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(54) **SYSTEMS AND METHODS FOR PROVIDING POSITIVE AIRWAY PRESSURE IN A TUBE-LIKE STRUCTURE**

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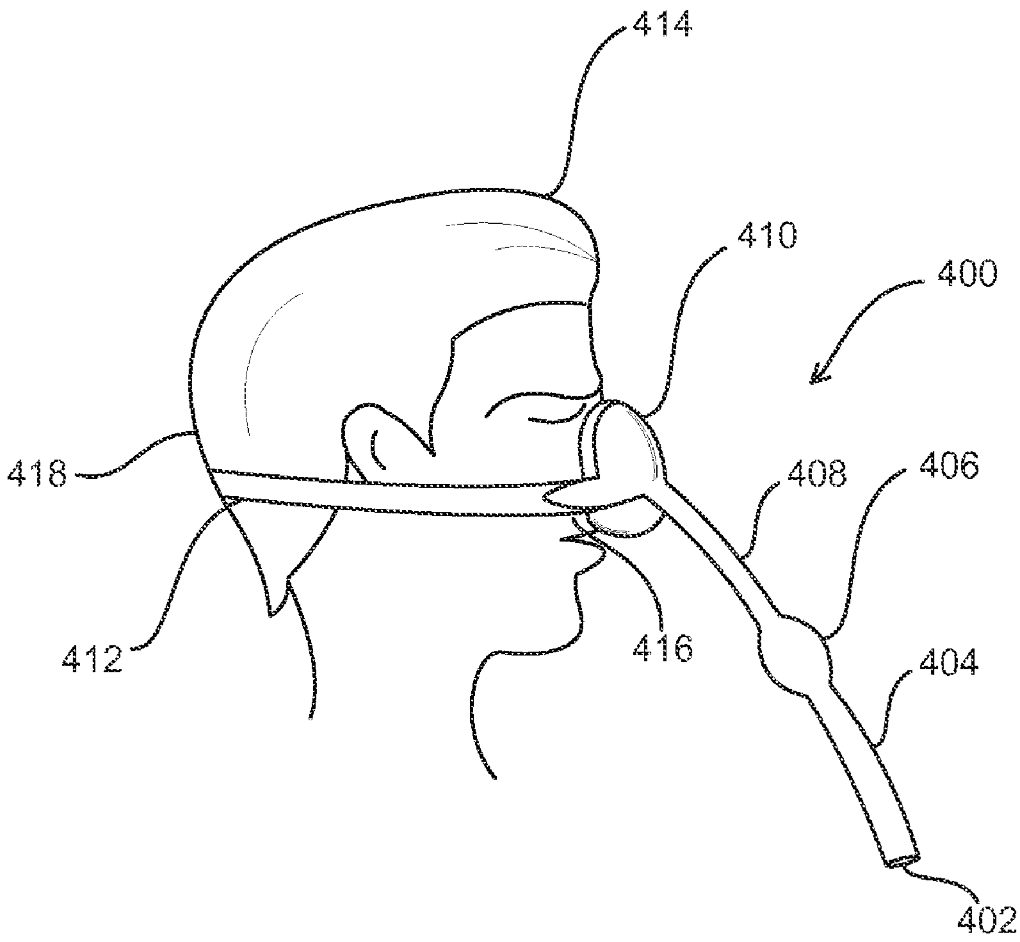
USPC **128/205.25**; 128/204.18

(57) **ABSTRACT**

The systems and methods described herein include a small system integrated within a tubing for providing positive air pressure to a patient. The system may include a tube with an inlet opening, an expansion section with a gas flow generator, and an outlet opening. The systems and methods described herein provide improved mobility, comfort, and usability for patients.



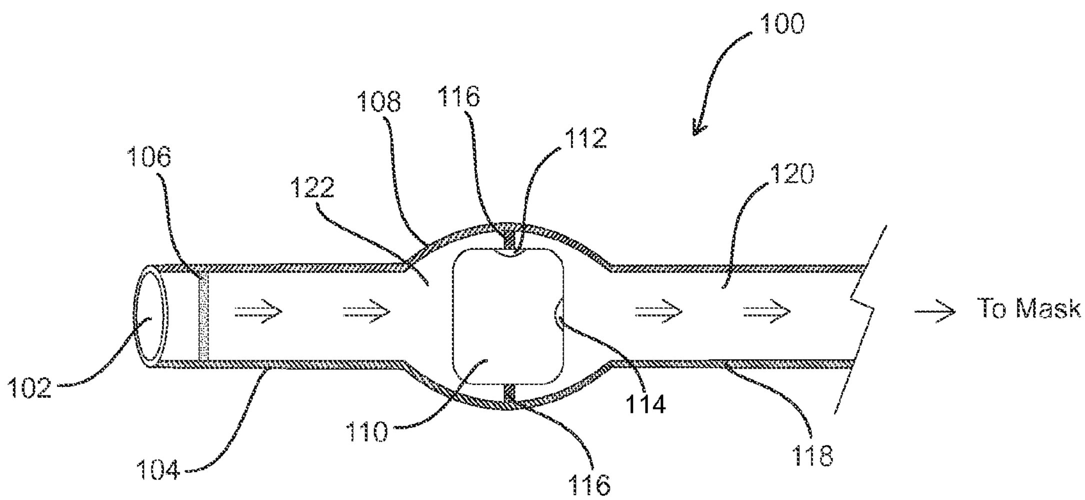


Fig. 1

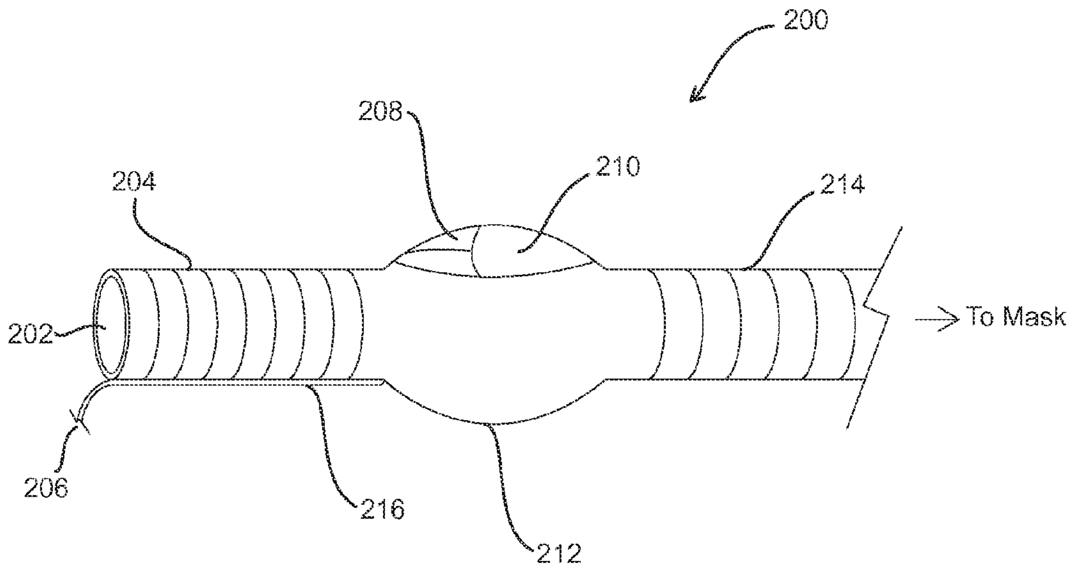


Fig. 2

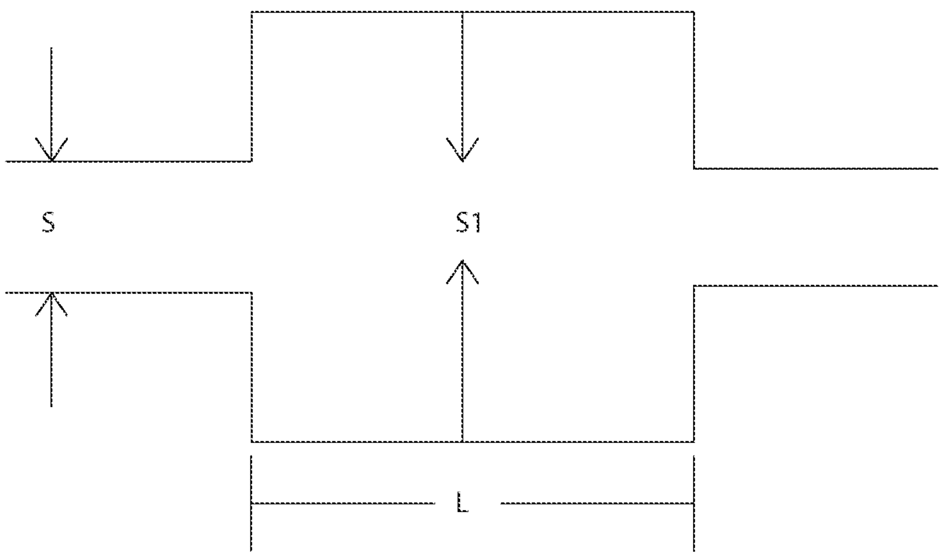


Fig. 3

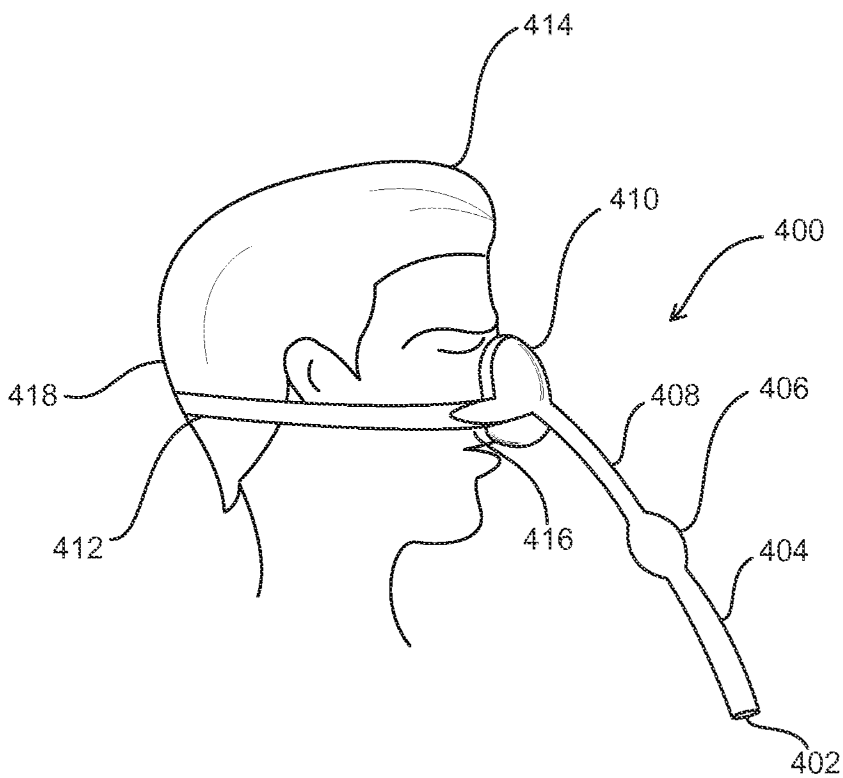


Fig. 4A

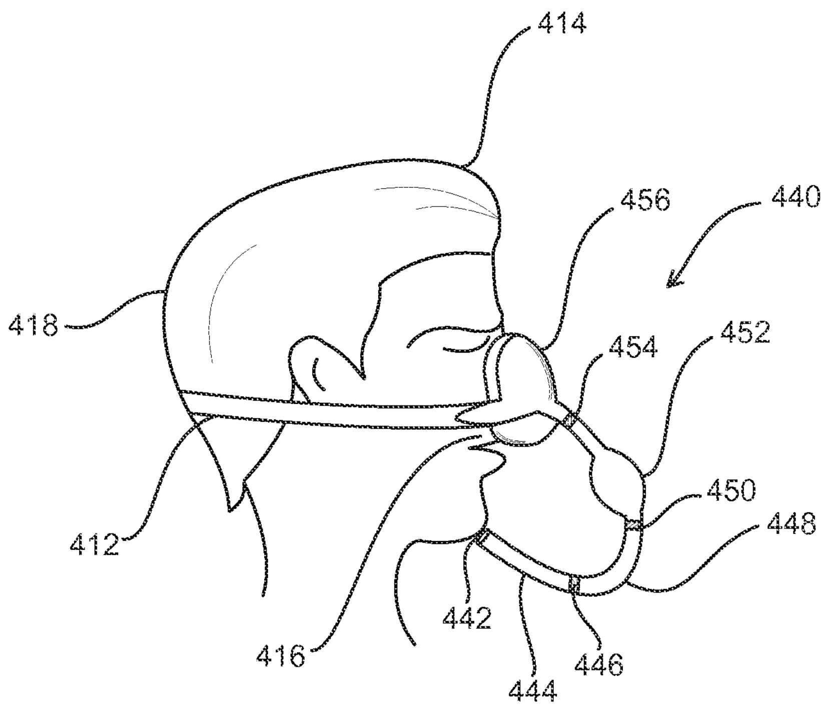
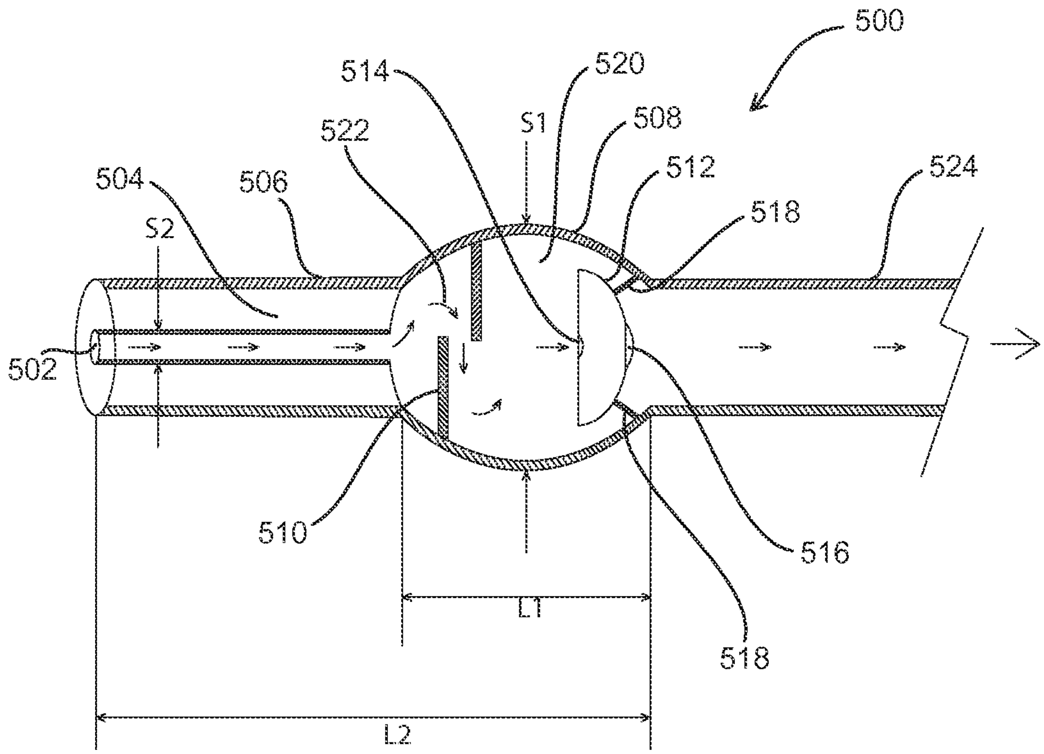


Fig. 4B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S2
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L1
L2

Fig. 5

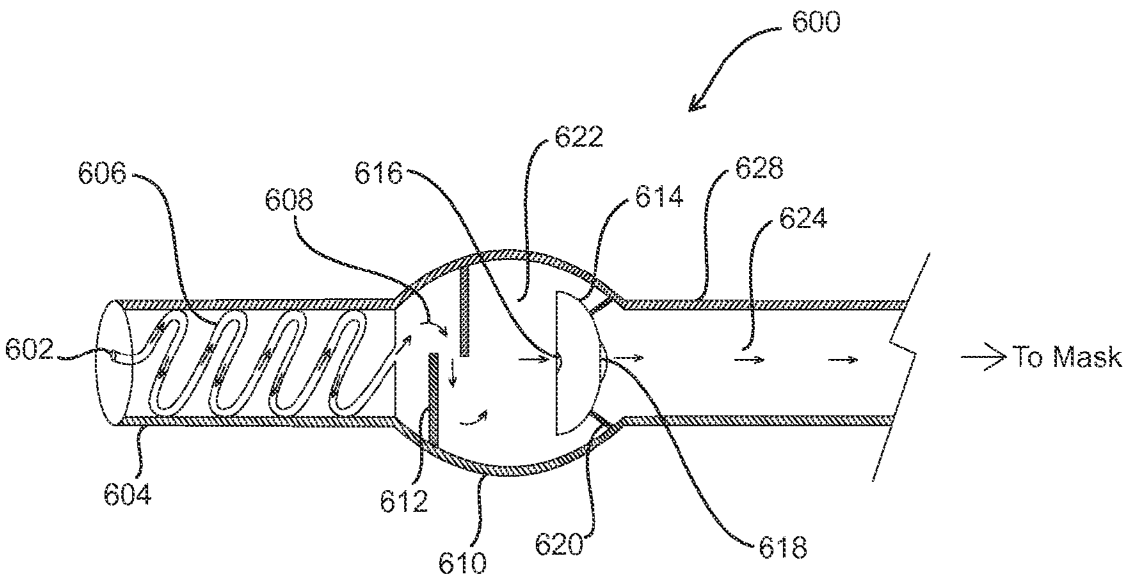


Fig. 6

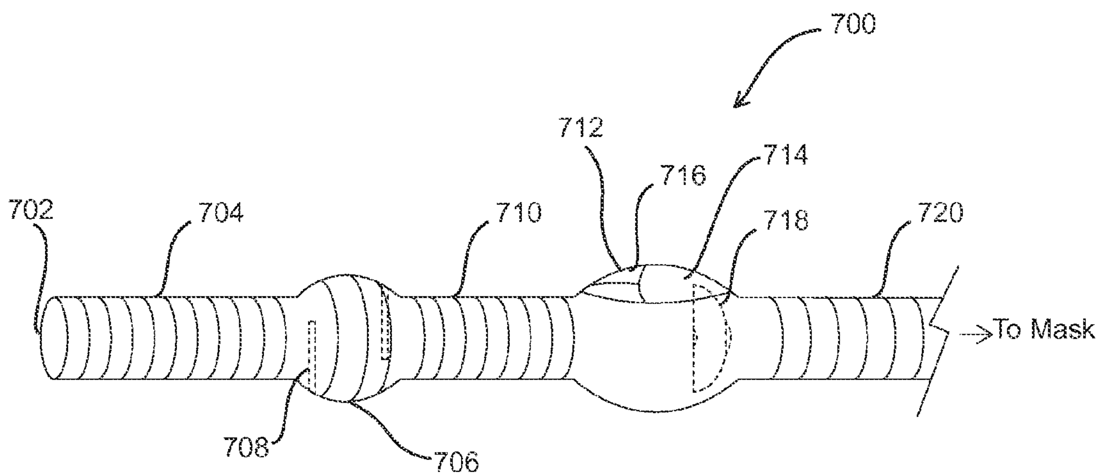


Fig. 7

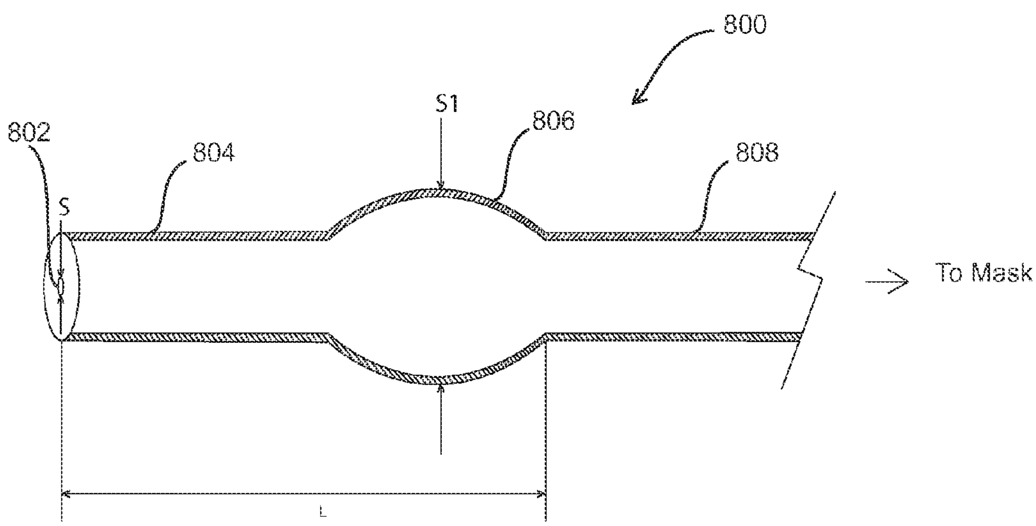
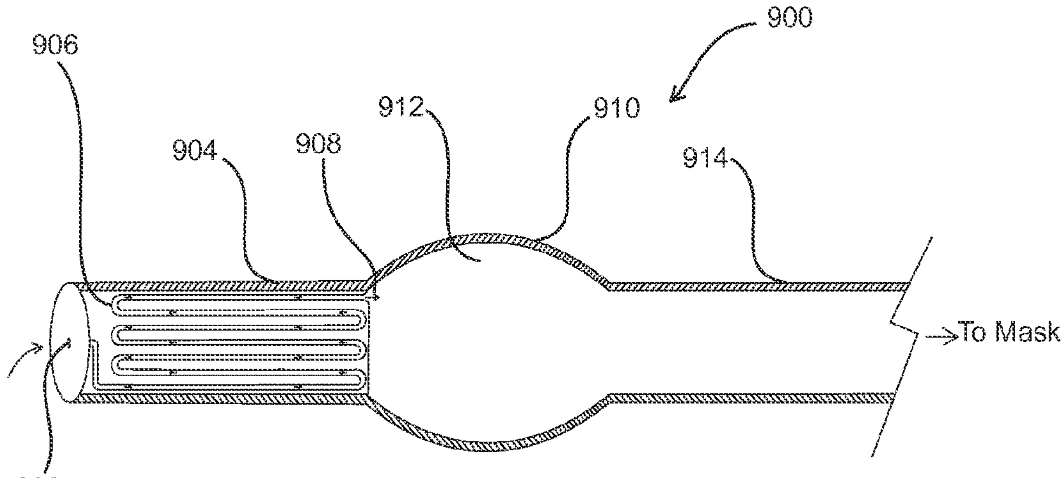


Fig. 8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904
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914
To Mask
902

Fig. 9A

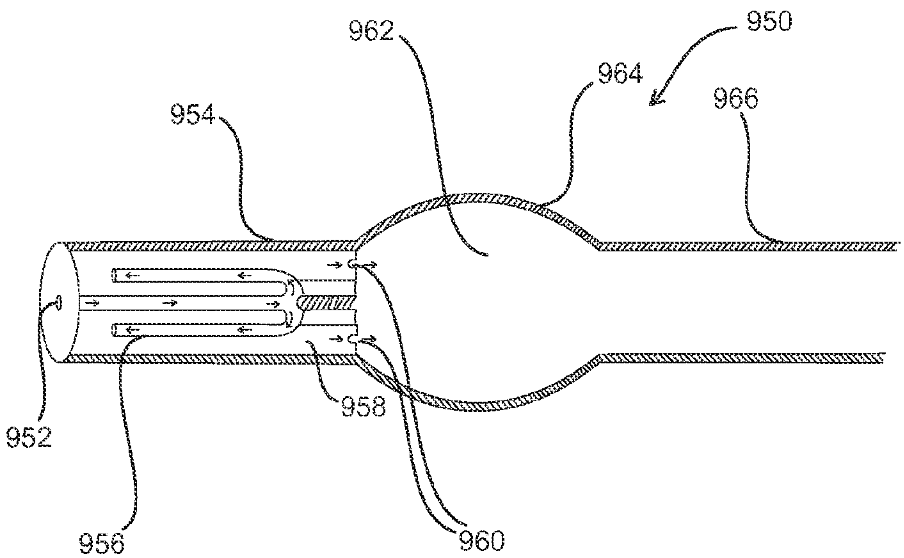
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Fig. 9B

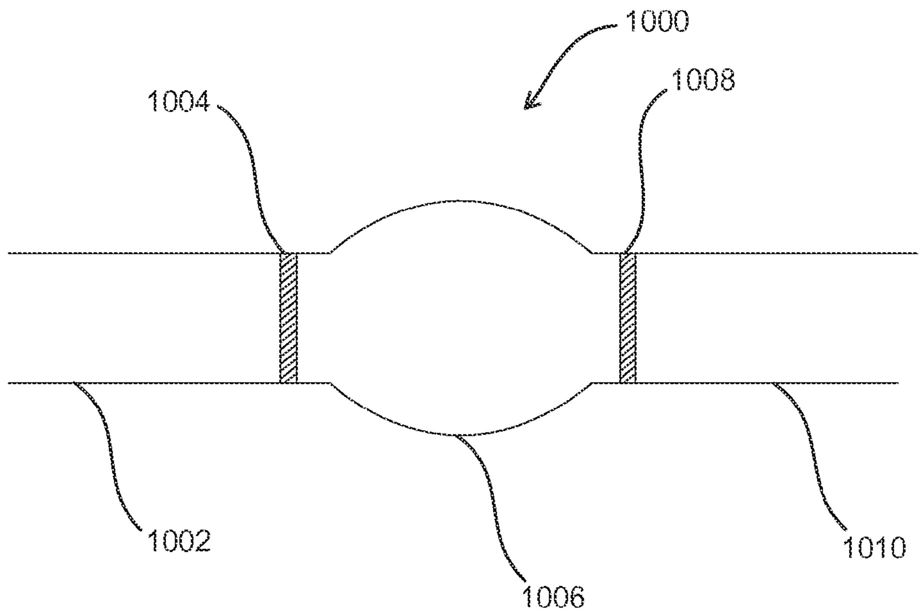

Fig. 10A

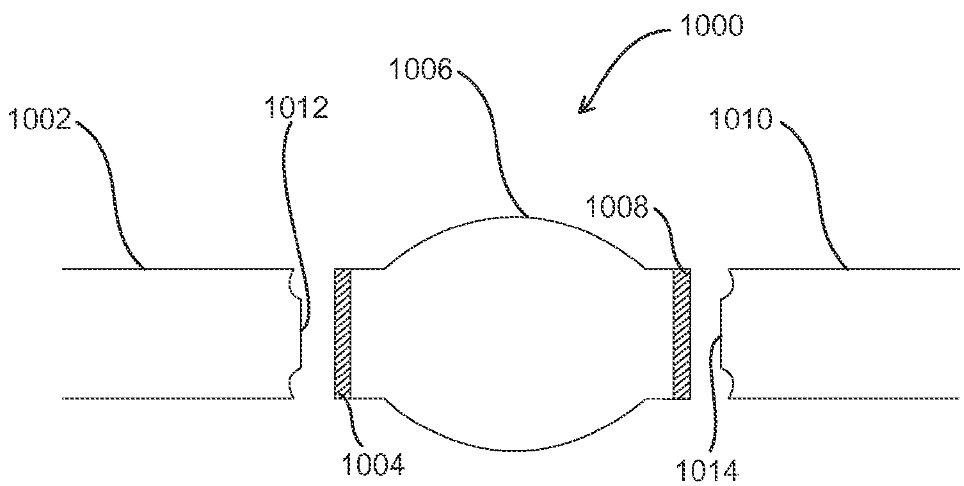

Fig. 10B

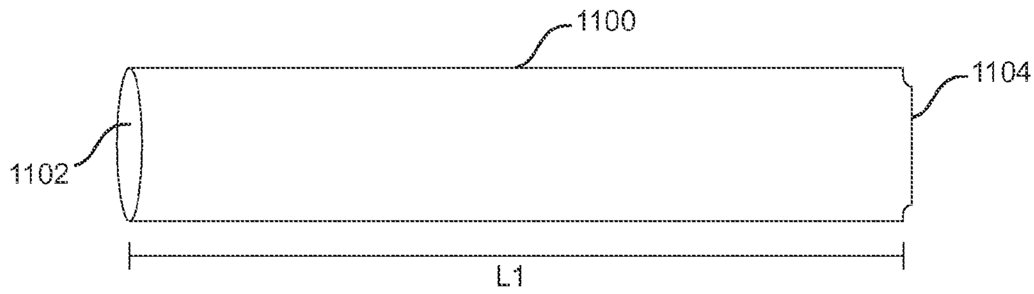

Fig. 11A

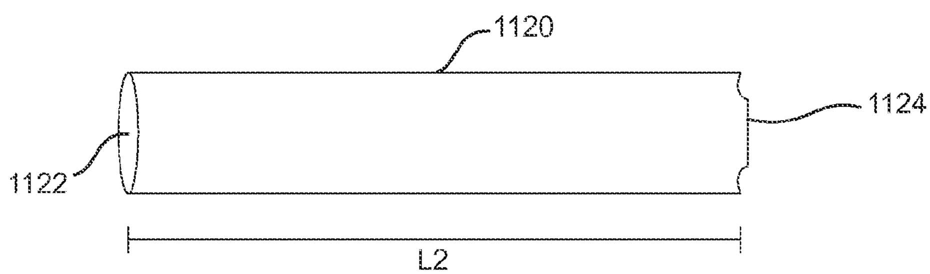

Fig. 11B

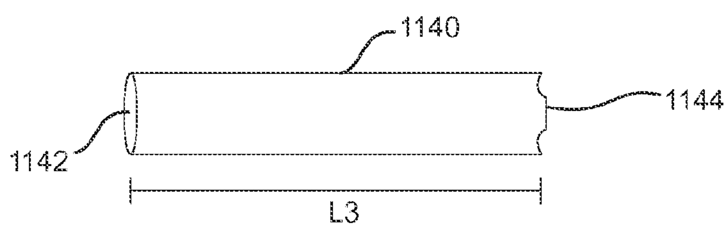

Fig. 11C

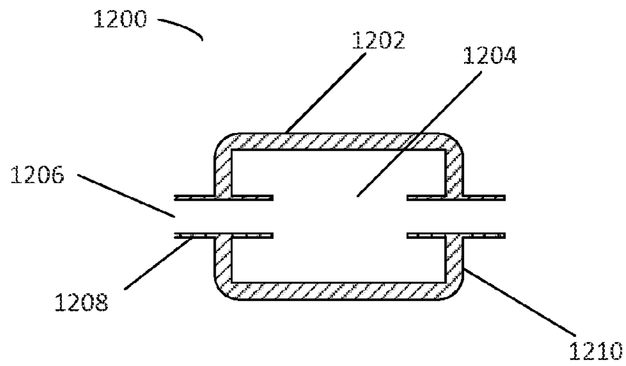

FIG. 12A

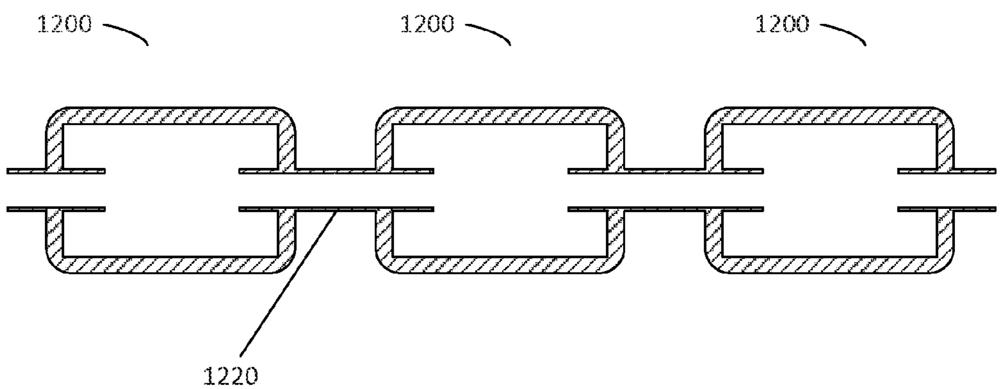

FIG. 12B

SYSTEMS AND METHODS FOR PROVIDING POSITIVE AIRWAY PRESSURE IN A TUBE-LIKE STRUCTURE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Patent Application 61/798,367 filed on Mar. 15, 2013; U.S. Patent Application 61/798,541 filed on Mar. 15, 2013; U.S. Patent Application 61/798,263 filed on Mar. 15, 2013; and U.S. Patent Application 61/798,462 filed on Mar. 15, 2013 which are incorporated herein by reference.

COPYRIGHT INFORMATION

FIELD OF THE INVENTION

[0003] The present invention relates to a positive airway pressure [PAP] devices, such as continuous positive airway pressure [CPAP] devices, and more particularly to a PAP device mounted or formed within a tube or hose.

BACKGROUND OF THE INVENTION

[0004] The sleep apnea syndrome afflicts an estimated 1% to 5% of the general population and is due to episodic upper airway obstruction during sleep. Those afflicted with sleep apnea experience sleep fragmentation and intermittent, complete, or nearly complete cessation of ventilation during sleep with potentially severe degrees of oxyhemoglobin desaturation.

[0005] It is known that applying a positive airway pressure to a patient with a CPAP device may prevent upper airway occlusion during sleep. CPAP devices have become the apparatus of choice for the treatment of chronic sleep apnea, chronic pulmonary obstruction and snoring. Many CPAP machines are readily available in the marketplace.

[0006] A typical CPAP system generally includes a bedside generator comprising, a blower unit powered by an electric motor. The blower unit, the motor, and associated controls are usually encased together within the bedside generator. A delivery tube, usually a flexible plastic tube having a proximal end and a distal end, is used to deliver pressurized air or other gasses to the patient. The proximal end of the delivery tube is connected to the bedside generator and the distal end of the delivery tube is fitted to the face of a patient. The patient interface may include features that allow the patient interface to be affixed to the patient and maintain a proper orientation with respect to the patient.

[0007] Bedside CPAP machines are typically large and heavy. They are usually plugged into a wall outlet for power or have a large external battery. The size, weight, and power constraints can interfere with patients' ability and willingness to use the machine. For example, these constraints can make it difficult to utilize the CPAP apparatus in areas away from their bedside or while traveling. Additionally, these constraints can also prohibit patients from moving freely during sleep, thereby inducing further discomfort.

[0008] Furthermore, typical CPAP devices are relatively loud and can interfere with a patient's sleep or the sleep of other people nearby. In a typical CPAP device, sound may be propagated from various locations and actions of the device, such as the flow of air the flow of air into and out of the device or the operation of the motor and fan. Because the apparatus is used mainly in a bedroom or other place having a low ambient noise level to facilitate sleep, it is important that the blower operates quietly so as not to disturb the patient or others in close proximity while they sleep.

[0009] A need therefore exists for PAP devices with size, weight, and sound characteristics that provide improved usability for patients.

[0010] Many CPAP devices are large in nature that they are required to be placed on a bedside table, under the bed, or otherwise away from the patient. Attempts have been to mount some CPAP devices on a mask or top of a person's head in an effort to make CPAP devices portable, less cumbersome and more comfortable. However, in some respects these devices fail to adequately address comfort, weight, noise attenuation from the device and so forth.

SUMMARY OF THE INVENTION

[0011] In one exemplary embodiment a long hose or tube comprises an expansion section that houses a blower configured to provide pressurized air flow. The intake portion of the hose may be configured to have a single inlet. Various replaceable filters may be placed immediately before or after the inlet of the hose.

[0012] In some embodiments the length of the hose provides a sufficient length to provide an effectively large enough chamber to reduce any attenuated noise.

[0013] In one embodiment multiple expansion chambers functioning as acoustic reduction chambers are provided.

[0014] In one embodiment a portion of the hose contains electrical leads or a power cord to supply power to the blower.

[0015] In one embodiment the exterior of the expansion portion contains a display screen and input buttons. (it is also contemplated the display screen may be a touch screen) The input buttons may be used to power on/off the CPAP in hose device and select various features.

[0016] In one embodiment flexible electrical circuitry is used in the non-expansion portion of the hose or tube.

[0017] In another embodiment a portable and elongated CPAP system comprising an expansion tube section having a blower comprised of a motor and impellor disposed therein; at least two detachable tube sections for attaching to an inlet and outlet port of the expansion tube section, wherein one of the detachable tube sections has acoustically designed inlet port that forms a low pass frequency filter with an expansion chamber disposed in the expansion tube section.

[0018] These aspects of the invention are not meant to be exclusive and other features, aspects, and advantages of the present invention will be readily apparent to those of ordinary skill in the art when read in conjunction with the following description, appended claims, and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The foregoing and other objects, features, and advantages of the invention will be apparent from the following description of particular embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

[0020] FIG. **1** is a cross-sectional schematic view of a PAP system integrated into a hose.

[0021] FIG. **2** is an exterior view of a PAP system integrated into a hose.

[0022] FIG. **3** illustrates noise filter system.

[0023] FIG. **4**A illustrates a PAP system integrated into a hose connected to a mask being worn by a user.

[0024] FIG. **4**B shows a PAP system integrated into a hose with detachable segments.

[0025] FIG. **5** depicts a cross-sectional view of PAP system integrated into a hose with a reduced-diameter air inlet tube.

[0026] FIG. **6** illustrates a PAP system integrated into a hose with an air inlet tube having multiple turns.

[0027] FIG. **7** is an exterior view of a PAP system integrated into a hose having multiple expansion sections.

[0028] FIG. **8** illustrates a PAP system integrated into a hose with a reduced diameter inlet opening.

[0029] FIGS. **9**A-B depict PAP systems integrated into a hose with curved or extended flow paths.

[0030] FIGS. **10**A-B depict a PAP system integrated into a hose with detachable segments.

[0031] FIGS. **11**A-C illustrate various silencer intake segments having varying lengths.

[0032] FIGS. **12**A-B illustrate linked expansion chambers.

DETAILED DESCRIPTION OF THE INVENTION

[0033] To provide an overall understanding of the systems, devices, and methods described herein, certain illustrative embodiments will be described. Although the embodiments and features described herein are frequently described for use in connection with CPAP apparatuses, systems, and methods, it will be understood that all the components, mechanisms, systems, methods, and other features outlined below may be combined with one another in any suitable manner and may be adapted and applied to other PAP apparatuses, systems, and methods, including, but not limited to, automatic positive airway pressure devices [APAP], variable positive airway pressure devices [VPAP], bi-level positive airway pressure devices [BPAP], and related apparatuses, systems, and methods.

[0034] Bedside CPAP machines are typically large, heavy, and noisy. The systems and methods described herein are directed towards a small, quiet, light-weight, and portable CPAP device to overcome this current limitations and disadvantages.

[0035] The systems and methods described herein provide pressurized gas to the airway of a patient. In certain embodiments, the systems and methods described herein include a gas flow generator for providing a flow of gas to a mask or other oral-nasal region device for the delivery of the gas to an airway of a patient. In certain approaches, a single hose is used with at least one expansion chamber housing a blower.

[0036] FIG. **1** is a cross-sectional schematic view of a PAP system integrated into a hose. PAP system **100** includes an upstream hose section **104**, expansion chamber **108** with a blower **110**, and downstream hose section **118**. System **100** may include a filter **106**. For example, filter **106** may be positioned in upstream portion **104**. In certain approaches, upstream portion **104** is removable from expansion chamber **108**. In certain approaches, downstream portion **118** is removable from expansion chamber **108**.

[0037] In certain embodiments, system **100** includes a filter **106** to clean the air of particulate matter. Filter is positioned upstream of blower **110**. For example, filter **106** may be positioned within upstream hose portion **104**. Additionally or alternatively, filter **106** may be positioned within expansion chamber **108**. In certain embodiments, filter **106** is removable so that it may be cleaned, replaced, or adapted for a particular need. For example, various types of filters may be used for filter **106** depending on a patient's health. Filter **106** may not be required for all patients, may be replaceable, or may be cleaned.

[0038] Blower **110** is positioned within the space **122** of expansion chamber **108**. In certain approaches, blower **116** fills space **122**. Blower **110** may have any appropriate shape, and in certain approaches may be shaped similarly as the interior space **122** of expansion camber **108**. In certain approaches, blower **116** is coupled to chamber **108** with mount connects **116**. In addition to connecting blower **110** to expansion chamber **108**, mount connects **116** may reduce or eliminate transfer of vibrations from the blower to other components of device **100**. In certain embodiments, blower **110** is a brushless air-bearing motor. Blower **110** may be an air-bearing blower or other type of blowers used in the industry, and may include various impellors that rotate sufficiently to create an internal vacuum for pulling air through intake **112** and/or increase pressure through blower output **114** to create pressurized air flow **120** through downstream hose portion **118**. In some embodiments the blower is an inline or pass-through blower meaning the impellor is placed directly in the flow path. See for example FIGS. **5** and **6**.

[0039] During operation, PAP device **100** creates positive air pressure through downstream hose section **118**. For example, when a patient interface, such as a mask, is attached, PAP device **100** creates positive air pressure, which can be provided to the patient when the patient places the patient interface at his or her airways (e.g., nose or mouth). Blower **110** includes intake **112**. When blower **110** is powered on, blower **110** intakes air through intake **112** and pushes out that air through outlet **114**. The reduced pressure at intake **112** causes air to flow through inlet **102**, through filter **106**, through upstream hose portion **104**, and into chamber **108**, where the air then flows into intake **112** of blower **110**. Blower **110** then pushes air through outlet **114**, and through downstream hose portion **118** to provide positive air pressure, for example, through a mask. In certain approaches, the pressurized air is delivered at a pressure ranging from approximately 2 centimeters (cm) of water to approximately 40 cm of water above atmospheric pressure at the point of use, although any appropriate pressure may be used.

[0040] Apparatus **100** may also include a pressure port. The pressure port may formed inline with the tubing downstream from the blower and run adjacent the tube into chamber **122**, where the pressure port couples to a pressure sensor, such as a pressure sensor on a circuitry board. The pressure port provides fluid communication from the output of device **100** to a pressure sensor coupled to control circuitry. The circuitry board may include control circuitry and control components for the operation of device **100**. The circuitry board may be positioned in the expansion section, remotely, embedded along the length of the tube and so forth. In certain approaches, the circuitry board includes a power sources, such as a power adapter or battery. In certain approaches, the control circuitry on board of device **100** is configured to display the pressure measured through pressure port at a display, such as display **210** depicted in FIG. **2**. In certain embodiments, the pressure output of device **100** may be adjusted manually by the user with user interface buttons. In certain approaches, the control circuitry on board is configured to automatically adjust the output of device **100** based on the pressure measurements. The output of device **100** may be adjusted by modulating the power of blower **110**.

[0041] FIG. **2** is an exterior view of a PAP system integrated into a hose. PAP system **200** includes an upstream hose section **204**, expansion chamber **212** where a blower (not depicted) is positioned, and downstream hose section **214**. System **200** includes a power cable **206**. In certain approaches, cable **206** is coupled to the exterior surface **216** of system **100**. Additionally or alternatively, power cable **206** may be positioned on the interior of system **100**. In certain approaches, upstream portion **204** is removable from expansion chamber **212**. In certain approaches, downstream portion **214** is removable from expansion chamber **212**.

[0042] System **200** includes user controls components, such as interface buttons **208** and display **210** for controlling and using apparatus **200**. For example, a user may be able to turn the power on and off, adjust pressure settings, set a timer, run system diagnostic tests, and control or adjust other functions. Display **210** may be any appropriate display, including, but not limited to an LED or LCD display. Although 1-3 user interface buttons **208** are depicted, any appropriate number of buttons may be used. In certain approaches, a PAP apparatus, such as system **200**, may include between 1 and 10 user interface buttons. In certain approaches, user interface buttons are included in display **210**. For example, display **210** may be a capacitive or pressure sensitive touch screen display. Further, buttons **208** and display **210** may vary in size between different embodiments. For example, some embodiments may include a larger display, while other embodiments may include a smaller display. Display **210** may display data or control functions, such as pressure levels, time, use time, or other information. Display **210** may show one piece of data or function or a plurality of data and functions.

[0043] The hose or tubing (such as upstream portion **204**, chamber **212**, and downstream portion **214**) used in system **200** may be flexible and provide the ability to somewhat conform to the movements and body of a user. In certain approaches, a user may be sleeping on his/her side or back and the system **200** is sufficiently light and flexible so that system **200** rotates or follows the rotation or turning of the user's body. In some embodiments (not shown in the figures) a battery source is contained within system **200**.

[0044] During operation, PAP device **200** creates positive air pressure through downstream hose section **214**. System **200** pulls air through opening **202** of upstream hose section **204**, through section **204**, into chamber **212**, and through downstream section **214**. For example, when a patient interface, such as a mask, is attached, PAP system **200** creates positive air pressure, which can be provided to the patient when the patient places the patient interface at his or her airways (e.g., nose or mouth).

[0045] FIG. **3** illustrates a low-pass acoustic filter system. The equation below describe the effects modifying each geometrical section of the filter system has on the system.

$$T_\pi = \left(\frac{1}{1 + \left(\frac{S_1 - S}{2S} \right) kL} \right) \qquad \text{Equation 1}$$

[0046] In Equation 1, T is the power transmission, also referred to as the acoustic output, sound level, or noise level; k is the wavenumber of the sound; S1 is the area of an expansion chamber; L is the length of an expansion chamber; and S is the area of an inlet port or tube. Thus, if S1 increases in size, L increases in length or S decreases in area, then the power transmission T is reduced.

[0047] In accordance with the present disclosure, the area of the respective expansion chamber (S1) and the area of its inlet port (S) may have a proportional relationship. For example, the area of the chamber may be larger than the area of the inlet port by a factor of 2. In additional embodiments, S1 may be larger than S by a factor ranging from a factor of approximately 2 to a factor of approximately 20 or more. In at least one embodiment, S1 is larger than S by a factor of about 10. Additionally, the length of L may be increased wherein the upstream portion of the tube and the expansion chamber effectively act as single chamber, thus decreasing the amount of noise emanating from the system.

[0048] Referring to FIG. **3**, the inlet pathway defined by S is smaller than the upstream portion of the expansion chamber. In accordance with equation 1, when S is reduced relative to S1, then T or the noise level is attenuated. By increasing L (the length of the expansion chamber), the noise may be further attenuated. In addition, if the inlet pathway is sufficiently long, the effective length of the expansion chamber increases from L to L1, thus also reducing the noise of the system. An increase in length of intake tubes helps decrease the amount of noise escaping the system. Thus, longer inlet or sections of tubes help attenuate the noise of the system.

[0049] There exists a proportional relationship between the length of the inlet tube or port and the cross-sectional area of the inlet port with the volume (and length) of the receiving acoustic chamber or expansion section/chamber. However, by increasing the length of the inlet port and restricting the cross-sectional area of the inlet port may cause increased resistance to air flow in the system. This may in turn cause a blower disposed inside an acoustic chamber to have to work harder, which may result in an increase in noise generation from the blower (and motor of the blower). Thus, a balancing and optimization step is often required when trying to create a sufficiently portable PAP device that is both quiet and small in size. Equation 2, illustrates this relationship of increasing modifying the various dimensions of the inlet port and the effect it has on the increased motor work and noise.

$$\text{Resistance of air flow} \propto \frac{\text{Length inlet}}{\text{Area inlet}} \propto \text{Motor Work} \propto \text{Motor Noise} \qquad \text{Equation 2}$$

[0050] Another way of describing this is a smaller inlet diameter increases air flow resistance, which increases motor noise. Some practical steps have been incorporated to also position inlet ports on the PAP device such that they point away from the ears of the user. For example, in several of the figures the inlet port is on the opposite end of the outlet port and adapters, which lead to the tubing that takes air to the mask placed over the user's nose and/or mouth. In several instances most of the noise escaping the system leaves through the inlet port.

[0051] In one preferred embodiment the tube has a diameter of approximately 1.0" and an inlet port has a diameter of ⅜" that leads into a larger volume. In another embodiment the ⅜" in diameter inlet port folds back or bends creating additional length and noise attenuation. However, as mentioned it is important to balance this with any increase in work to motor of the blower, which may result in increased noise generation. Inline blowers may be placed substantially down the length of the tubing leading to the mask.

[0052] Equation 1 can also be used to describe the relationship between length and noise attenuation in an individual tube. In the case of a single, individual tube, S1 is equal to S. Accordingly, the noise output T is reduced when the tube is lengthened (L is increased). This characteristic is important because the length of the intake tube (such as intake tube **115**) can be used to decrease the noise of the PAP device (such as device **100** and other systems and methods described herein).

[0053] Equation 3 describes the relationship between the cut-off frequency of the acoustic filtering and the length and areas of the chamber and tube:

$$f_c = \left(\frac{Sc}{\pi L(S_1 - S)}\right) \quad \text{Equation 3}$$

[0054] In equation 3: f_c is the cutoff frequency; c is the speed of sound; S1 is the area of the expansion chamber; L is the length of the tube or chamber; and S is the area of inlet port. Thus, as L or S1 become larger in value, and/or S becomes smaller, the cutoff frequency becomes lower and every frequency above the cutoff frequency is significantly attenuated. In practical terms, the cutoff frequency f_c can be reduced by increasing the ratio of S1:S, for example by decreasing the area of the inlet and/or increasing the area of the expansion chamber. Additionally, lengthening the expansion chamber (increase L) will also reduce the cutoff frequency.

[0055] The length of an intake tube may range from approximately 1 inch to approximately 8 inches or longer. In accordance with FIG. **3**, equation 1, and equation 2, the length and diameter of the intake tube may be adjusted to affect the overall noise attenuation of the PAP device.

[0056] In order to maximize the length of the intake tube so as to further attenuate the noise of the device, the tube may be angled, have one or more bends or turns in any 3-dimensional direction, or it may have a spiral-like configuration. Similarly, interchamber tubes and outlet tubes may also include bends, turns, angles, spirals, or other configurations.

[0057] FIG. **4**A illustrates a PAP system integrated into a hose connected to a mask being worn by a user. PAP system **400** includes an upstream hose section **404**, expansion chamber **408** with a blower (not depicted), and downstream hose section **408** coupled to a user mask **410**. Mask **410** is coupled to the respiratory pathways **416** of user **414**. A strap **412** is integrated with mask **410** and wraps around the head **418** of user **414**. In certain approaches, upstream portion **404** is removable from expansion chamber **406**. In certain approaches, downstream portion **408** is removable from expansion chamber **406**.

[0058] During operation, PAP device **400** creates positive air pressure to the respiratory pathways **416** through mask **410**. An internal blower positioned within chamber **406** of system **400** pulls air through opening **402**, through section **404**, into chamber **406**, through downstream section **408**, and into mask **410**.

[0059] FIG. **4**B shows a PAP system integrated into a hose with detachable segments. PAP system **440** includes a first upstream hose section **444** with opening **442**, second upstream hose section **448**, chamber **452**, and mask **456**. Expansion chamber **456** includes an internal blower (not depicted). Mask **456** is coupled to the respiratory pathways **416** of user **414**. A strap **412** is integrated with mask **456** and wraps around the head **418** of user **414**.

[0060] In certain approaches, section **444**, section **448**, chamber **452**, and mask **454** are removably coupled. Although two hose sections are depicted, any number of sections may be used. Additionally or alternatively, hose sections may also be used downstream of chamber **452**. System **440** also includes coupler **446** to join first upstream hose section **444** with section upstream hose section **448**, coupler **450** to join second upstream hose section **448** with chamber **452**, and coupler **454** to join chamber **452** with mask **456**. Hose section **444** and hose section **448** may be curved. For example, as depicted, hose section **444** and **448** may be curved to reduce the overall length of system **440** to make it more convenient and easier to move with. In certain embodiments, the hoses sections, and specifically, the intake hole **442**, or directed away from the ears of user **414** to minimize noise heard by the operation of system **440**.

[0061] FIG. **5** depicts a cross-sectional view of PAP system integrated into a hose with a reduced-diameter air inlet tube. PAP system **500** includes an upstream hose section **506** with an intake **502** having a reduced diameter S_2. As described in relation to FIG. **3**, equation 1, and equation 2, a reduced diameter intake can attenuate the noise of operation, thereby making the operation and use of system **500** quieter and more comfortable for the user. Hose section **506** may also include closed portion **504**, which has no airlow. In certain approaches, section **504** contains other parts of system **500**, such as a cables or wire for powering or controlling system **500**. Expansion chamber **508** is effectively hermetically sealed with only the intake **502** and downstream section **524** allowing for fluid to enter and escape.

[0062] Hose section **504** leads to expansion chamber **508** with a blower **512**. In certain approaches, blower **512** is coupled to chamber **508** with mount connects **518**. In addition to connecting blower **512** to expansion chamber **508**, mount connects **518** may reduce or eliminate transfer of vibrations from the blower to other components of device **500**. Expansion chamber **508** may include attenuators **510**. For purposes of the systems and methods described herein, an attenuator may refer to any of a plane, bar, circular, semi-circular, sphere, cone, or other mechanism configured to deflect, absorb, weaken and/or reduce a sound wave. Although two attenuators **510** are depicted in FIG. **5**, any number of attenuators may be used. The attenuators **510** create an extended airflow path **522**, which reduces the noise of the system. The air flows through space **520** and into the inlet **514** of blower **512**, which then blows air through outlet **515** into section **524**.

[0063] Expansion chamber **508** has a first length of L_1 and an area depicted by S_1. The length of hose section **506** and chamber **508** is indicated by L_2. These representative dimension are analogous to those discussed in relation to FIG. **3**.

[0064] In certain approaches, upstream portion **506** is removable from expansion chamber **108**. In certain approaches, downstream portion **118** is removable from expansion chamber **108**.

[0065] FIG. **6** illustrates a PAP system integrated into a hose with an air inlet tube having multiple turns. PAP system **600** includes an upstream hose section **604** with an intake **602** having a reduced diameter. As described in relation to FIG. **3**, equation 1, and equation 2, a reduced diameter intake can attenuate the noise of operation, thereby making the operation and use of system **600** quieter and more comfortable for the user.

[0066] Hose section **604** may include air pathway **606**. As shown, air pathway **606** has multiple turns thereby extending the total air pathway length leading to expansion chamber **610**. The bends and turns in air pathway **606** help prevent noise from escaping the CPAP in a tube system. Pathway **606** may spiral internally inside the upstream portion **604**. Although pathway **606** is depicted as internal within portion **604**, in certain approaches, portion **604** itself can spiral or turn, for example, in a fashion similar to a telephone cord. Hose section **604** leads to expansion chamber **610** with a blower **614**. In certain approaches, blower **614** is coupled to chamber **610** with mount connects **620**. In addition to connecting blower **614** to expansion chamber **610**, mount connects **620** may reduce or eliminate transfer of vibrations from the blower to other components of device **600**.

[0067] Expansion chamber **610** may include attenuators **612**. Although two attenuators **612** are depicted in FIG. **6**, any number of attenuators may be used. The attenuators **612** create an extended airflow path **608**, which reduces the noise of the system. The air flows through space **622** and into the inlet **616** of blower **614**, which then blows air through outlet **618** into section **628**, where it then flows along path **624** for delivery to a patient.

[0068] FIG. **7** is an exterior view of a PAP system integrated into a hose having multiple expansion sections. PAP system **700** includes a first upstream hose section **704** with opening **702**, first expansion chamber **706**, second upstream hose section **710**, expansion chamber **712** where blower **718** is positioned, and downstream hose section **712**. In certain approaches, sections **704**, **710**, **720** and chamber **706** and **712** are removably coupled. In certain approaches, system **700** includes attenuators, such as attenuators **708** positioned in chamber **706** for reducing noise output of system **700**. Although attenuators **708** are depicted in chamber **706**, they may be positioned in any portion of system **700**, including, first upstream hose section **704**, chamber **706**, second upstream hose section **710**, chamber **712**, and downstream section **720**.

[0069] System **700** includes user controls components, such as interface buttons **716** and display **714** for controlling and using apparatus **700**. For example, a user may be able to turn the power on and off, adjust pressure settings, set a timer, run system diagnostic tests, and control or adjust other functions. Buttons **716** and display **714** may be similar to previously described buttons **208** and display **210**.

[0070] The expansion chambers **706** and **712** serve to reduce the noise output of system **700**. As previously described in relation to FIG. **3** and equation 1 and equation 2, the tubing and expansion chambers form noise filters. Expansion chambers **706** and **712** may include anechoic or dissipative materials to further reduce the sound levels. Dissipative elements may include anechoic materials such as foam, rubber, clay, silicon, or any other suitable soft and/or porous materials. Although two expansion chambers are depicted, any appropriate number of chambers may be used.

[0071] During operation, PAP device **700** creates positive air pressure through downstream hose section **720**. System **700** pulls air through opening **702** of first upstream hose section **704**, through section **704**, through chamber **706** through second upstream hose section **704**, and into chamber **712**. Blower **718** then blows the air through downstream section **720**, which can be provided to the patient when the patient places the patient interface (e.g., mask) at his or her airways (e.g., nose or mouth).

[0072] FIG. **8** illustrates a PAP system **800** integrated into a hose with a reduced diameter inlet opening **802**. Inlet opening **802** of upstream hose portion **804** has an opening area S, which is smaller than the general diameter of upstream hose portion **804**. Inlet opening **802** immediately opens or expands into the larger internal diameter of the tube, which leads into expansion chamber **806** with an area **51**. In this example, upstream hose portion **804** acts as a first expansion chamber for purpose of the noise-pass filter equations and expansion chamber **806** acts as a second expansion chamber. Alternatively, upstream hose portion **804** and expansion chamber **806** may effectively be calculated as a single chamber with increased area, where L becomes the length of the inlet **802** to the end of expansion chamber **806** where the positive air pressure is formed exiting from the blower (not depicted) into downstream hose portion **808**. Each interface with a size change provides an opportunity to create a frequency cutoff system or low power transmission region.

[0073] Although the hosing and tubing is generally depicted as round, any appropriate shape may be used. For example, a square cross-sectional shaped hose or tube may be used.

[0074] FIGS. **9**A-B depict PAP systems integrated into a hose with curved or extended flow paths. In FIG. **9**A, PAP system **900** includes an upstream hose section **904** with a reduced diameter intake **902**. As described in relation to FIG. **3**, equation 1, and equation 2, a reduced diameter intake can attenuate the noise of operation, thereby making the operation and use of system **600** quieter and more comfortable for the user.

[0075] Hose section **904** includes air pathway **906**. As shown, air pathway **906** has multiple turns thereby extending the total air pathway length leading to expansion chamber **910**. The bends and turns in air pathway **906** help prevent noise from escaping the CPAP in a tube system. Pathway **906** may spiral internally inside the upstream portion **905**. Hose section **904** leads to expansion chamber **910** with a blower (not depicted). In certain approaches, expansion chamber **910** may include attenuators, similar to attenuators **612**. The air flows through space **912** and is blown into section **914**, where it then can be delivered to a patient.

[0076] FIG. **9**B illustrates an additional embodiment with a curved intake path. PAP system **950** includes an upstream hose section **954** with a reduced diameter intake **952** leading to air pathway **956**. As shown, air pathway **956** has multiple turns thereby extending the total air pathway length leading to expansion chamber **964**. The bends and turns in air pathway **956** help prevent noise from escaping the CPAP in a tube system. Pathway **956** may have sections that split into other portions of section **954**, such as inner portion **958**. For example, pathway **956** may be a curved tube within hose section **954** that has an open end positioned within inner portion **958**. Hose section **904** leads to expansion chamber **964** with a blower (not depicted). For example, hose section **954** has outlets **960** from inner portion **958** into chamber **964**. In certain approaches, expansion chamber **964** may include attenuators, similar to attenuators **612**. The air flows through space **962** and is blown into section **966**, where it can then be delivered to a patient.

[0077] FIGS. **10**A-B depict a PAP system integrated into a hose with detachable segments. System **1000** includes a first hose **1002**, expansion chamber **1006**, and second hose **1010**. First hose **1002** is removably coupled to expansion chamber **1006** with coupler **1004**. Similarly, second hose **1010** is removably coupled to expansion chamber **1006** with coupler **1008**. End **1012** of hose **1002** is coupled to coupler **1004**. Similarly, end **1014** of hose **1010** is coupled to coupler **1008**. Although coupler **1004** and coupler **1008** are shown in FIG. **10**B as attached to chamber **1006**, other configurations are possible. In certain approaches, at least one of coupler **1004** and coupler **1008** are permanently coupled to chamber **1006**. In certain approaches, coupler **1004** is permanently coupled to hose **1002**. In certain approaches coupler **1008** is permanently coupled to hose **1010**. In certain approaches coupler **1004** is a separate component that is removably coupled to both hose **1002** and chamber **1006**. Similarly, in certain approaches coupler **1008** is a separate component that is removably coupled to both hose **1010** and chamber **1006**. Coupler **1004** and coupler **1008** may be a compression fitting, threaded fitting, push-fit fitting, friction fit fitting, or any other appropriate fitting or coupling mechanism.

[0078] In certain approaches, the systems and methods described herein can be adaptable to accommodate different tube lengths to meet patient requirements for noise levels, comfort, and size. For example, a longer intake tube acts as a better noise attenuator than a shorter intake tube.

[0079] FIG. **11**A illustrates a first hose **1100**, with an intake end **1102** and a coupling end **1104**. First hose **1100** has a length of L1. Coupling end **1104** may be coupled to an expansion chamber with a coupler, for example, to expansion chamber **1006** with coupler **1004**. FIG. **11**B illustrates a second hose **1120**, with an intake end **1122** and a coupling end **1124**. Second hose **1120** has a length of L2, which is shorter than L1. Coupling end **1124** may be coupled to an expansion chamber with a coupler, for example, to expansion chamber **1006** with coupler **1004**. FIG. **11**C illustrates a third hose **1140**, with an intake end **1142** and a coupling end **1144**. Third hose has a length of L3, which is shorter than L2. Coupling end **1144** may be coupled to an expansion chamber with a coupler, for example, to expansion chamber **1006** with coupler **1004**.

[0080] These hoses represent, from a general principle, different sound properties when used with the PAP systems and devices described herein. In general, a longer intake tube results in less noise. Other characteristics, such as diameter, can also be modified to adjust the sound. The tubes illustrated in FIGS. **11**A-C provide a range of noise attenuating intakes suitable for the user. In some instances a longer silencer with increased noise attenuation is desired, whereas for another user the option of a short tube with slightly louder noise output is desired for convenience and size purposes over the increase of noise generated from the noise. The option of offering ranges of intake tubes with varying sound attenuation properties is beneficial for users of PAP systems and other ventilation devices.

[0081] In addition to the intake tubes illustrated in FIGS. **11**A-C, various expansion chamber units **1200** may also be linked together and form a flexible length as shown in FIGS. **12**A-B. Expansion chamber unit **1200** has a housing **1202** with an interior expansion chamber **1204** that is proportionally defined by inlet port **1206** its cross-section, and length **1208** and wherein the inlet port **1206** is also proportionally defined by interior expansion chamber **1204**. To help the linking expansion chamber units be more flexible when connected in series a portion of sidewall **1210** may be flexible near and around inlet port **1206**, which helps the **1200** units hinge and flex about the inlet ports. Similar to FIGS. **11**A-C these expansion chamber units may be of varying length. In some versions the expansion chamber units may include noise attenuating deflectors and/or materials such as porous material.

[0082] The systems and methods described herein are not exclusive to CPAP devices, but rather any device requiring flow to be generated and particularly pressurized flow. For example, the systems and methods described herein may also be adapted and applied to other PAP apparatuses, systems, and methods, including, but not limited to, automatic positive airway pressure devices [APAP], variable positive airway pressure devices [VPAP], bi-level positive airway pressure devices [BPAP], and related apparatuses, systems, and methods.

[0083] In certain approaches, the sound levels of the PAP systems and devices described herein range from less than 31 dBA, less than 30 dBA, less than 29 dBA, less than 26 dBA, and even less than 26 dBA.

[0084] In certain approaches, the systems and devices described herein may be less than 3 feet, less than 2 feet and even less than 1 foot in length. Though the system may be longer than 3 feet in length it is generally understood that shorter lengths are preferred.

[0085] It is contemplated that electronic circuitry, power supplies, processors, and other electronic components may be disposed outside of the tube containing the blower. Electrical leads/power connections may connect the external electronic components to the blower and screen contained within or on the CPAP in a hose system. In certain approaches, batteries may be used to power a PAP device to provide improved portability and ease of use.

[0086] In some embodiments the externally connected electrical components may be housed in a separate unit that is attached to a user/person's body via a strap, hook and loop system (such as Velcro®), inserted into pockets, glued, stapled, magnetically connected and so forth. These attachment devices may be used to attach, hang or otherwise dispose the external system to locations on or off the body or clothing of a user that is desired.

[0087] In some embodiments, external electrical components may be in wireless communication. Power sources may also be wireless and operate on principles such as inductive charging or powering.

[0088] The various components of PAP tube/hose provided herein may be physically coupled (e.g., wired) or wireless coupled. For example, a sensor may be wirelessly coupled to control circuitry in the expansion chamber via Bluetooth, Wi-Fi, near field communication, ZigBee, DECT, or other appropriate wireless protocol.

[0089] A processor may receive an input signal from the sensor. The processor may then process the signal according to software instructions stored in memory on a device such as smartphone, computer or remote control device. The processor may electronically store the signal or the processed signal as data in storage. The processor may send a control signal to flow generator/blower **614** to apply or adjust the air delivered by flow generator **614**. In certain approaches, the processor provides a signal to display a value, instruction, or indicator related to the input signal at visual display on the smartphone, computer, remote control or other display either attached or remote from the PAP tube device. Additionally or alternatively, the processor may provide an audio signal, such as data, instructions, alarm, or indicator at audio output. In certain approaches, the processor may send or receive data, signals, indicators, instructions, or other information through remote network interface. For example, a PAP apparatus may communicate with an external electronic device, such as a phone, computer, or server. A remote network interface may be a transmitter, receiver, transceiver, antenna, communication port, or any other appropriate interface for communication with other systems and devices.

[0090] While the principles of the invention have been described herein, it is to be understood by those skilled in the art that this description is made only by way of example and not as a limitation as to the scope of the invention. Other embodiments are contemplated within the scope of the present invention in addition to the exemplary embodiments shown and described herein. Modifications and substitutions by one of ordinary skill in the art are considered to be within the scope of the present invention.

1. A CPAP system comprising:

a tube having at least one expansion section; and

a gas flow generator disposed in a portion of the expansion section, wherein the gas flow generator comprises a motor to drive an impellor whereby a positive air pressure and flow are generated.

2. The system of claim **1**, further comprising a coupling device along a downstream portion of the tube from the expansion section that detachably couples with a mask.

3. The system of claim **1**, further comprising a display screen on a portion of the external surface of the expansion section of the tube.

4. The system of claim **1**, wherein a power supply cord runs along the length of an upstream portion of the tube to the expansion section.

5. The system of claim **1**, wherein the expansion section is an acoustic reduction chamber.

6. The system of claim **1**, further comprising a second expansion section, configured to function as an acoustic reduction chamber.

7. The system of claim **6**, further including noise deflectors placed within the second expansion section.

8. The system of claim **6**, wherein noise reduction attenuating material is placed within the second expansion section.

9. The system of claim **6**, wherein a portion of the electronics driving the motor are placed within the second expansion section.

10. The system of claim **1**, wherein the blower is configured to produce pressures ranging from 2-40 cm H_2O.

11. The system of claim **1**, wherein the tube is comprised of a plurality of detachable sections.

12. The system of claim **1**, further comprising at least one of a circuit board, sensor, or power supply component disposed within the expansion section.

13. The system of claim **1**, wherein electronic circuitry, processors or other electronic components are disposed outside of the tube.

14. The system of claim **12**, wherein an electrical communication and power source connects the external electronic circuitry, processes, or electronic components with the blower.

15. The system of claim **12**, wherein the electric circuitry, processors or other electronic components and/or the power supply and/or battery are attached to the mask or to a user.

16. An elongated CPAP system comprising:

a tube having an inlet port, an outlet, and an expansion section, and wherein the expansion section is positioned between the inlet port and the outlet; and

a gas flow generator positioned in the expansion section, wherein the gas flow generator generates positive gas pressure and flow through the outlet.

17. The system of claim **16**, further comprising at least detachable attenuating noise tube section, configured to reduce the noise attenuated from the system.

18. The attenuating noise tube section of claim **17**, further including an inlet that expands into a larger volume disposed within the attenuating noise tube section.

19. The attenuating noise tube section of claim **17**, further including circuitous flow path within the attenuating noise tube section.

20. The system of claim **16**, further comprising a separated user interface that remotely communicates with the blower.

21. The system of claim **16**, further including at least one sensor for detecting flow rates connected to a flow port that is disposed downstream from the blower.

22. A portable and elongated CPAP system comprising:

an expansion tube section having a blower comprised of a motor and impellor disposed therein;

at least two detachable tube sections for attaching to an inlet and outlet port of the expansion tube section, wherein one of the detachable tube sections has acoustically designed inlet port that forms a low pass frequency filter with an expansion chamber disposed in the expansion tube section.

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