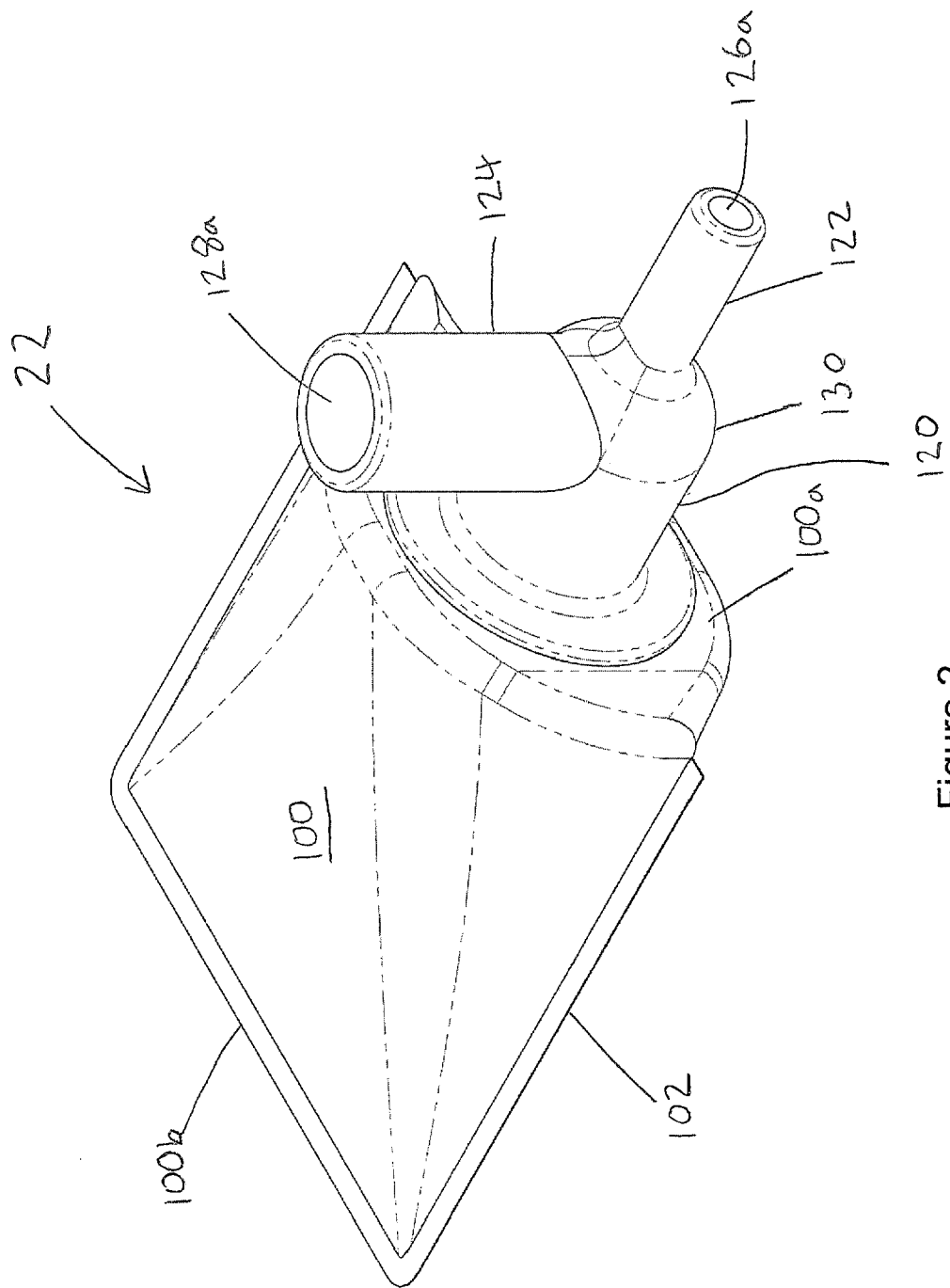


Figure 2

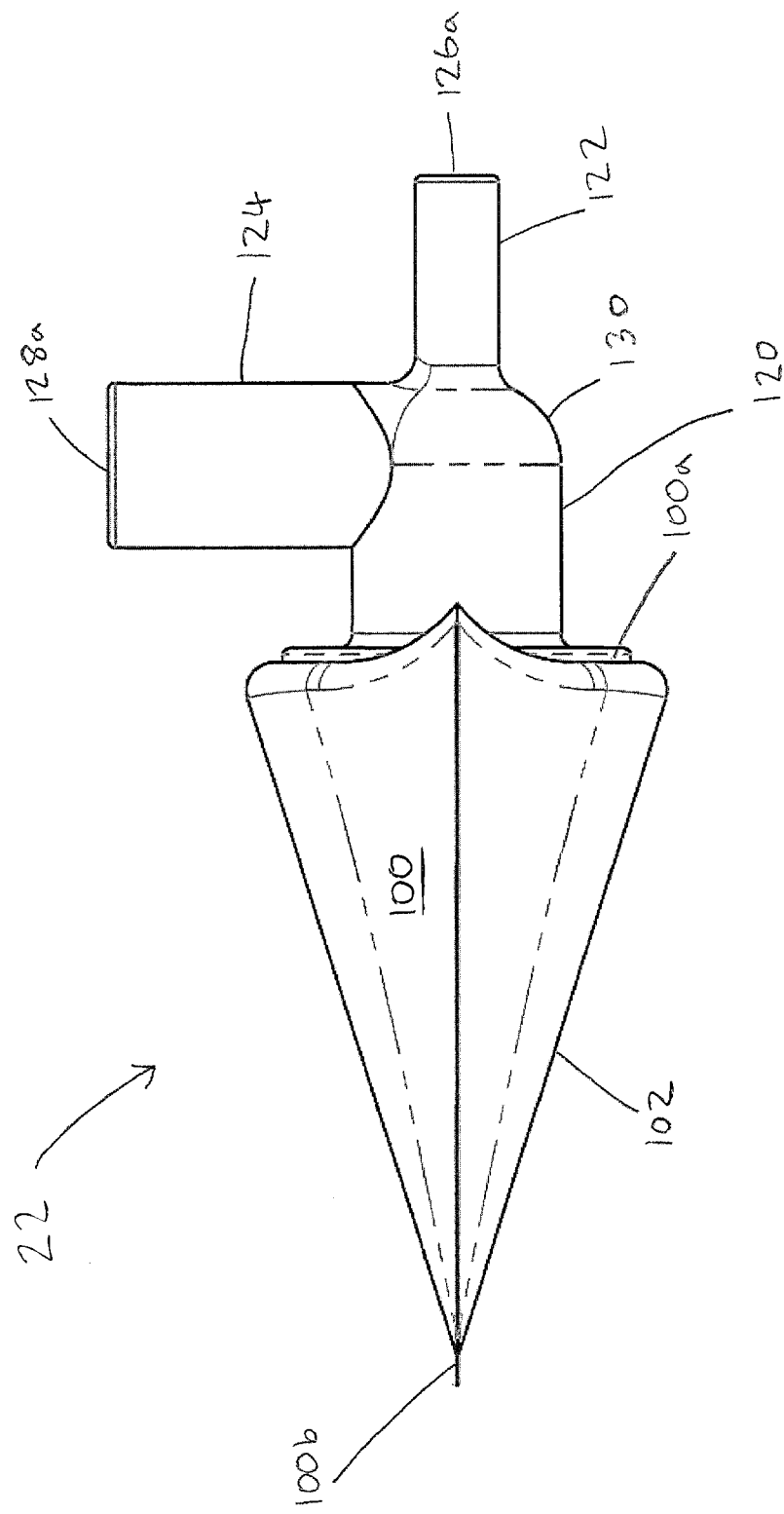


Figure 3

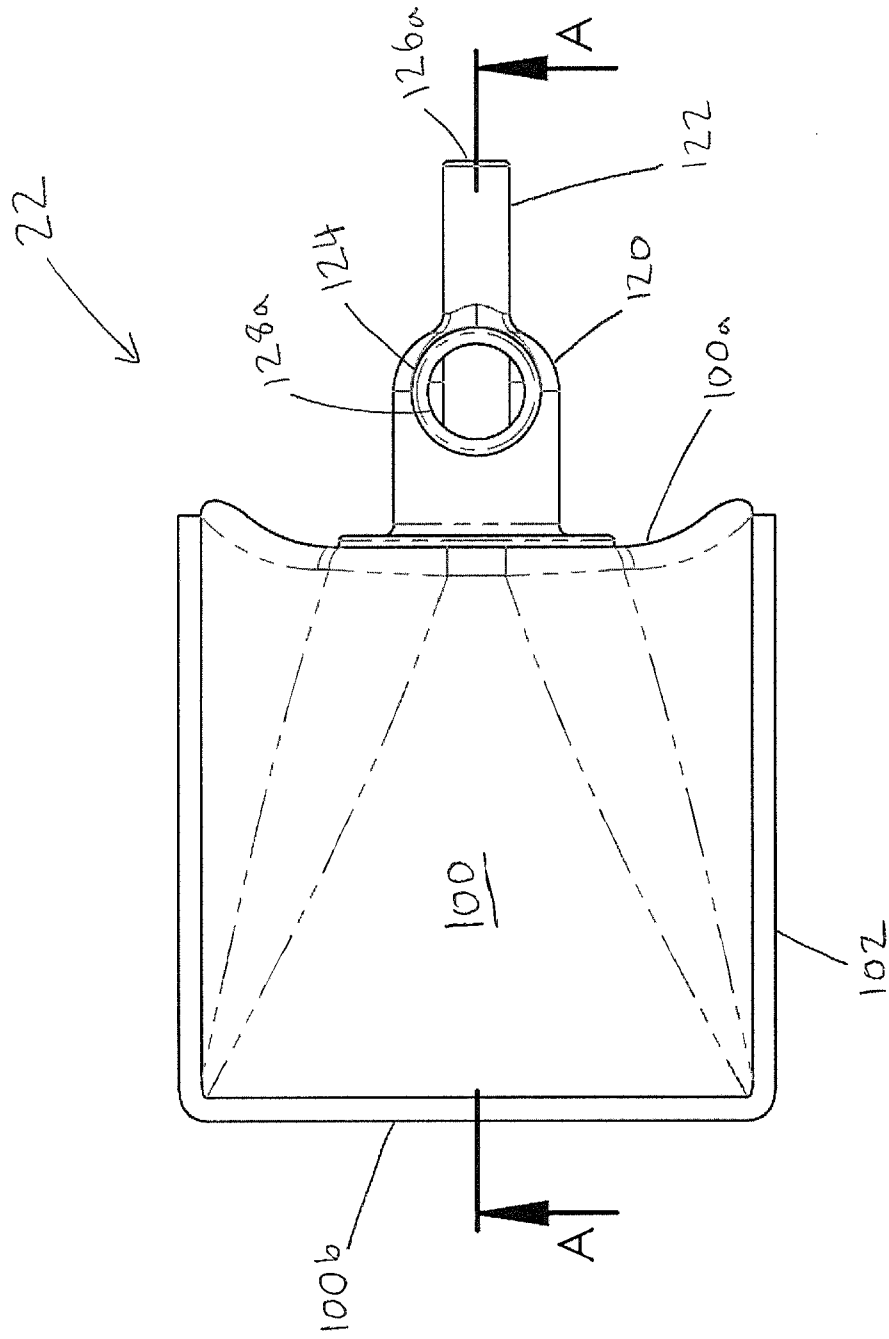


Figure 4

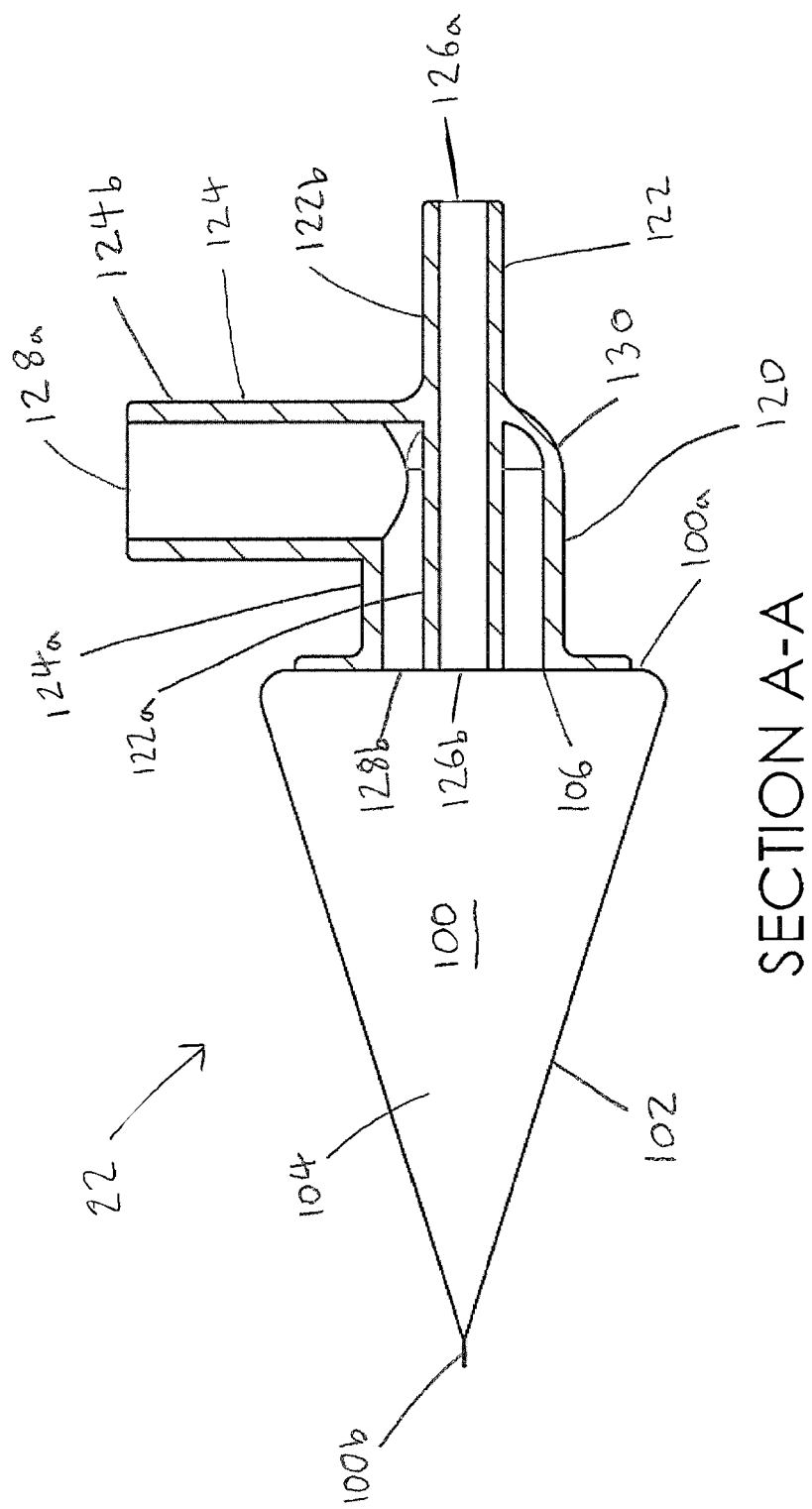


Figure 5

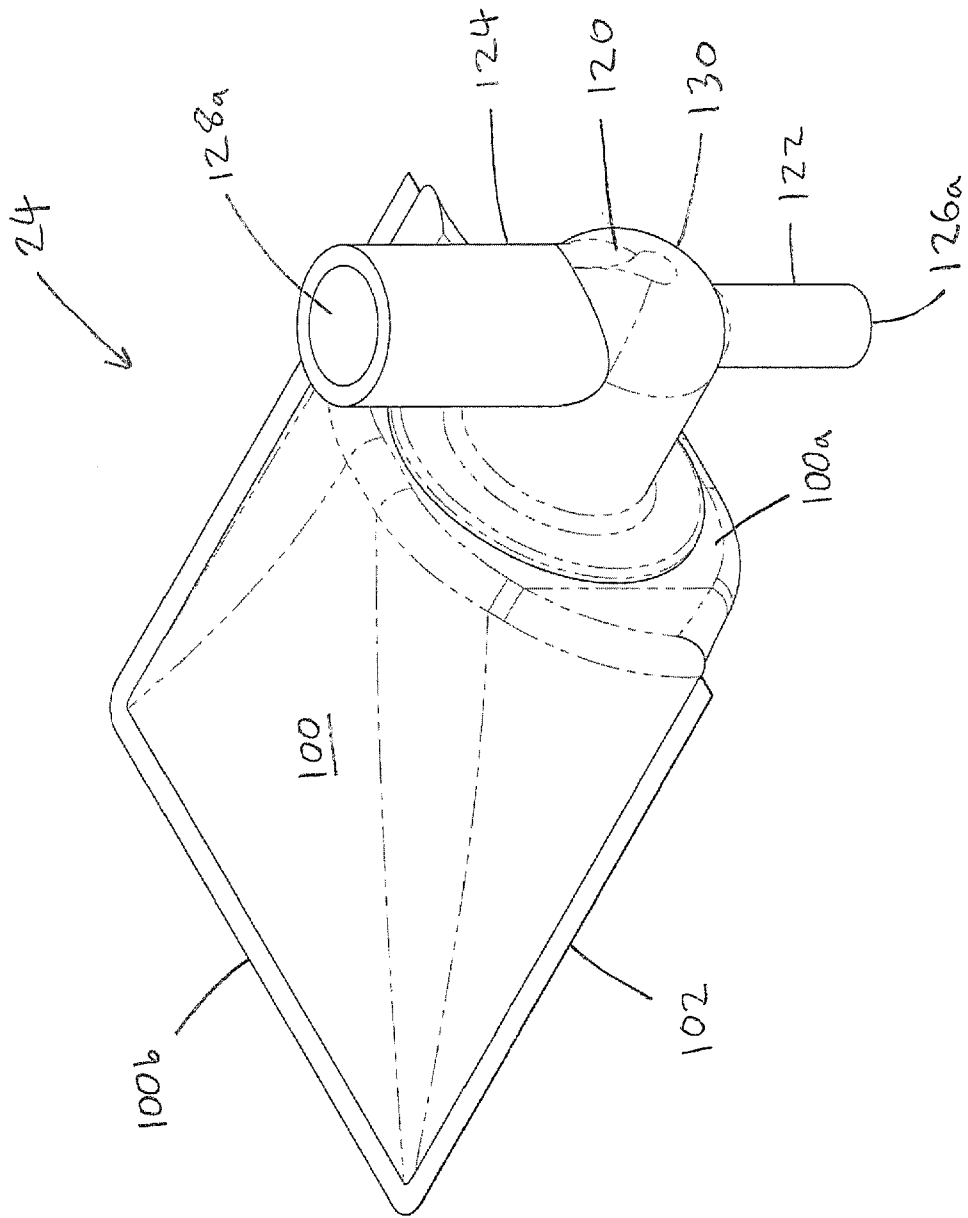


Figure 6

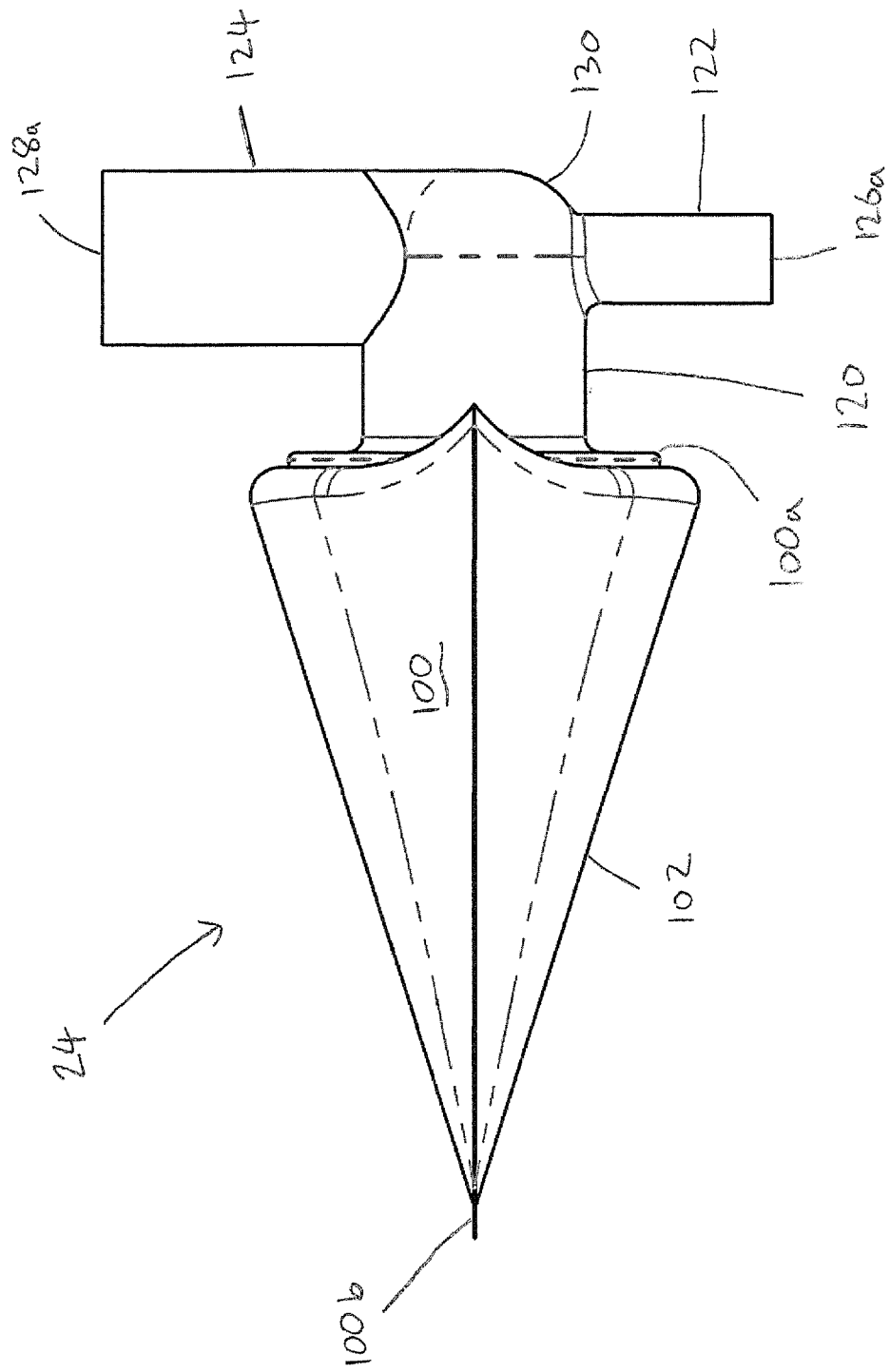


Figure 7

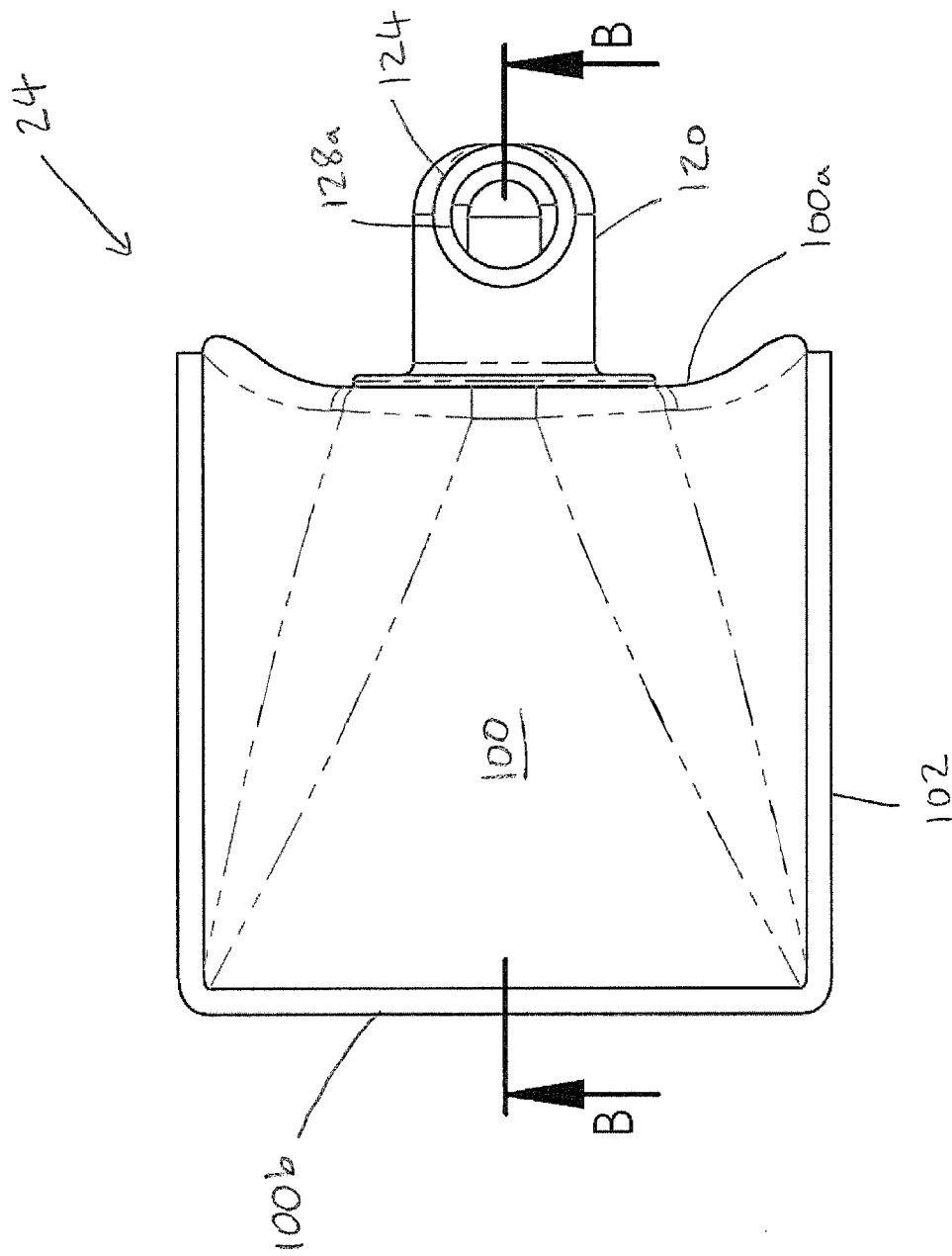


Figure 8

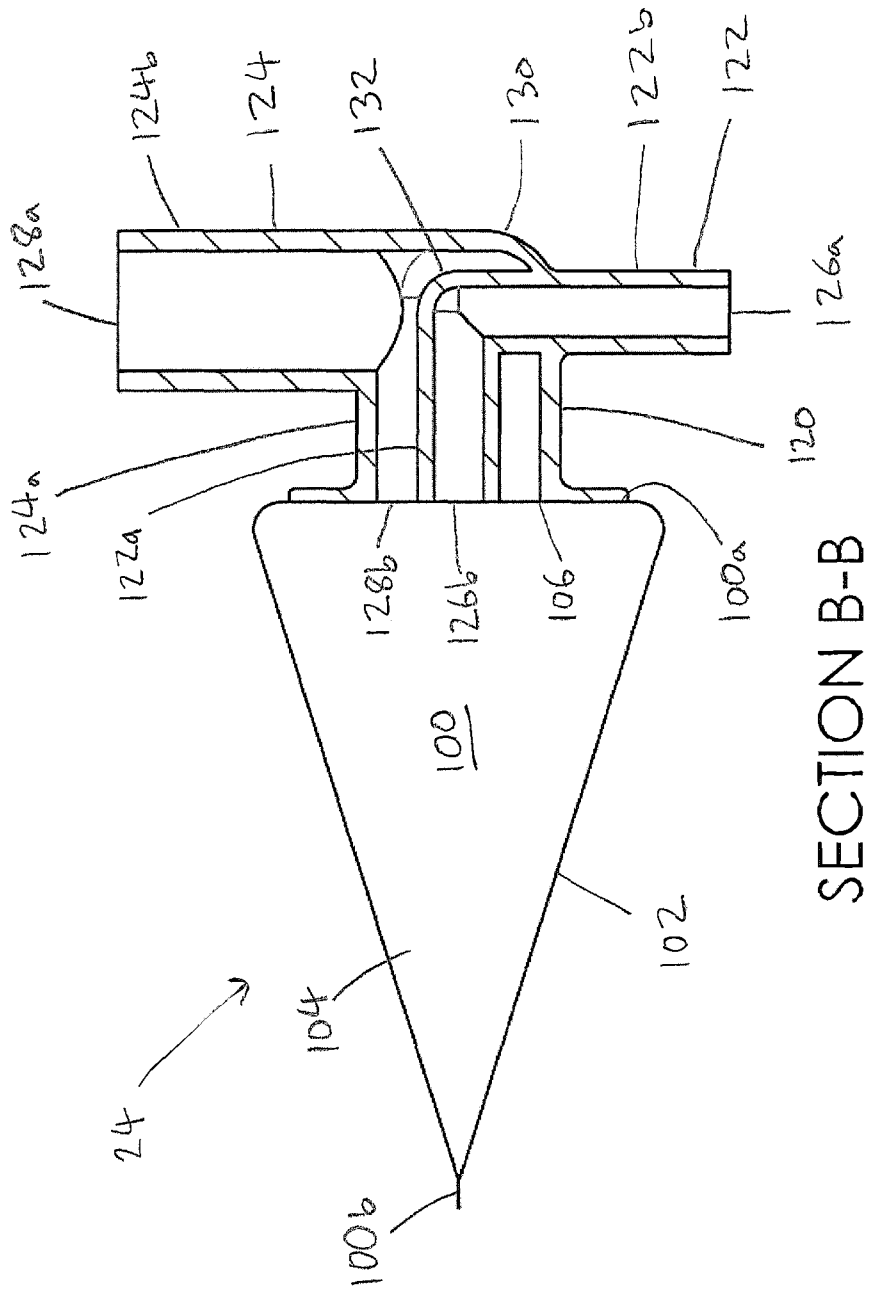


Figure 9

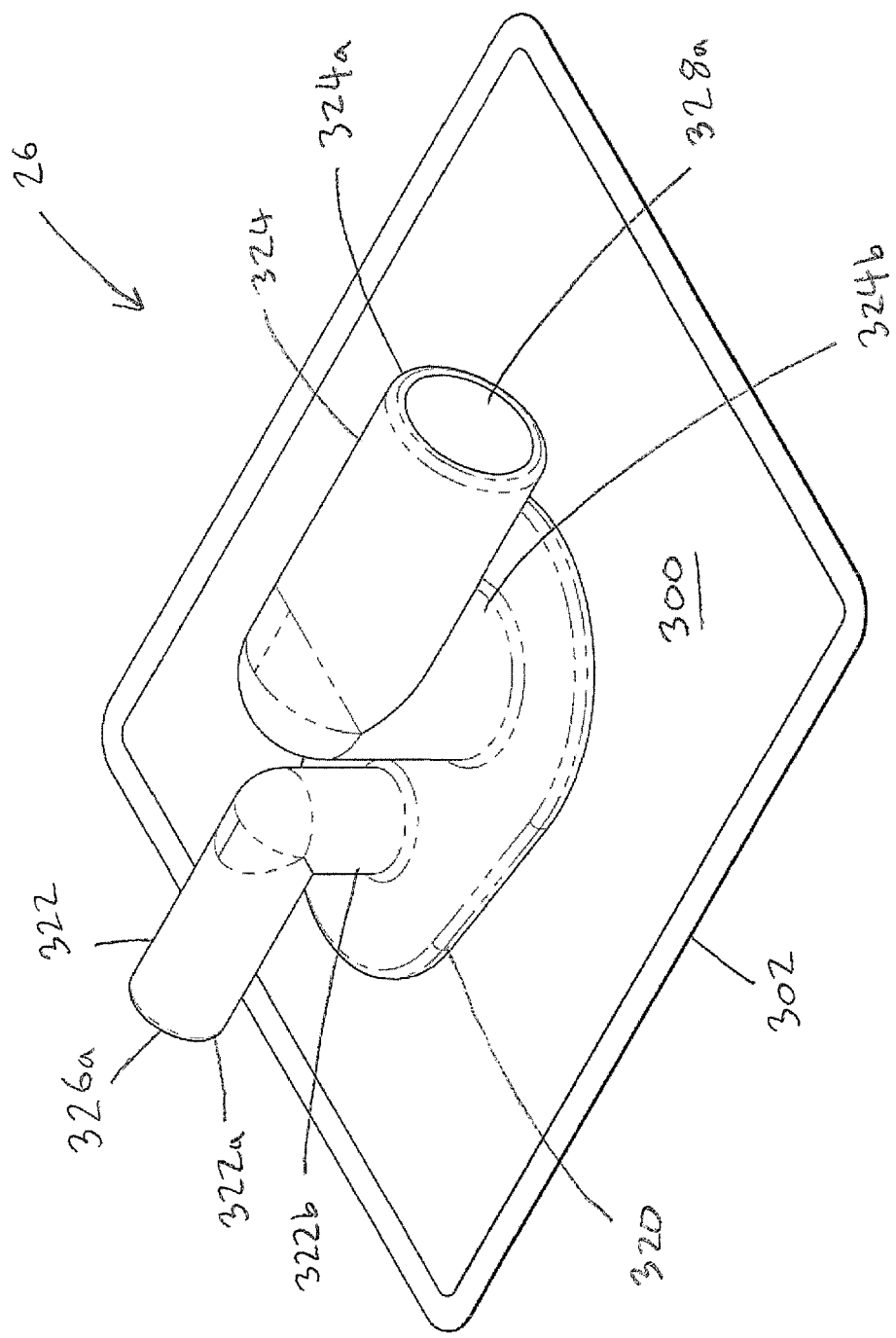


Figure 10

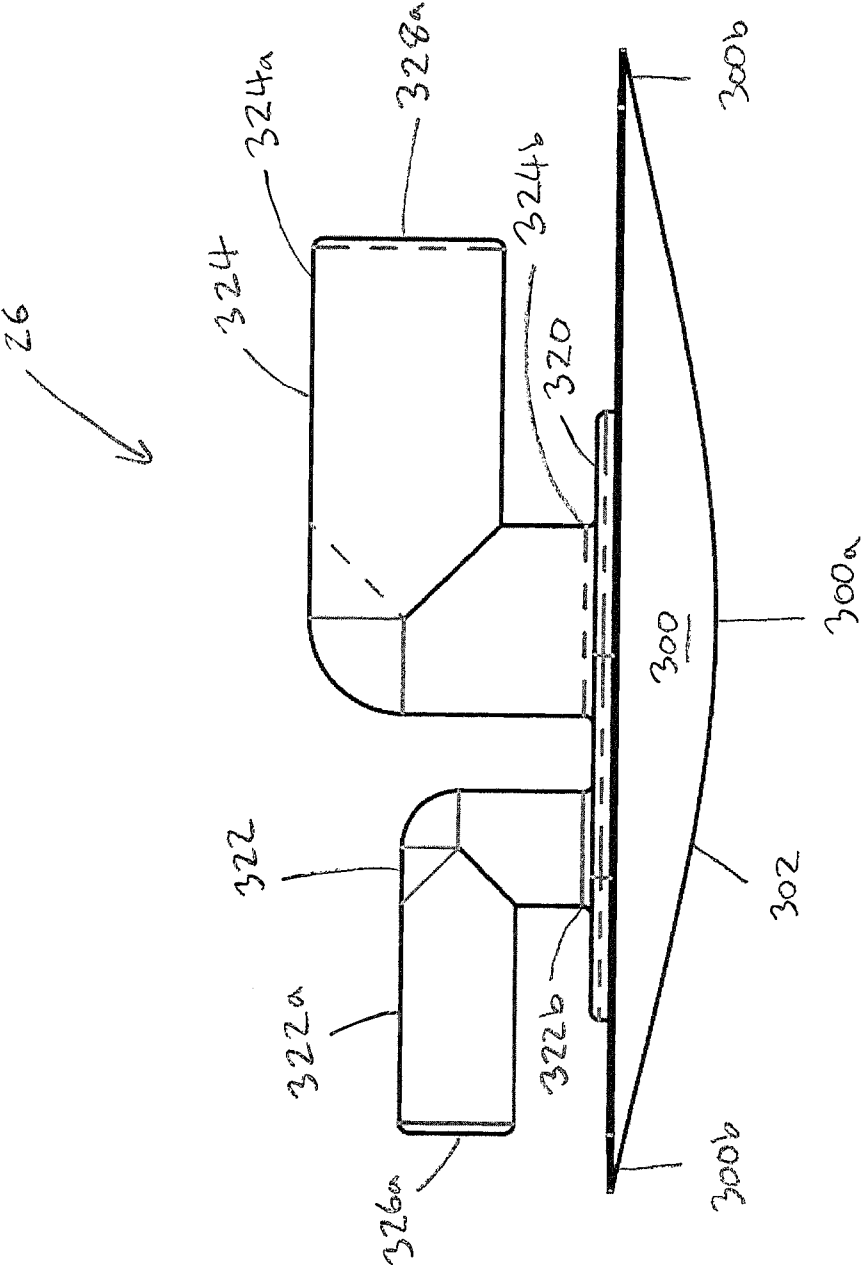


Figure 11

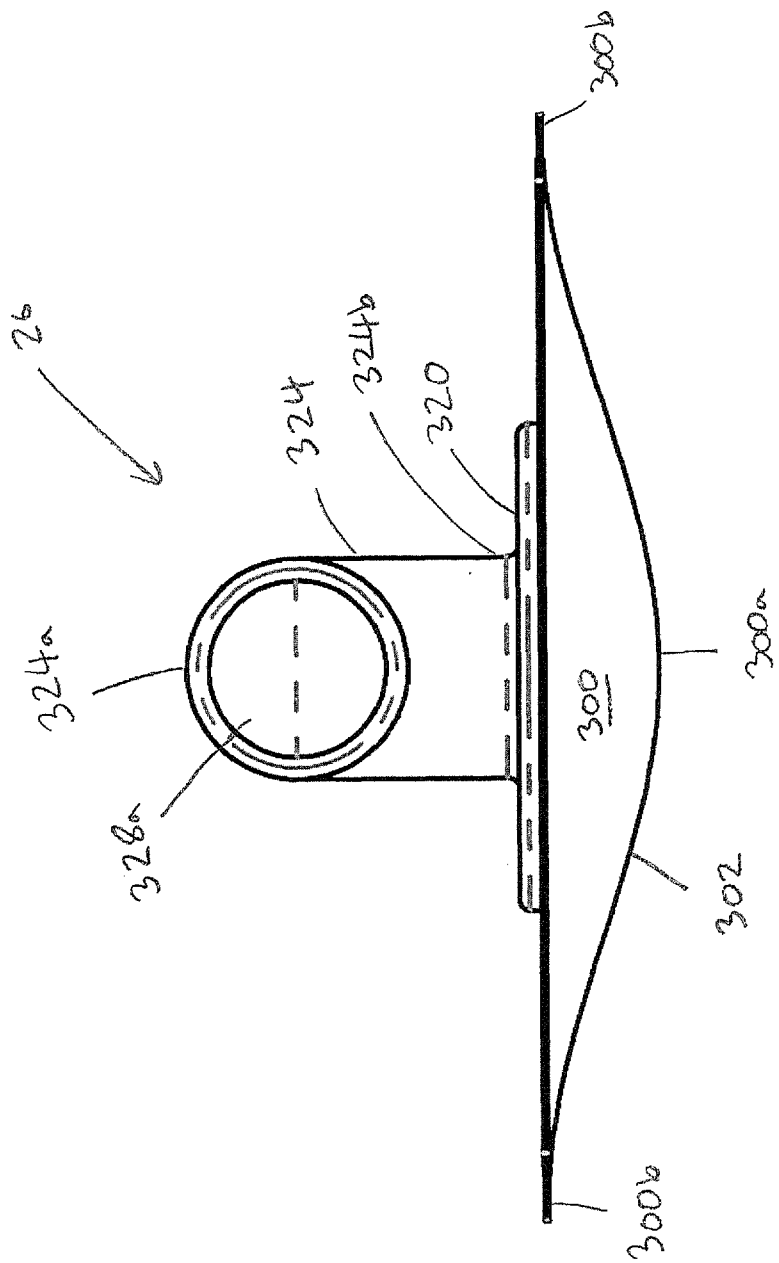


Figure 12

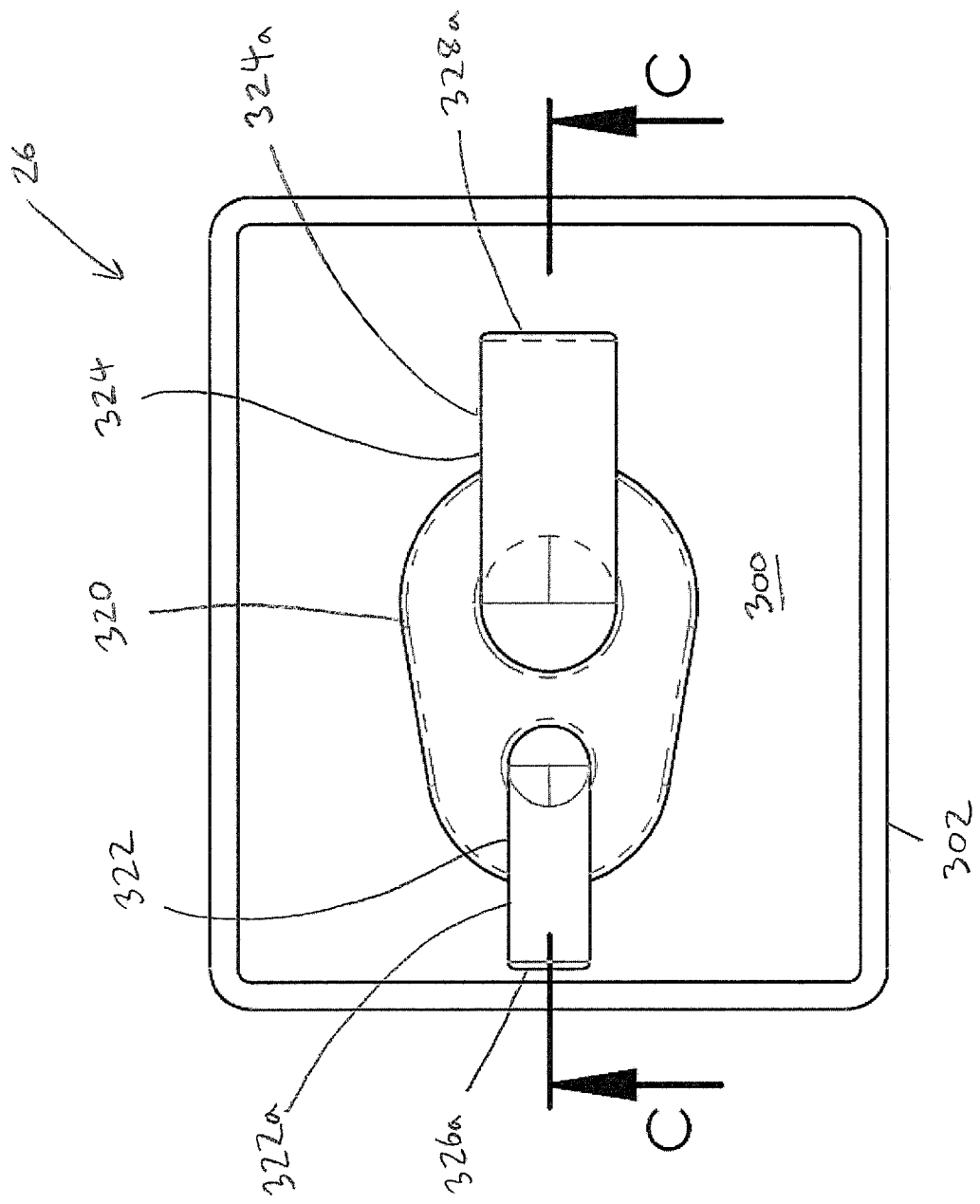


Figure 13

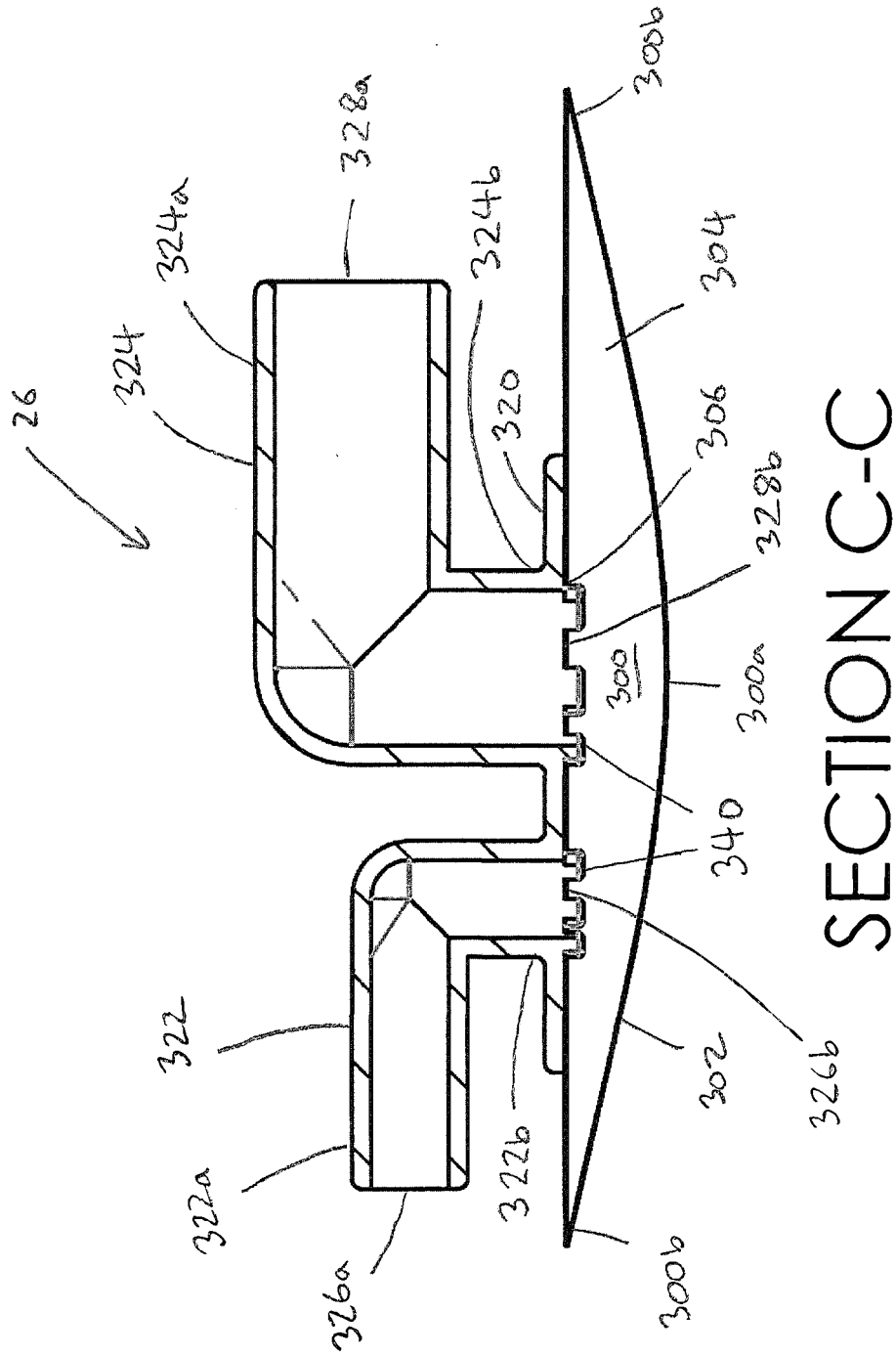


Figure 14

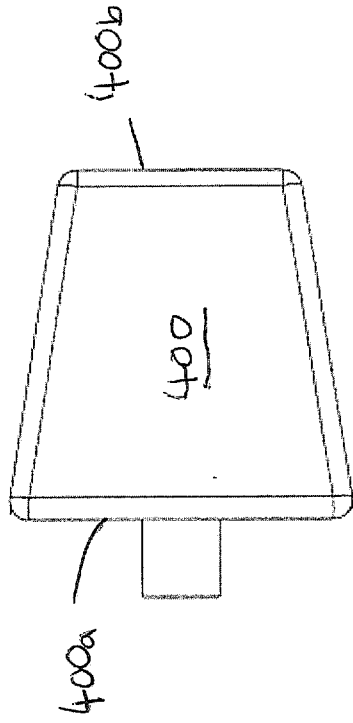


Figure 15b

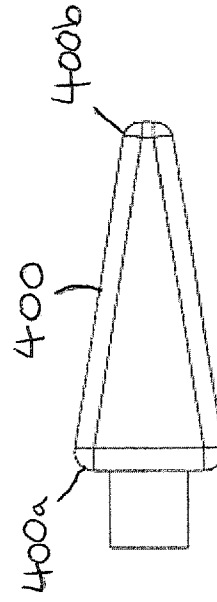


Figure 15c

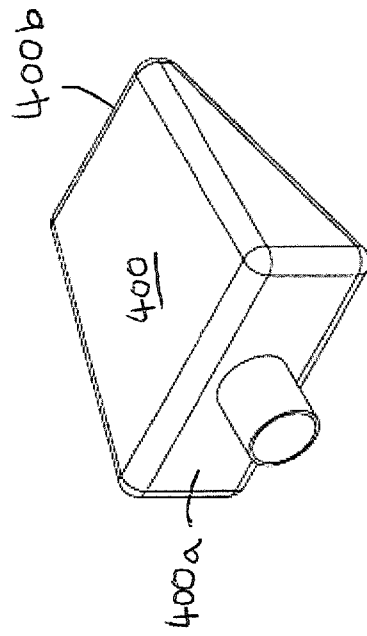


Figure 15a

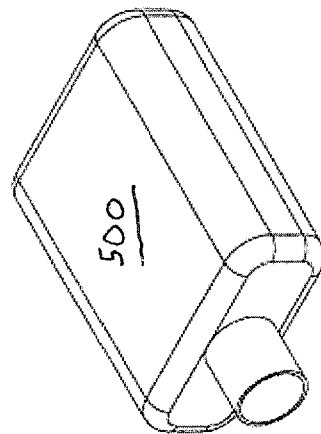


Figure 16a

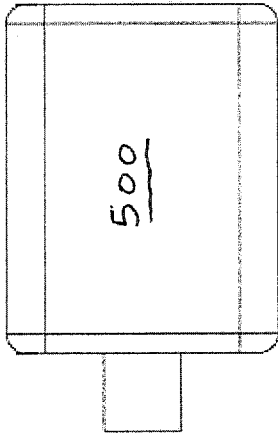


Figure 16b

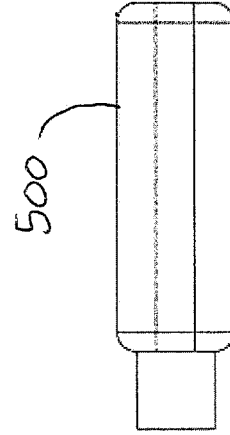


Figure 16c

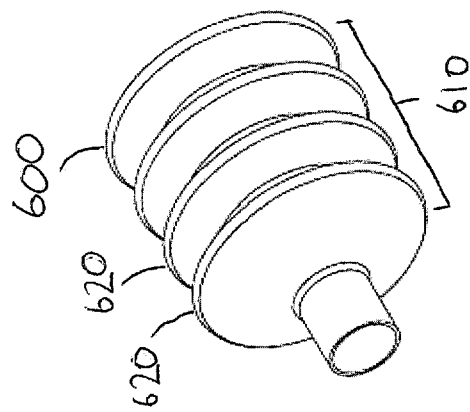


Figure 17a

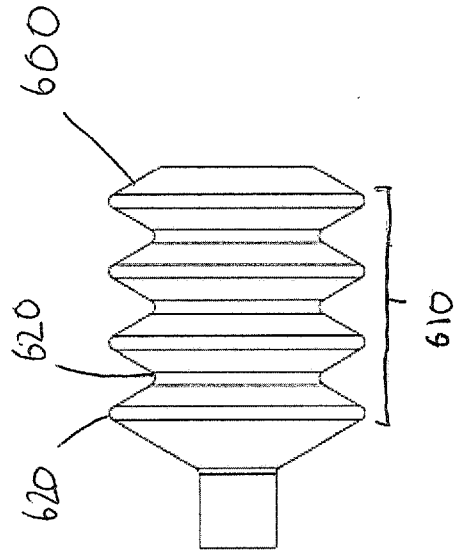


Figure 17b

GAS CONSERVATION APPARATUS

The present invention relates to apparatus for conserving a gas
5 delivered to a subject. The present invention further relates to a method of
delivering a gas to a subject.

Apparatus for delivering gases to a subject are widely used in hospitals
and other care settings, such as a subject's place of residence. Such
10 apparatus may deliver supplementary oxygen, or other gases or mixtures of
gases, such as anaesthetics or medical air, to a subject.

It should be noted that, throughout this specification, reference is made
in particular to oxygen. However, it is to be understood that apparatus and
15 methods embodying the present invention are equally applicable to gases
other than oxygen for delivery to a subject, for example inhalational
anaesthetics such as nitrous oxide, desflurane, isoflurane, and sevoflurane.

One significant problem encountered when delivering a gas to a
20 subject is wastage or otherwise inefficient utilisation of the gas. Oxygen, for
example, is expensive to produce and transport. Furthermore, cylinders of
oxygen are bulky, heavy, and cumbersome to manoeuvre. It is therefore
costly and difficult to produce and store large reserves of oxygen in care
settings such as hospitals and care homes, or indeed in a subject's place of
25 residence.

Consequently, when demand for oxygen is high, oxygen reserves can
become depleted or even exhausted entirely. This is particularly problematic
and potentially life-threatening in care settings such as hospitals and care
30 homes, in which some subjects, for example those in intensive care, may
depend entirely upon being provided with supplementary oxygen.

Additionally, rapid depletion of, for example, an oxygen cylinder necessitates the frequent changing of the cylinder, which is time consuming, and may require the assistance of a care-giver.

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One significant source of oxygen wastage when delivering oxygen to a subject is the inefficient utilisation of oxygen retained within the upper respiratory tract of the subject following inhalation.

10

A respiratory cycle may be divided into stages. During a first stage of the respiratory cycle, the subject inhales. This first stage is known in the art as 'inspiration'. During inspiration, gas is drawn into the airways of the subject, including the upper and lower respiratory tracts.

15

Oxygen enriched gas is drawn into the lower respiratory tract during a first part of the inspiration stage and enters the trachea, the bronchi and bronchioles, and the alveoli, which make up the lungs of the subject. Gas exchange within the alveoli absorbs oxygen from the inspired gas, and releases carbon dioxide into the inspired gas from the blood of the subject.

20

A portion of oxygen enriched gas inhaled during a second part of the inspiration stage, however, remains within the upper respiratory tract of the subject, including the nose or nostrils, nasal cavity, mouth, throat (pharynx), and voice box (larynx). As will be appreciated by one skilled in the art, oxygen remaining in the upper respiratory tract throughout one respiratory cycle (i.e. the gas inhaled during the second part of the inspiration stage) is not absorbed by the subject.

25

During a second stage of the respiratory cycle, the subject exhales. This second stage is known in the art as 'expiration'. During a first part of the expiration stage, gas is expelled from the upper respiratory tract of the

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subject. This gas remains oxygen rich, having not been depleted by gas exchange within the alveoli of the lungs of the subject.

During a second part of the expiration stage, gas is expelled from the lower respiratory tract of the subject. This gas is oxygen poor, and carbon dioxide rich, the oxygen having been depleted by gas exchange within the alveoli of the lungs of the subject.

It will be appreciated that this cycle of inspiration and expiration includes an inefficiency in the use of inhaled oxygen. When a subject is being provided with supplementary oxygen, this inefficiency in the inspiration/expiration cycle results in an inefficient use of the oxygen supply. Following inhalation of oxygen from an oxygen supply, only oxygen which enters the alveoli within the lungs of a subject is absorbed into the bloodstream of the subject and utilised. This oxygen is drawn into the lungs at the start of the inhalation cycle. Later in the inhalation cycle, supplementary oxygen from the oxygen supply is instead retained in the so called 'dead space' within the upper respiratory tract, including the bronchi, trachea, throat, larynx, nose and mouth of a subject, where it cannot be absorbed into the bloodstream. Some, if not all, of this dead space oxygen may be lost to the ambient atmosphere upon exhalation. It is therefore desirable to minimise the amount of dead space oxygen that is expelled to the atmosphere upon exhalation.

Some gases, such as anaesthetic gases, also contribute to climate change. It is therefore desirable to minimise the amount of such gases required to be delivered to a subject to achieve a desired effect, such as an anaesthetic effect, thereby minimising the quantity of such gases ultimately released into the atmosphere.

Previously, a variety of apparatus have been provided to deliver a gas to a subject.

5 An example of a known oxygen therapy method and apparatus is disclosed in WO 84/01295 A1. This document discloses a rebreathing apparatus comprising a changeable volume chamber having a maximum volume less than the maximum volume of the respiratory tract of a user and to which a continuous source of oxygen is supplied so that the initial gas exhaled on exhalation is directed into the changeable volume chamber and so that the
10 remainder of the exhaled gas is vented to the ambient. Oxygen is supplied to the apparatus to increase the oxygen content of the retained gas as some of the retained gas is displaced from the apparatus so as to create a bolus of oxygen enriched gas. On inhalation this quantity is initially taken into the respiratory tract and the latter is then filled concurrently with ambient air and
15 gas from the apparatus. This sequence is followed as long as the therapy is administered.

Further examples of oxygen therapy apparatus rely on the inclusion of a valve mechanism, such as a diaphragm to stop a flow of gas from a gas
20 supply following inhalation. US4535767, for example, discloses an oxygen delivery apparatus including a nasal cannula in which the partial vacuum created during inhalation has the effect of collapsing a diaphragm to substantially close off the interior of a gas receptacle between the cannula and the gas supply lines.

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However, apparatus including valves or diaphragms are complex to assemble, expensive and are sensitive to moisture so must be replaced approximately every 3-4 weeks, negating any cost saving achieved by reduced gas consumption.

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There remains a need for an improved apparatus for supplying a gas to a subject. It would be advantageous if the apparatus could provide the gas to the subject in a manner that allows the gas to be used more efficiently, with a lower amount of the gas being wasted to the atmosphere. It would be
5 advantageous if the apparatus could be simple to construct and operate.

Accordingly, in a first aspect of the present invention there is provided an apparatus for supplying a gas to a subject, the apparatus comprising:

a reservoir having a wall for holding a volume of gas, the reservoir
10 having an inlet opening in a wall for entry into the reservoir of a gas to be supplied to the subject and an outlet opening in the wall for supplying gas from within the reservoir to the subject;

a first conduit extending from the inlet opening for connection to a supply of the gas to be supplied to the subject;

15 a second conduit extending from the outlet opening for connection to a device for providing gas to the subject;

wherein the inlet opening is disposed in the wall of the reservoir relative to the outlet opening such that the gas flowing in the first conduit is caused to enter the reservoir through the inlet opening before passing to the outlet
20 opening and into the second conduit; and

wherein the flow of gas through the inlet opening into the reservoir from the first conduit draws gas from the second conduit through the outlet opening when the gas in the second conduit is subjected to a back pressure.

25

When the apparatus of the present invention is being used to supply a gas to a subject, such as supplementary oxygen, the first conduit is connected to a supply of the gas. The second conduit is connected to a device for delivering gas to a subject, such as a mask or nasal cannula. The subject
30 breathes normally. The operation of the apparatus will be summarised with reference to supplying oxygen to a subject, purely by way of example only.

In a first phase, the subject inhales. During inhalation, oxygen flows from the supply through the first conduit and into the reservoir through the inlet opening in the wall of the reservoir. At the same time, gas within the reservoir is drawn out of the reservoir through the outlet opening and along the second conduit to be drawn into the respiratory system of the subject. This first phase typically last for about 2 seconds, when the subject is breathing normally.

Typically, once inhalation has finished, the subject will hold their breath or pause for about 1 second. During this second phase, the action of the subject stopping inhalation induces a back pressure in the second conduit. The gas in the second conduit starts to become enriched in the oxygen supplied.

In the third phase, the subject exhales for a period of about 2 seconds when breathing normally. During this phase, the action of the subject exhaling causes a back pressure to occur within the second conduit. The reservoir will fill with gas.

Finally, the subject inhales once again, the action of which is to remove the back pressure applied to the second conduit, and the subject inhales gas from the reservoir, including oxygen supplied through the first conduit from the oxygen supply.

As described above, during normal breathing, the first portion of the gas exhaled by the subject is the gas from the upper respiratory tract, which has not been subjected to gas exchange within the lungs and is therefore rich in oxygen. The action of the apparatus is to direct this first portion of the exhaled gas into the reservoir via the second conduit through the outlet opening. The flow of this gas into the reservoir is enhanced by the flow of

oxygen entering the reservoir via the first conduit through the outlet opening, which is in sufficiently close proximity to the outlet opening. In this way, the oxygen-rich gas from the upper respiratory tract of the subject is conserved and inhaled by the subject at the start of the next cycle.

5

The present invention finds use in a wide range of situations where one or more gases is required to be delivered to a subject, for example a care setting, such as a hospital or care home or a subject's place of residence, in which it may be desirable or necessary to provide a subject or patient with a supply of gas, such as oxygen.

10

In one embodiment, the present invention may be used to supply oxygen to a subject to increase the amount of oxygen delivered to a subject's respiratory tract. The additional supply of oxygen may provide therapeutic benefits, or may simply improve the quality of life of a subject who has difficulty breathing or finds day-to-day activities, such as walking, particularly strenuous.

15

In addition, the present invention finds use outside care settings, for example in settings in which it may be desirable to deliver oxygen to a subject to improve the quality of breathable air, for example in environments in which the ambient air contains increased levels of pollution and/or allergens. In this respect, apparatus according to the invention finds use in non-therapeutic settings.

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It has been found that the apparatus of the present invention allows a gas to be supplied to a subject in a reduced volume, compared with the prior art devices, while still meeting the needs of the subject. As a result, the apparatus of the present invention allows for a more efficient use of the gas, in turn reducing gas consumption. For example, the apparatus provides

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significant reductions in the volume of gases, such as oxygen, that are required to be provided to subjects in a range of different circumstances.

Furthermore the flow of gas through the inlet opening into the reservoir
5 from the first conduit draws gas from the second conduit through the outlet
opening when the gas in the second conduit is subjected to a back pressure.
This may promote mixing of exhaled gas entering via the outlet opening with
the gas supplied to the reservoir via the inlet opening, thereby enriching the
exhaled gas re-captured in the reservoir with further supplemental gas, such
10 as oxygen.

The apparatus of the present invention comprises a reservoir having a
wall. The wall of the reservoir defines a closed space which, in use, holds a
15 volume of gas. The reservoir may be any suitable shape and configuration.
Preferably, the reservoir is generally elongate having a first end and a second
end, with the first and second conduits both being arranged in the first end. In
one preferred embodiment, the reservoir is tapered, with at least one lateral
dimension of the reservoir decreasing in the direction from the first end to the
20 second, that is away from the first and second conduits. In one particularly
preferred embodiment, the reservoir is generally rectangular when viewed in
plan view and is generally triangular when viewed from the side, perpendicular
to the plan view.

25 The wall of the reservoir may be formed from any suitable material.
Polymers are very suitable materials for forming the wall of the reservoir and
suitable medical grade polymers for forming the wall of the reservoir are
known in the art. Preferred polymers include High Density Polyethylene
(HDPE), Low Density Polyethylene (LDPE), Polypropylene (PP), and Polyvinyl
30 Chloride (PVC). LDPE is particularly preferred due to its high levels of stress
crack resistance.

The wall of the reservoir is preferably flexible, more preferably sufficiently flexible for the wall to flex under the normal action of a subject using the apparatus and breathing normally. In this way, movement of the wall of the reservoir can provide a visual indication to a medical practitioner of the respiration activity of the subject and give an indication of conditions where the breathing of the subject may be abnormal, such as apnoea.

Preferably, in the expanded state, the reservoir has a maximum internal volume of up to 500 ml, more preferably up to 400 ml, still more preferably up to 300 ml, more preferably still up to 250 ml, especially up to 125ml. Preferably, in the expanded state, the reservoir has a maximum internal volume of from 10 ml, preferably from 20 ml, more preferably still from 50 ml, still more preferably from 100 ml, especially from 125 ml. In a preferred arrangement, the volume of the reservoir is from 10 ml to 300 ml, more preferably from 20 ml to 250 ml.

The reservoir wall is provided with an inlet opening and an outlet opening. In use, a gas to be supplied to the subject, such as oxygen to supplement the oxygen in the air being breathed by the subject, is provided to the inlet opening. In use, as discussed in more detail hereinbefore, during part of the inspiration cycle of the subject, gas from within the reservoir passes out through the outlet opening and is supplied to the subject. During another part of the inspiration cycle, as also discussed in more detail hereinbefore, exhaled gas from the subject enters the reservoir through the outlet opening.

The inlet opening and the outlet opening are arranged in the same region of the wall of the reservoir. In particular, the inlet opening is disposed in the wall of the reservoir at a position relative to the position of the outlet opening such that the gas flowing in the first conduit is caused to enter the

reservoir through the inlet opening before passing to the outlet opening and into the second conduit. In addition, the flow of gas through the inlet opening into the reservoir from the first conduit draws gas from the second conduit through the outlet opening when the gas in the second conduit is subjected to a back pressure. The gas in the second conduit is subjected to a back pressure when the subject exhales using the apparatus, as described hereinbefore.

The inlet opening and the outlet opening are separate openings in the wall of the reservoir. However, as noted above, the inlet opening and the outlet opening in the wall of the reservoir are sufficiently close together to allow gas flowing into the reservoir through the inlet opening to draw gas through the outlet opening into the reservoir.

In one embodiment, the outlet opening in the wall of the reservoir is spaced apart from the inlet opening in the wall. In an alternative embodiment, the inlet opening and the outlet opening are adjacent one another, the openings being separated by a wall of a conduit. In a further alternative, the wall of the reservoir is provided with a single opening, a first portion of the single opening providing the inlet opening and a second portion of the single opening providing the outlet opening. In one preferred embodiment, the first and second portions of the single opening are arranged in an annular manner, preferably with the inlet opening lying within the outlet opening.

The distance separating the inlet opening and the outlet opening will depend upon such factors as the pressure of gas within the first conduit and the second conduit, the rate of flow of gas through each opening and the velocity of the gas flowing through each opening, in particular the velocity of the gas flowing through the inlet opening into the reservoir.

The distance between the edge of the inlet opening and the edge of the outlet opening may be up to 5 cm, preferably up to 4 cm, more preferably up to 3.5 cm, still more preferably up to 3 cm, more preferably still up to 2.5 cm, especially up to 2 cm, more especially up to 1.5 cm, more especially still up to 1 cm. In a preferred arrangement, the distance between the edge of the inlet opening and the edge of the outlet opening may be less than 1 cm, for example from 3 mm to 9 mm, preferably from 4 mm to 8 mm.

In general, it is preferred that the area of the outlet opening in the wall of the reservoir is greater than the area of the inlet opening. The ratio of the area of the outlet opening to the area of the inlet opening is preferably from 1.1:1, more preferably from 1.25:1, still more preferably from 1.5:1, more preferably still from 2:1, especially from 2.25:1, more especially from 2.5:1, still more especially from 2.75:1, more especially still from 3:1. The ratio of the area of the outlet opening to the area of the inlet opening is preferably up to 20:1, more preferably up to 17.5:1, still more preferably up to 16:1, more preferably still up to 15:1, especially up to 13:1, more especially up to 12:1, still more especially up to 11:1, more especially still up to 10:1. In particularly preferred embodiments, the ratio of the area of the outlet opening to the area of the inlet opening is up to 5:1, for example 1.5:1, 2:1, 3:1, 4:1, or 5:1.

The inlet opening and the outlet opening in the wall of the reservoir may be any suitable shape. A circular opening is preferred for most embodiments.

The apparatus comprises a first conduit. The first conduit extends from the first opening in the wall of the reservoir and is for connection to a supply of gas to be supplied to the subject, for example a supply of oxygen. Any suitable source for the gas may be used. For example, many subjects may use a bottle or cylinder containing pressurised gas, as is well known in the art. In many medical facilities, such as hospitals and clinics, a supply of gas, such

as oxygen, is provided as part of the infrastructure of the building as with other utilities. In general, the first conduit will be connected to a device controlling the supply of the gas, such as a valve, with an indicator showing the flowrate of the gas, such as a rotameter. Again, such facilities are well known in the art. Suitable tubes or lines for connecting the first conduit to the gas supply equipment are well known in the art.

The first conduit has a bore therethrough in communication with the inlet opening in the wall of the reservoir. The first conduit may have any suitable form. Preferably, the first conduit is tubular with a circular cross-section. The inner diameter of the first conduit is preferably the same as the diameter of the inlet opening in the wall of the reservoir. The first conduit may have an inner diameter of up to 30 mm, preferably up to 25 mm, still more preferably up to 20 mm, more preferably still up to 15 mm, especially up to 12mm. The first conduit may have an inner diameter of from 3 mm, preferably from 5 mm, more preferably from 10 mm, still more preferably from 15 mm, especially from 20 mm. An inner diameter of from 2 mm to 15 mm is preferred, more preferably from 3 mm to 12 mm.

The first conduit may have any suitable wall thickness. Preferably, the first conduit has a wall thickness of from 0.5 mm, preferably from 0.75 mm, more preferably from 1 mm, still more preferably from 1.25 mm, more preferably still from 1.5 mm, especially from 1.75 mm. The first conduit may have a wall thickness of up to 5 mm, preferably up to 4.5 mm, more preferably up to 4 mm, still more preferably up to 3.5 mm, more preferably still up to 3 mm, especially up to 2.5 mm. A wall thickness of from 0.5 mm to 2 mm is preferred.

The first conduit may be formed from any suitable material. Polymers, in particular medical grade polymers are preferred and suitable medical grade materials are known in the art.

The apparatus comprises a second conduit. The second conduit extends from the second opening in the wall of the reservoir and is for supplying gas from within the reservoir to the subject, for example an oxygen-enriched gas, and for receiving gas exhaled by the subject during normal breathing. Suitable masks, cannulae, tubes or lines for connecting the second conduit to a device for supplying gas to be inhaled by the subject are known in the art.

10 The second conduit has a bore therethrough in communication with the outlet opening in the wall of the reservoir. The second conduit may have any suitable form. Preferably, the second conduit is tubular with a circular cross-section. The inner diameter of the second conduit is preferably the same as the diameter of the outlet opening in the wall of the reservoir. The second
15 conduit may have an inner diameter of up to 50 mm, preferably up to 45 mm, more preferably up to 40 mm, still more preferably up to 35 mm, more preferably still up to 30 mm, still more preferably up to 25 mm, especially up to 20 mm, for example up to 15 mm. The second conduit may have an inner diameter of from 5 mm, preferably from 6 mm, more preferably from 7 mm,
20 still more preferably from 8 mm. In one embodiment, the second conduit may have an inner diameter of from 7 mm to 20 mm, preferably from 8 mm to 15 mm, for example 11 mm.

 The second conduit may have any suitable wall thickness. Preferably,
25 the second conduit has a wall thickness of from 0.5 mm, preferably from 0.75 mm, more preferably from 1 mm, still more preferably from 1.25 mm, more preferably still from 1.5 mm, especially from 1.75 mm. The second conduit may have a wall thickness of up to 5 mm, preferably up to 4.5 mm, more preferably up to 4 mm, still more preferably up to 3.5 mm, more preferably still
30 up to 3 mm, especially up to 2.5 mm. A wall thickness of from 1 mm to 2 mm is preferred.

The second conduit may be formed from any suitable material. Polymers, in particular medical grade polymers are preferred and suitable medical grade materials are known in the art.

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As described above, the first and second conduits extend from the inlet and outlet openings in the wall of the reservoir respectively. In this way, the ends of the first and second conduits are co-terminus.

10

As described hereinbefore, the inlet opening and outlet opening in the wall of the reservoir and, hence, the ends of the first and second conduits extending from the inlet and outlet openings are in close proximity. In one preferred embodiment, as described hereinbefore, the wall of the reservoir is provided with a single opening therein providing both the inlet opening and the outlet opening, that is one of the inlet and outlet openings in the wall of the reservoir lies within the other of the inlet and outlet openings, such that the one of the inlet and outlet openings extends at least partially around the other of the inlet and outlet openings. Preferably, the inlet opening and the outlet opening are arranged in an annular manner, that is with one of the inlet and outlet openings extending fully around the other of the inlet and outlet openings. Most preferably, the inlet opening lies within the outlet opening, more preferably with the outlet opening extending fully around the inlet opening.

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Preferably, at least a portion of one of the first and second conduits extends within at least a portion of the other of the first and second conduits. More preferably, a portion of one of the first and second conduits extends within a portion of the other of the first and second conduits. In this arrangement, the ends of the first and second conduits distal from the reservoir are separate and can be connected separately to their respective lines for supply and/or delivery of the gas. Preferably, the portion of the first

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or second conduit extending within the portion of the second or first conduit is arranged co-axially with the portion of the second or first conduit.

Most preferably, a portion of the first conduit lies within and is
5 surrounded by the second conduit. In this preferred embodiment, at least a portion of the first conduit extends from the inlet opening in the wall of the reservoir within at least a portion of the second conduit. Preferably, at least a portion of the first conduit extends from the inlet opening within at least a portion of the second conduit in an annular manner, preferably with the said
10 portions of the first and second conduits extending co-axially.

Having at least a portion of one of the first or second conduits extend within at least a portion of the other of the first and second conduits provides a technical advantage. In particular, this arrangement allows heat to be
15 exchanged between the gas flowing in the first conduit and the gas within the second conduit. This serves to reduce condensation forming within the reservoir.

In one preferred embodiment, the apparatus comprises a connecting
20 member comprising both the first conduit and the second conduit. In this way, the first and second conduits are formed in a single component. The connecting member is affixed to the outer surface of the wall of the reservoir, such that the first and second conduits align with the inlet and outlet openings in the wall of the reservoir.

25

As discussed above, one problem when employing a reservoir having a flexible wall is that, in the event the reservoir collapses during the breathing cycle of the subject, the flexible wall can partially or wholly occlude the opening into the first conduit and/or the second conduit. In one preferred
30 embodiment, one or more spaced apart protrusions are provided adjacent the or each opening in the wall of the reservoir. The protrusions act to hold the

flexible wall away from the adjacent opening and ensure the opening remains open, even when the reservoir is fully collapsed.

According to a further aspect of the present invention, there is provided
5 a method for supplying a gas to a subject, the method comprising:

providing a reservoir for holding gas having a first opening for supplying gas from within the reservoir to the subject and receiving gas exhaled by the subject;

supplying the gas to the reservoir through a second opening, whereby
10 the flow of the gas into the reservoir through the second opening draws gas through the first opening when a back pressure is applied to the first opening by the subject exhaling.

Details of the methods are described hereinbefore. The method
15 preferably employs an apparatus as hereinbefore described.

As noted hereinbefore, allowing the gas flowing from the gas supply into the reservoir to exchange heat with the gas within the conduit supplying
20 gas from the reservoir to the subject reduces the amount of water vapour in the gas exhaled by the subject which condenses within the reservoir.

Accordingly, in a further aspect, the present invention provides an apparatus for supplying a gas to a subject, the apparatus comprising:

25 a reservoir having a wall for holding a volume of gas, the reservoir having an inlet opening in the wall for entry into the reservoir of a gas to be supplied to the subject and an outlet opening in the wall for supplying gas from within the reservoir to the subject;

a first conduit extending from the inlet opening for connection to a
30 supply of the gas to be supplied to the subject;

a second conduit extending from the outlet opening for connection to a device for providing gas to the subject;

wherein at least a portion of the first conduit and the second conduit are arranged to allow heat exchange between gas within the first conduit and
5 gas within the second conduit to occur.

Details of the features of the apparatus of this second aspect of the present invention are as described hereinbefore.

10 In a further aspect, the present invention provides a method for supplying a gas to a subject, the method comprising:

providing a reservoir for holding gas having a first opening for supplying gas from within the reservoir to the subject and receiving gas exhaled by the subject;

15 supplying the gas to the reservoir through a second opening, whereby the gas flowing into the reservoir through the second opening exchanges heat with gas exhaled by the subject and entering the reservoir through the first opening.

20 Further details of the method are as hereinbefore described. The method preferably employs an apparatus of the second aspect of the present invention.

As described hereinbefore, a preferred arrangement for the reservoir is
25 one having the first and second conduits extending from a first end of the reservoir and the reservoir being tapered in the direction from the first end to the second end. As described below, this arrangement provides advantages when the wall of the reservoir is flexible and the reservoir collapses during the breathing cycle of the subject. In particular, this arrangement prevents the
30 openings in the wall of the reservoir from being blocked and the ends of the first and second conduits being occluded.

Accordingly, in a still further aspect, the present invention provides an apparatus for supplying a gas to a subject, the apparatus comprising:

5 a reservoir having a flexible wall for holding a volume of gas, the reservoir having a first end and a second end, the reservoir further comprising an inlet opening in the first end of the wall for entry into the reservoir of a gas to be supplied to the subject and an outlet opening in the first end of the wall for supplying gas from within the reservoir to the subject;

10 a first conduit extending from the inlet opening for connection to a supply of the gas to be supplied to the subject;

a second conduit extending from the outlet opening for connection to a device for providing gas to the subject;

wherein the wall of the reservoir is tapered in the direction extending from the first end of the reservoir to the second end of the reservoir.

15

The wall of the reservoir of the apparatus of this aspect of the invention is tapered, that is the width of the reservoir in at least one direction perpendicular to the direction extending from the first end to the second end reduces in the direction extending from the first end to the second end. The taper extends at least partially from the first end to the second end of the reservoir, more preferably substantially the entire length from the first end to the second end. The reduction in the width of the reservoir may be continuous or stepwise and is preferably continuous.

25 In one preferred embodiment, the reservoir has a cross-section that is substantially triangular. In one particularly preferred embodiment, the reservoir is generally rectangular when viewed in plan view and is generally triangular when viewed from the side, perpendicular to the plan view.

30 Other features of the apparatus and its operation are as hereinbefore described.

Embodiments of the present invention will now be described, by way of example only, having reference to the accompanying drawings, in which:

Figure 1 is a representation of an apparatus according to an
5 embodiment of the present invention in use supplying oxygen to a subject;

Figure 2 is a perspective view from above and one side of an apparatus according to a first embodiment of the present invention;

10 Figure 3 is a perspective view of the apparatus of Figure 2 viewed from one side;

Figure 4 is a perspective view of the apparatus of Figure 2 viewed from above;

15 Figure 5 is a cross-sectional view of the apparatus of Figure 2 taken along the line A-A shown in Figure 4;

Figure 6 is a perspective view of an apparatus according to a second
20 embodiment of the present invention;

Figure 7 is a perspective view of the apparatus of Figure 6 viewed from one side;

25 Figure 8 is a perspective view of the apparatus of Figure 6 viewed from above;

Figure 9 is a cross-sectional view of the apparatus of Figure 6 taken along the line B-B shown in Figure 8;

30

Figure 10 is a perspective view of an apparatus according to a third embodiment of the present invention;

5 Figure 11 is a perspective view of the apparatus of Figure 10 viewed from a first side;

Figure 12 is a perspective view of the apparatus of Figure 10 viewed from a second side;

10 Figure 13 is a perspective view of the apparatus of Figure 10 viewed from above; and

Figure 14 is a cross-sectional view of the apparatus of Figure 10 taken along the line C-C shown in Figure 13;

15

Figure 15a is a perspective view from above and one side of an alternative reservoir for use in the apparatus of Figures 1-14;

20 Figure 15b is a perspective view of the alternative reservoir of Figure 15a viewed from above;

Figure 15c is a perspective view of the alternative reservoir of Figure 15a viewed from one side;

25 Figure 16a is a perspective view from above and one side of a further alternative reservoir for use in the apparatus of Figures 1-14;

Figure 16b is a perspective view of the alternative reservoir of Figure 16a viewed from above;

30

Figure 16c is a perspective view of the alternative reservoir of Figure 16a viewed from one side;

Figure 17a is a perspective view from above and one side of a further
5 alternative reservoir for use in the apparatus of Figures 1-14;

Figure 17b is a perspective view of the alternative reservoir of Figure 17a viewed from above.

10 Turning first to Figure 1, there is shown a representation of a subject 2 being provided with oxygen using an apparatus according to the present invention, generally indicated as 22. The apparatus 22 is connected to a supply of oxygen in the form of a gas cylinder 6 by a gas supply line 8. The apparatus 22 is further connected by a gas delivery line 10 to a nasal cannula
15 12 being worn by the subject 2.

Figure 2 is a perspective view of an apparatus according to a first embodiment, indicated generally as 22. The apparatus is shown in perspective view from a first side in Figure 3 and from above in Figure 4. A
20 cross-sectional view of the apparatus is shown in Figure 5, taken along the line A-A shown in Figure 4.

The apparatus 22 includes a reservoir 100 having a wall formed from a flexible membrane 102 having a first end 100a and a second end 100b. The
25 flexible membrane is enclosed to define an interior 104. An opening 106 is formed in the flexible membrane at the first end 100a of the reservoir 100 allowing for the transfer of gas to and from the interior of the reservoir 100 via the opening 106. As can be seen in Figure 3, the reservoir 100 of this embodiment is generally wedge-shaped, tapering from the first end 100a to
30 the second end 100b, with a triangular side profile. The reservoir 100 is generally rectangular when viewed from a plan view, as shown in Figure 4.

A connecting member 120 is arranged over the opening 106. The connecting member is provided with a first conduit 122 and a second conduit 124.

5

In the first embodiment shown in Figures 2 to 5, the first conduit 122 is adapted to be connected to a gas supply line, for example a supply line from an oxygen cylinder (not shown), and the second conduit 124 is adapted to be connected to a gas delivery line, for example the gas delivery line of a nasal cannula (not shown), for delivering a gas to a subject.

10

In an alternative arrangement, the first conduit 122 may be adapted to be connected to a gas delivery line, and the second conduit 124 may be adapted to be connected to a gas supply line.

15

The first and second conduits 122, 124 are hollow tubes. The first conduit 122 includes a first opening 126a at a first end distal from the reservoir 100, and a second opening 126b at a second end proximal to the reservoir 100. The second opening 126b of the first conduit 122 is at the opening 106 in the wall 102 of the reservoir 100 and is in communication with the interior 104 of the reservoir.

20

The second conduit 124 includes a first opening 128a at a first end distal from reservoir 100 and a second opening 128b at a second end proximal to the reservoir 100. The second opening 128b of the second conduit is at the opening 106 in the wall 102 of the reservoir 100, such that the interior of the second conduit 124 opens into the reservoir 100.

25

In this manner both the first and second conduits 122, 124 communicate with the interior 104 of the reservoir 100 via the opening 106 in the flexible wall 102 of the reservoir.

30

As can be seen in the cross-sectional view shown in Figure 5, a portion 122a of the first conduit 122 proximal to the reservoir extends within a portion 124a of the second conduit 124 proximal to the reservoir. The proximal portions 122a, 124a of the first and second conduits 122, 124 are arranged in an annular manner and have the same central longitudinal axis. The first conduit 122 has a distal portion 122b which extends from and lies outside the second conduit 124. The second conduit 124 has a distal portion 124b which extends perpendicular to the proximal portion 124a.

A method of operating the apparatus 22 according to the first embodiment is described in more detail below. For the purposes of illustration only, a mode of action for delivering supplementary oxygen to a subject's respiratory tract is described. However, as will be appreciated by a person skilled in the art, the apparatus may be analogously employed to deliver additional or alternative gases to a subject.

In use, the first conduit 122 of the connecting member 120 is connected to an oxygen supply line, for example the oxygen supply line 8 shown in Figure 1. The second conduit 124 of the connecting member 120 is connected to a gas delivery line for delivering oxygen to the respiratory tract of a subject, for example the gas delivery line 10 shown in Figure 1. Oxygen is typically conveyed to the respiratory tract of the subject from the gas delivery line via a mask or a nasal cannula 12, as also shown in Figure 1.

Nasal cannulae and masks are widely used for the delivery of gases to a subject. Their form and method of operation will be known to one of ordinary skill in the art and, in the interests of brevity, shall not be described here.

During operation of the apparatus 22, oxygen flows into the interior 104 of the reservoir 100 from the oxygen supply line via the first conduit 122 and

the opening 106. The oxygen introduced via the first conduit 122 enriches any gases already retained within the reservoir 100 with supplementary oxygen.

5 The flow of gas into the reservoir 100 inflates the reservoir to its maximal volume at the start of a respiratory cycle of the subject.

10 During inspiration in the first stage of the respiratory cycle, as the subject inhales, the oxygen enriched gas within the interior 104 of the reservoir 100 is drawn from the interior of the reservoir via the second conduit 124 under the action of negative pressure created within the subject's respiratory tract, by expansion of the chest cavity.

15 Oxygen enriched gas from within the reservoir 100 is thus delivered to the respiratory tract of the subject during inspiration, causing the reservoir to deflate and collapse.

20 Depending upon the relative volume of the reservoir 100 and the respiratory tract of the subject, the reservoir may partially or completely deflate during inspiration. For example, if the maximum volume of the interior 104 of the reservoir 100 is greater than that of the subject's respiratory tract, the reservoir will only partially deflate during inspiration. Conversely, if the maximum volume of the interior 104 of the reservoir 100 is equal to or less than the volume of subject's respiratory tract, the reservoir will completely deflate during inspiration.

25

30 In the case where the maximum volume of the interior 104 of the reservoir 100 is less than that of the subject's respiratory tract, additional supplementary oxygen may be drawn from the oxygen supply line into the subject's respiratory tract via the first conduit 122, reservoir 100, and second conduit 124 during inspiration, without re-inflating the reservoir to any significant degree.

Nasal cannulae do not form a gas-tight seal around the nostrils of the subject. Therefore, additionally or alternatively, air may be drawn into the subject's respiratory tract from the ambient atmosphere during inspiration, and
5 in particular during the last part of the inspiratory cycle, once all of the oxygen enriched gas within the reservoir 100 has been drawn into the subject's respiratory tract.

During inspiration, gaseous exchange occurs within the alveoli of the
10 subject and supplementary oxygen, delivered from the interior 104 of the reservoir 100 to the subject's lungs, is depleted while waste carbon dioxide is expelled from the subject's bloodstream, increasing the concentration of carbon dioxide in the gas mixture within the lungs of the subject.

15 However, supplementary oxygen remaining in the upper respiratory tract of the subject, for example in the nose and mouth, will not be depleted as gaseous exchange does not occur within this part of the respiratory tract of the subject.

20 During inspiration, oxygen continues to flow into the reservoir 100 from the oxygen supply via the first conduit 122 and opening 106. This may begin to re-inflate, or partially inflate, the reservoir 100.

Following inspiration, after a short pause, during the second stage of
25 the respiratory cycle, the subject exhales. The gas remaining in the upper respiratory tract is the first to be expelled during expiration. This gas contains supplementary oxygen that was not absorbed by the subject via gas exchange within the alveoli. The gases exhaled during the first part of expiration therefore remain enriched with oxygen.

30

Positive pressure within the respiratory tract of the subject created by contraction of the subject's chest cavity generates a backflow of gases and a back pressure within the second conduit 124, such that oxygen enriched gas from the upper respiratory tract of the subject flows into the deflated or
5 partially inflated reservoir 100 via the gas delivery line and the second conduit 124.

Once the reservoir 100 has re-inflated to its maximum volume, the remaining gas within the subject's respiratory tract, in particular the volume of
10 gas in the lower respiratory tract, having been depleted of supplementary oxygen and being rich in carbon dioxide, is unable to enter the reservoir and instead is vented to the ambient atmosphere.

During expiration, oxygen continues to flow under pressure from the
15 oxygen supply line into the interior 104 of the reservoir 100 via the first conduit 122. This oxygen may displace gases retained within the reservoir, for example gases exhaled during the first part of expiration, to further enrich the gas within the interior 104 of the reservoir 100 with supplementary oxygen, prior to inspiration at the start of the next respiratory cycle.

20

Accordingly, supplementary oxygen that enters the respiratory tract of the subject, in particular the upper respiratory tract, and is not involved in gas exchange, is recaptured within the reservoir 100 during a first part of the expiration stage, so that it can be further enriched and reutilised during the
25 next respiratory cycle. In this manner, the apparatus 22 prevents this unutilised oxygen being wasted and thereby conserves oxygen delivered to a subject.

The volume of exhaled gas captured within the reservoir 100 during
30 exhalation may be adjusted by adjusting the pressure and/or flow rate of the oxygen supply. For example, by increasing the pressure and/or flow rate of

the oxygen supply, the reservoir 100 may be caused to re-inflate to its maximum volume more quickly following inspiration, thereby reducing the volume of gas that may re-enter the reservoir during exhalation.

5 In some cases, it may not be desirable to recapture any exhaled gases, for example to prevent moisture or other contaminants entering the interior 104 of the reservoir 100. This may be achieved by increasing the pressure and/or flow rate of the oxygen supply relative to the pressure and/or flow rate of the backflow of gases generated by the subject, such that the reservoir 100
10 re-inflates to its maximum volume following inspiration before the subject begins to exhale.

 The apparatus 22 according to the first embodiment provides certain important advantages over prior art arrangements, which improve the
15 efficiency of gas conservation and reutilisation, and thereby minimise wastage.

 Firstly, in the embodiment shown in Figures 2 to 5, a portion 122a of the first conduit 122 extends within a portion 124a of the second conduit 124.
20 In this manner, the first conduit 122 extends to the opening 106 in the flexible wall 102 of the reservoir 100 such that the second opening 126b of the first conduit 122 opens into the interior 104 of the reservoir within the region of the second opening 128b of the second conduit 124.

25 In the embodiment shown in Figures 2-5, the second conduit 124 forms an elbow 130 and a portion 122a of the first conduit 122 extends within a portion 124a of the second conduit 124 from the elbow 130 to the aperture 106 in the flexible membrane 102 of the reservoir 100. Preferably, the elbow 130 is a 90° elbow.

30

Arranging the first conduit 122 so that the second opening 126b of the first conduit 122 opens into the interior 104 of the reservoir 100 within the region of the second opening 128b of the second conduit 124 is advantageous.

5

In particular, arranging the conduits 122, 124 in this manner, ensures that the flow of gas entering the reservoir from a gas supply line, via the second opening 126b in the first conduit 122, is substantially parallel to and in the same direction as a backflow of gas entering the reservoir from the gas delivery line via the second opening 128b of the second conduit 124 as the subject exhales. The action of oxygen flowing into the reservoir 100 from the first conduit 122 in close proximity to the backflow of gas from the subject flowing in the second conduit 124 draws gas into the reservoir from the second conduit, enhancing the flow of gas from the second conduit 124. This arrangement reduces or substantially eliminates any resistance to backflow during exhalation caused by the flow of gas entering the reservoir from the gas supply via the first conduit 122 and reduces the tendency for enriched gases to vent preferentially from the upper respiratory tract of the subject to the ambient atmosphere during the first part of expiration.

20

Additionally, the positive pressure required within the respiratory tract of the subject to generate a backflow during the first part of expiration is minimized by this arrangement. This ensures that even subjects who are weak or frail and unable to generate a substantial positive pressure upon exhalation, can nevertheless provide enough pressure to generate a backflow of gases during the first part of expiration, thereby conserving unutilised gases, for example oxygen, remaining within the upper respiratory tract of the subject following inspiration.

25

Such an arrangement has the further benefit of permitting a lower flow rate of gas entering the reservoir 100 from a gas supply line via the first

30

conduit 122, whilst still providing adequate enrichment of the gases retained within the interior 104 of the reservoir 100.

5 In particular, the flow of gas into the reservoir 100 from a gas supply line via the first conduit 122 will not be opposed by a backflow of gas entering the reservoir via the second conduit 124 upon exhalation. There is therefore no requirement for the pressure and flow rate of gas entering the reservoir 100 via the first conduit 122 to overcome that of the backflow of gas entering the reservoir 100 via the second conduit 124 in order to continue delivering
10 gas to the interior 104 of the reservoir 100 via the first conduit 122 throughout a respiratory cycle of the subject.

Thus, a gas may be delivered to the interior 104 of the reservoir 100 via the first conduit 122 at lower pressures and/or flow rates than in prior art
15 arrangements whilst still achieving adequate enrichment of the gas retained within the reservoir 100. This further helps to conserve gas by minimizing the rate of depletion of a finite gas source, such as an oxygen cylinder.

Furthermore, by arranging the first and second conduits 122, 124 so
20 that the flow of gas entering the reservoir from a gas supply line, via the first conduit 122, is in substantially the same direction as a backflow of gas entering the reservoir from the gas delivery line via the second conduit 124, the cross-sectional area of the second conduit can be selected to achieve a desired backflow pressure and flow rate, irrespective of the pressure and flow
25 rate of gas conveyed via the first conduit 122 from a gas supply.

Thus, the cross-sectional area of the second conduit 124 may be selected so that minimal positive pressure is required within the respiratory tract of the subject to generate a backflow during the first part of expiration. As
30 discussed above, this will reduce the tendency for gases to vent preferentially to the ambient atmosphere until the reservoir 100 is fully inflated, and ensures

that even subjects who are weak or frail can generate a backflow of enriched gases during the first part of expiration.

5 A further advantage of the connecting member 120 is that it can be formed as a single component. Similarly, only a single opening need be provided in the flexible wall 102 of the reservoir 100 to accommodate the first and second conduits 122 124. This simplifies the manufacture and assembly of the apparatus 22 according to the first embodiment, when compared to prior art arrangements including conduits formed as separate components
10 which necessitate the formation of multiple openings in the reservoir.

Still further, by having the proximal portions 122a, 124a of the first and second conduits 122, 124 arranged one inside the other, preferably in an annular manner as shown in Figures 2 to 5, the gases within the first and
15 second conduits are able to exchange heat. This in turn reduces the tendency for condensation to form within the reservoir, in particular from water vapour contained in the gases exhaled by the subject which enter the reservoir during expiration.

20 As shown in Figure 5 and described above, the reservoir 100 tapers from the first end 100a to the second 100b. Preferably the reservoir 100 is generally triangular in cross-section, as shown in Figure 5.

This shape is advantageous as, when a subject inhales, the flexible
25 wall 102 of the reservoir 100 collapses from the second end 100b towards the first end 100a. This ensures that the opening 106 is at no point blocked by the collapsed flexible wall 102 before all gas is drawn from the interior 104 of the reservoir 100 via the second conduit 124.

30 Furthermore, in the case where the maximum volume of the interior 104 of the reservoir 100 is less than that of the subject's respiratory tract,

additional supplementary gases may be drawn from the gas supply line into the subject's respiratory tract via the first conduit 122, reservoir 100, and second conduit 124 during inspiration, without re-inflating the reservoir to any significant degree. This ensures a continuous and uninterrupted supply of
5 supplementary gases to a subject, even when the reservoir is in a collapsed state.

Figure 6 is a perspective view of an apparatus according to a second embodiment, indicated generally as 24. The apparatus 24 is shown in
10 perspective view from a first side in Figure 7 and from above in Figure 8. A cross-sectional view of the apparatus is shown in Figure 9, taken along the line B-B shown in Figure 7.

The second embodiment of Figures 6 to 9 differs from the first
15 embodiment of Figures 2 to 5 in that the first conduit 122 also includes an elbow 132. Preferably the elbow 132 is a 90° elbow. Otherwise, all features of the second embodiment are identical to those of the first embodiment. Accordingly, the same reference numerals have been used to refer to like features throughout Figures 2 to 9.

20

The apparatus 24 according to the second embodiment operates in substantially the same manner as the apparatus 22 according to the first embodiment and, in the interest of brevity, the mode of action and associated advantages of the second embodiment shall not be repeated here.

25

Figure 10 is a perspective view of an apparatus according to a third embodiment, indicated generally as 26. The apparatus 26 is shown in perspective view from a first side in Figure 11, from a second side in Figure 12, and from above in Figure 13. A cross-sectional view of the apparatus is
30 shown in Figure 14, taken along the line C-C shown in Figure 13.

The apparatus 26 according to the third embodiment differs from the apparatus 22 and 24 according to the first and second embodiments, as described in more detail below.

5 The apparatus 26 includes a reservoir 300 formed from a flexible wall 302. The flexible wall is enclosed to define an interior 304. An opening 306 is formed in the flexible wall 302 allowing for the transfer of gas to and from the interior of the reservoir via the opening.

10 A connecting member 320 is arranged over the opening 306. The connecting member is provided with a first conduit 322 and a second conduit 324.

15 The first and second conduits 322, 324 are hollow tubes. The first conduit 322 includes a first opening 326a at a first end 322a distal from the reservoir 300, and a second opening 326b at a second end 322b proximal to the reservoir 300. The second opening 326b of the first conduit 322 is in communication with the interior 304 of the reservoir via the opening 306 in the flexible wall 302. The second conduit 324 includes a first opening 328a at a
20 first end 324a distal from the reservoir 300, and a second opening 328b at a second end 324b proximal to the reservoir 300. The second opening 328b of the second conduit 324 is in communication with the interior 304 of the reservoir via the opening 306 in the flexible wall 302.

25 The reservoir 300 differs from the reservoir 100 in that it tapers from a first region 300a proximal to the connecting member 320 at the centre of the reservoir 300, to a second region 300b distal from the connecting member 320 at an outer edge of the reservoir 300.

30 The connecting member 320 differs from the connecting members 120 of the first and second embodiments in that the first conduit 322 does not

extend within the second conduit 324. Instead, the conduits are separated such that the second opening 326b of the first conduit 322 opens into the interior 304 of the reservoir adjacent the second opening 328b of the second conduit 324.

5

The configuration of the reservoir 300 and the separation of the second openings 326b and 328b in the third embodiment is such that the apparatus 26 of the third embodiment operates in substantially the same manner as the apparatus 22 and 24 of the first and second embodiments and the advantages described above with respect to the first embodiment are still achieved in an analogous manner.

10

In particular arranging the conduits 322, 324 so that the second opening 326b of the first conduit 322 opens into the interior 304 of the reservoir adjacent the second opening 328b of the second conduit 324, again ensures that the flow of gas entering the reservoir from a gas supply line, via the second opening 326b in the first conduit 322, is substantially in parallel with and in the same direction as a backflow of gas entering the reservoir from the gas delivery line via the second opening 328b of the second conduit 324 as the subject exhales.

15

20

The shape of the reservoir 300 is similarly advantageous as, when a subject inhales, the flexible membrane 302 of the reservoir 300 collapses from the outer region 300b distal from connecting member 320 towards the centre region 300a proximal to the connecting member 320. This ensures that the opening 306 is at no point blocked by the collapsed flexible wall 302 before all gas is drawn from the interior 304 of the reservoir 300 via the second conduit 324.

25

30

Furthermore, in the case where the maximum volume of the interior 304 of the reservoir 300 is less than that of the subject's respiratory tract,

additional supplementary gases may be drawn from the gas supply line into the subject's respiratory tract via the first conduit 322, reservoir 300, and second conduit 324 during inspiration, without re-inflating the reservoir to any significant degree. This ensures a continuous and uninterrupted supply of supplementary gases to a subject, even when the reservoir is in a collapsed state.

The connecting member 320 further includes a series of protrusions 340 extending about the circumference of the second openings 326b, 328b. These protrusions prevent the flexible wall 302 from blocking the second openings 326b, 328b in a collapsed state, again ensuring a continuous and uninterrupted supply of supplementary gases to a subject, even when the reservoir is in a collapsed state.

As will be appreciated, the reservoirs 100, 300, and connecting members 120, 320 may be used interchangeably. For example, the reservoir 100 may be combined with the connecting member 320. Similarly, the reservoir 300, may be used in conjunction with the connecting members 120. Protrusions, similar to protrusions 340 included in the apparatus 26 according to the third embodiment, may analogously be included in the apparatus 22, 24 of the first and second embodiments, and may extend about the circumference of the second opening 126b of the first conduit 122 and/or the second opening 128b of the second conduit 124.

Figures 15a-c show an alternative reservoir 400 that may be used interchangeably with reservoirs 100, 300 included in the embodiments of Figures 1-14.

The reservoir 400 tapers from a first end 400a to a second end 400b of the reservoir.

Figures 16a-c show a further alternative reservoir 500 that may be used interchangeably with reservoirs 100, 300 included in the embodiments of Figures 1-14. The reservoir 500 has a generally cuboidal shape.

- 5 Figures 17a and 17b show a further alternative reservoir 600 that may be used interchangeably with reservoirs 100, 300 included in the embodiments of Figures 1-14.

10 The reservoir 600 is generally cylindrical in shape and includes a concertinaed portion 610. The wall of the concertinaed portion 610 may deform along a plurality of fold lines 620 to collapse and expand the reservoir as a subject inhales and exhales over the course of a respiratory cycle.

CLAIMS

1. Apparatus for supplying a gas to a subject, the apparatus comprising:
 - 5 a reservoir having a wall for holding a volume of gas, the reservoir having an inlet opening in a wall for entry into the reservoir of a gas to be supplied to the subject and an outlet opening in the wall for supplying gas from within the reservoir to the subject;
 - a first conduit extending from the inlet opening for connection to a
 - 10 supply of the gas to be supplied to the subject;
 - a second conduit extending from the outlet opening for connection to a device for providing gas to the subject;
 - wherein the inlet opening is disposed in the wall of the reservoir relative to the outlet opening such that the gas flowing in the first conduit is caused to
 - 15 enter the reservoir through the inlet opening before passing to the outlet opening and into the second conduit; and
 - wherein the flow of gas through the inlet opening into the reservoir from the first conduit draws gas from the second conduit through the outlet opening when the gas in the second conduit is subjected to a back pressure.
- 20 2. Apparatus according to claim 1, wherein the reservoir is generally elongate having a first end and a second end, with the first and second conduits both being arranged in the first end.
- 25 3. Apparatus according to claim 1 or claim 2, wherein the reservoir is tapered.
4. Apparatus according to any preceding claim, wherein the inlet opening and the outlet opening are adjacent one another, the openings being
- 30 separated by a wall of one of the first and second conduits.

5. Apparatus according to any preceding claim, wherein the wall of the reservoir is provided with a single opening, a first portion of the single opening providing the inlet opening and a second portion of the single opening providing the outlet opening.

5

6. Apparatus according to claim 5, wherein the first and second portions of the single opening are arranged in an annular manner.

7. Apparatus according to claim 5 or claim 6, wherein the inlet opening
10 lies within the outlet opening.

8. Apparatus according to claim 7, wherein the outlet opening extends fully around the inlet opening.

15 9. Apparatus according to claims 1-3, wherein the outlet opening in the wall of the reservoir is spaced apart from the inlet opening in the wall of the reservoir.

10 10. Apparatus according to any preceding claim, wherein at least a portion of one of the first and second conduits extends within at least a portion of the other of the first and second conduits.

11. Apparatus according to claim 10, wherein the portion of the first or second conduit extending within the portion of the second or first conduit is
25 arranged co-axially with the portion of the second or first conduit.

12. Apparatus according to any preceding claim, wherein at least a portion of the first conduit extends from the inlet opening in the wall of the reservoir within at least a portion of the second conduit.

30

13. Apparatus according to any preceding claim, wherein the distance between the edge of the inlet opening and the edge of the outlet opening is from 4 mm to 8 mm.
- 5 14. Apparatus according to any preceding claim, wherein the ratio of the area of the outlet opening to the area of the inlet opening is up to 5:1.
15. Apparatus according to any preceding claim, wherein the first conduit is tubular with a circular cross-section.
- 10 16. Apparatus according to claim 15, wherein the first conduit has an inner diameter of from 3 mm to 12 mm.
- 15 17. Apparatus according to any preceding claim, wherein the second conduit is tubular with a circular cross-section.
18. Apparatus according to claim 17, wherein the second conduit has an inner diameter of from 8 mm to 15 mm.
- 20 19. Apparatus according to any preceding claim, further comprising a connecting member comprising both the first conduit and the second conduit.
20. Apparatus according to any preceding claim, further comprising one or more protrusions provided adjacent the or each opening in the wall of the
25 reservoir.
21. A method for supplying a gas to a subject, the method comprising:
providing a reservoir for holding gas having a first opening for supplying gas from within the reservoir to the subject and receiving gas exhaled by the
30 subject;

supplying the gas to the reservoir through a second opening, whereby the flow of the gas into the reservoir through the second opening draws gas through the first opening when a back pressure is applied to the first opening by the subject exhaling.

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22. The method according to claim 21, employing an apparatus according to any of claims 1-20.

23. Apparatus for supplying a gas to a subject, the apparatus comprising:

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a reservoir having a wall for holding a volume of gas, the reservoir having an inlet opening in the wall for entry into the reservoir of a gas to be supplied to the subject and an outlet opening in the wall for supplying gas from within the reservoir to the subject;

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a first conduit extending from the inlet opening for connection to a supply of the gas to be supplied to the subject;

a second conduit extending from the outlet opening for connection to a device for providing gas to the subject;

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wherein at least a portion of the first conduit and the second conduit are arranged to allow heat exchange between gas within the first conduit and gas within the second conduit to occur.

24. A method for supplying a gas to a subject, the method comprising:

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providing a reservoir for holding gas having a first opening for supplying gas from within the reservoir to the subject and receiving gas exhaled by the subject;

supplying the gas to the reservoir through a second opening, whereby the gas flowing into the reservoir through the second opening exchanges heat with gas exhaled by the subject and entering the reservoir through the first opening.

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25. Apparatus for supplying a gas to a subject, the apparatus comprising:
- a reservoir having a flexible wall for holding a volume of gas, the reservoir having a first end and a second end, the reservoir further comprising an inlet opening in the first end of the wall for entry into the reservoir of a gas
 - 5 to be supplied to the subject and an outlet opening in the first end of the wall for supplying gas from within the reservoir to the subject;
 - a first conduit extending from the inlet opening for connection to a supply of the gas to be supplied to the subject;
 - a second conduit extending from the outlet opening for connection to a
 - 10 device for providing gas to the subject;
 - wherein the wall of the reservoir is tapered in the direction extending from the first end of the reservoir to the second end of the reservoir.

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CLAIMS

1. Apparatus for supplying a gas to a subject, the apparatus comprising:

5 a reservoir having a wall for holding a volume of gas, the reservoir having an inlet opening in a wall for entry into the reservoir of a gas to be supplied to the subject and an outlet opening in the wall for supplying gas from within the reservoir to the subject;

10 a first conduit extending from the inlet opening for connection to a supply of the gas to be supplied to the subject;

15 a second conduit extending from the outlet opening for connection to a device for providing gas to the subject, wherein the second conduit comprises a first opening at a first end of the second conduit distal from the reservoir and a second opening at a second end of the second conduit proximal to the reservoir, the second opening being at the outlet opening in the wall of the reservoir, in use all gas flowing through the second conduit flows between the first and second openings;

20 wherein the inlet opening is disposed in the wall of the reservoir relative to the outlet opening such that the gas flowing in the first conduit is caused to enter the reservoir through the inlet opening before passing to the outlet opening and into the second conduit; and

25 wherein the flow of gas through the inlet opening into the reservoir from the first conduit draws gas from the second conduit through the outlet opening when the gas in the second conduit is subjected to a back pressure when the subject exhales.

2. Apparatus according to claim 1, wherein the reservoir is generally elongate having a first end and a second end, with the first and second conduits both being arranged in the first end.

3. Apparatus according to claim 1 or claim 2, wherein the reservoir is tapered.

4. Apparatus according to any preceding claim, wherein the inlet opening
5 and the outlet opening are adjacent one another, the openings being separated by a wall of one of the first and second conduits.

5. Apparatus according to any preceding claim, wherein the wall of the reservoir is provided with a single opening, a first portion of the single opening
10 providing the inlet opening and a second portion of the single opening providing the outlet opening.

6. Apparatus according to claim 5, wherein the first and second portions of the single opening are arranged in an annular manner.

7. Apparatus according to claim 5 or claim 6, wherein the inlet opening lies within the outlet opening.

8. Apparatus according to claim 7, wherein the outlet opening extends
20 fully around the inlet opening.

9. Apparatus according to claims 1-3, wherein the outlet opening in the wall of the reservoir is spaced apart from the inlet opening in the wall of the reservoir.

25 10. Apparatus according to any preceding claim, wherein at least a portion of one of the first and second conduits extends within at least a portion of the other of the first and second conduits.

11. Apparatus according to claim 10, wherein the portion of the first or second conduit extending within the portion of the second or first conduit is arranged co-axially with the portion of the second or first conduit.

5 12. Apparatus according to any preceding claim, wherein at least a portion of the first conduit extends from the inlet opening in the wall of the reservoir within at least a portion of the second conduit.

10 13. Apparatus according to any of claims 1-3, or claims 5-12, when dependent on claims 1-3, wherein the distance between the edge of the inlet opening and the edge of the outlet opening is from 4 mm to 8 mm.

15 14. Apparatus according to any preceding claim, wherein the ratio of the area of the outlet opening to the area of the inlet opening is up to 5:1.

15 15. Apparatus according to any preceding claim, wherein the first conduit is tubular with a circular cross-section.

20 16. Apparatus according to claim 15, wherein the first conduit has an inner diameter of from 3 mm to 12 mm.

17. Apparatus according to any preceding claim, wherein the second conduit is tubular with a circular cross-section.

25 18. Apparatus according to claim 17, wherein the second conduit has an inner diameter of from 8 mm to 15 mm.

19. Apparatus according to any preceding claim, further comprising a connecting member comprising both the first conduit and the second conduit.

20. Apparatus according to any preceding claim, further comprising one or more protrusions provided adjacent the or each opening in the wall of the reservoir.

5 21. A method for supplying a gas to a subject to improve the quality of breathable air, the method comprising:

providing a reservoir for holding gas having a first opening for supplying gas from within the reservoir to the subject and receiving gas exhaled by the subject;

10 supplying the gas to the reservoir through a second opening, whereby the flow of the gas from a first conduit into the reservoir through the second opening draws gas from a second conduit through the first opening when a back pressure is applied to the first opening by the subject exhaling;

15 wherein the second conduit comprises a first opening at a first end of the second conduit distal from the reservoir and a second opening at a second end of the second conduit proximal to the reservoir, the second opening being at the first opening in the wall of the reservoir, in use all gas flowing through the second conduit flows between the first and second openings.

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22. The method according to claim 21, employing an apparatus according to any of claims 1-20.

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Claims searched: 1-20

Date of search: 12 September 2022

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	EP 2145644 A1 (IPH ESTABLISHMENT) See figures 1 & 4 for example.
A	-	WO 2016/097669 A1 (SMITHS MEDICAL INT LTD) See figure 4 for example.
A	-	US 4110419 A (MILLER) See figure 2 for example.
A	-	EP 3313487 A1 (FISHER & PAYKEL HEALTHCARE LTD) See figures 23 & 24 for example.
A	-	GB 2072526 A (BAXTER TRAVENOL LAB) See figures 1 & 3.
A	-	WO 2013/001216 A1 (HEALTHC AIR) See figure 8 for example.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

A61M

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, Patent Fulltext, INTERNET



International Classification:

Subclass	Subgroup	Valid From
None		