(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 January 2017 (05.01.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/001601 A1

(51) International Patent Classification:
A61M 16/00 (2006.01)

(21) International Application Number:
PCT/EP2016/065384

(22) International Filing Date:
30 June 2016 (30.06.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/186,431 30 June 2015 (30.06.2015) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

(54) Title: BAROMETRIC PRESSURE SENSOR FOR VARIABLE RESISTANCE POSITIVE AIRWAY PRESSURE DEVICE CIRCUIT COMPENSATION

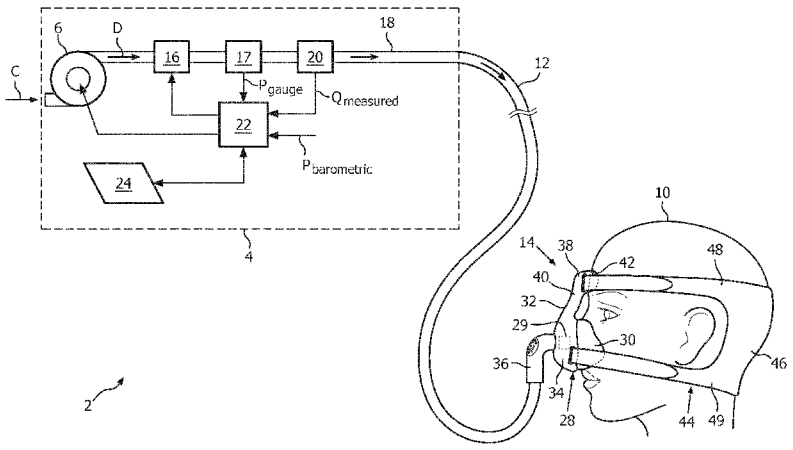

FIG. 1

(57) Abstract: A pressure support system includes a pressure generating system structured to generate a flow of breathing gas, a patient circuit including a patient interface device, the patient circuit being coupled to the pressure generating system and structured to carry the flow of breathing gas, a barometric pressure sensor coupled to the patient circuit within a gas flow path of the patient circuit, wherein the barometric pressure sensor is structured to generate a barometric pressure signal indicative of a barometric pressure within the gas flow path proximate the patient, and a control system. The control system is structured to control an outlet pressure of the pressure generating system based on at least the barometric pressure signal in a manner that compensates for a pressure drop across the patient circuit due to a pneumatic resistance of the patient circuit.

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BAROMETRIC PRESSURE SENSOR FOR VARIABLE RESISTANCE POSITIVE AIRWAY PRESSURE DEVICE CIRCUIT COMPENSATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

[01] The present invention pertains to airway pressure support devices, and, in particular, to a positive airway pressure support device and associated method that employs a barometric pressure sensor in the airflow path to compensate for variable resistance in the patient circuit.

2. Description of the Related Art

[02] Many individuals suffer from disordered breathing during sleep. Sleep apnea is a common example of such sleep disordered breathing suffered by millions of people throughout the world. One type of sleep apnea is obstructive sleep apnea (OSA), which is a condition in which sleep is repeatedly interrupted by an inability to breathe due to an obstruction of the airway; typically the upper airway or pharyngeal area. Obstruction of the airway is generally believed to be due, at least in part, to a general relaxation of the muscles which stabilize the upper airway segment, thereby allowing the tissues to collapse the airway. Another type of sleep apnea syndrome is a central apnea, which is a cessation of respiration due to the absence of respiratory signals from the brain's respiratory center. An apnea condition, whether obstructive, central, or mixed, which is a combination of obstructive and central, is defined as the complete or near cessation of breathing, for example a 90% or greater reduction in peak respiratory air-flow.

[03] Those afflicted with sleep apnea experience sleep fragmentation and complete or nearly complete cessation of ventilation intermittently during sleep with potentially severe degrees of oxyhemoglobin desaturation. These symptoms may be translated clinically into extreme daytime sleepiness, cardiac arrhythmias, pulmonary-artery hypertension, congestive heart failure and/or cognitive dysfunction. Other consequences of sleep apnea include right ventricular dysfunction, carbon dioxide

retention during wakefulness, as well as during sleep, and continuous reduced arterial oxygen tension. Sleep apnea sufferers may be at risk for excessive mortality from these factors as well as by an elevated risk for accidents while driving and/or operating potentially dangerous equipment.

[04] Even if a patient does not suffer from a complete or nearly complete obstruction of the airway, it is also known that adverse effects, such as arousals from sleep, can occur where there is only a partial obstruction of the airway. Partial obstruction of the airway typically results in shallow breathing referred to as a hypopnea. A hypopnea is typically defined as a 50% or greater reduction in the peak respiratory air-flow. Other types of sleep disordered breathing include, without limitation, upper airway resistance syndrome (UARS) and vibration of the airway, such as vibration of the pharyngeal wall, commonly referred to as snoring.

[05] It is well known to treat sleep disordered breathing by applying a continuous positive air pressure (CPAP) to the patient's airway. This positive pressure effectively "splints" the airway, thereby maintaining an open passage to the lungs. It is also known to provide a positive pressure therapy in which the pressure of gas delivered to the patient varies with the patient's breathing cycle, or varies with the patient's breathing effort, to increase the comfort to the patient. This pressure support technique is referred to as bi-level pressure support, in which the inspiratory positive airway pressure (IPAP) delivered to the patient is higher than the expiratory positive airway pressure (EPAP). It is further known to provide a positive pressure therapy in which the pressure is automatically adjusted based on the detected conditions of the patient, such as whether the patient is experiencing an apnea and/or hypopnea. This pressure support technique is referred to as an auto-titration type of pressure support, because the pressure support device seeks to provide a pressure to the patient that is only as high as necessary to treat the disordered breathing.

[06] Pressure support therapies as just described involve the placement of a patient interface device including a mask component having a soft, flexible sealing cushion on the face of the patient. The mask component may be, without limitation, a

nasal mask that covers the patient's nose, a nasal/oral mask that covers the patient's nose and mouth, or a full face mask that covers the patient's face. Such patient interface devices may also employ other patient contacting components, such as forehead supports, cheek pads and chin pads. The patient interface device is typically secured to the patient's head by a headgear component. The patient interface device is connected to a gas delivery tube or conduit to form what is commonly referred to as a patient circuit. The patient circuit interfaces the pressure support device with the airway of the patient, so that a flow of breathing gas can be delivered from the pressure/flow generating device to the airway of the patient.

[07] Patient circuits as just described have pneumatic resistance (which is a function of flow) that needs to be compensated for with additional pressure by the pressure support device. In applications desiring a high degree of pressure delivery accuracy and/or with high or variable patient circuit resistance, monitoring pressure at the interface to the patient (i.e., proximal to the patient) is necessary so that the proper amount of additional compensation pressure can be determined and provided. For this purpose, it is known to the art to measure gauge pressure at the patient using a gauge pressure sensor located either at the patient (i.e., at the patient interface device) or inside the pressure support device (in which case gas is communicated from the patient interface device to the gauge pressure sensor through a pneumatic pick off tube).

[08] Gauge pressure sensors are expensive and typically very large. In addition, power consumption is typically relatively high with gauge pressure sensors.

SUMMARY OF THE INVENTION

[09] Accordingly, it is an object of the present invention to provide a pressure support system that overcomes the shortcomings of conventional pressure support systems. This object is achieved according to one embodiment of the present invention by providing a pressure support system for delivering a flow of breathing gas to an airway of a patient that includes a pressure generating system structured to generate the flow of breathing gas, a patient circuit including a patient interface device, the patient circuit

being coupled to the pressure generating system and structured to carry the flow of breathing gas, a barometric pressure sensor coupled to the patient circuit within a gas flow path of the patient circuit, wherein the barometric pressure sensor is structured to generate a barometric pressure signal indicative of a barometric pressure within the gas flow path proximate the patient, and a control system. The control system is structured to control an outlet pressure of the pressure generating system based on at least the barometric pressure signal in a manner that compensates for a pressure drop across the patient circuit due to a pneumatic resistance of the patient circuit.

[10] It is yet another object of the present invention to provide a method of controlling a pressure support system that does not suffer from the disadvantages associated with conventional control techniques. This object is achieved by providing a method that includes determining a barometric pressure within a gas flow path of a patient circuit proximate the patient, and controlling an outlet pressure of a pressure generating system based on at least the barometric pressure in a manner that compensates for a pressure drop across the patient circuit due to a pneumatic resistance of the patient circuit.

[11] These and other objects, features, and characteristics of the present invention, as well as the methods of operation and functions of the related elements of structure and the combination of parts and economies of manufacture, will become more apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of this specification, wherein like reference numerals designate corresponding parts in the various figures. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[12] FIG. 1 is a schematic diagram showing an airway pressure support system according to one particular, non-limiting exemplary embodiment;

[13] FIG. 2 is a flowchart showing a method that may be implemented in the pressure support system of FIG. 1 for compensating for the pressure drop across the

patient circuit due to the pneumatic resistance thereof according to an exemplary embodiment of the disclosed concept; and

[14] FIG. 3 is a schematic diagram showing an airway pressure support system according to an alternative, non-limiting exemplary embodiment.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[15] As used herein, the singular form of "a", "an", and "the" include plural references unless the context clearly dictates otherwise. As used herein, the statement that two or more parts or components are "coupled" shall mean that the parts are joined or operate together either directly or indirectly, i.e., through one or more intermediate parts or components, so long as a link occurs. As used herein, "directly coupled" means that two elements are directly in contact with each other. As used herein, "fixedly coupled" or "fixed" means that two components are coupled so as to move as one while maintaining a constant orientation relative to each other.

[16] As used herein, the word "unitary" means a component is created as a single piece or unit. That is, a component that includes pieces that are created separately and then coupled together as a unit is not a "unitary" component or body. As employed herein, the statement that two or more parts or components "engage" one another shall mean that the parts exert a force against one another either directly or through one or more intermediate parts or components. As employed herein, the term "number" shall mean one or an integer greater than one (i.e., a plurality).

[17] Directional phrases used herein, such as, for example and without limitation, top, bottom, left, right, upper, lower, front, back, and derivatives thereof, relate to the orientation of the elements shown in the drawings and are not limiting upon the claims unless expressly recited therein.

[18] FIG. 1 is a schematic diagram showing an airway pressure support system 2 according to one particular, non-limiting exemplary embodiment. As described in detail herein, pressure support system 2 uses a barometric pressure sensor instead of a gauge pressure sensor to determine the pressure drop over a variable resistance patient circuit,

and thus the amount of pressure compensation that is required to overcome the pressure drop due to the variable resistance.

[19] Referring to FIG. 1, airway pressure support system 2 includes a pressure generating device base unit 4 which houses a gas flow generator 6, such as a blower used in a conventional CPAP or bi-level pressure support device. Gas flow generator 6 receives breathing gas, generally indicated by arrow C, from the ambient atmosphere and generates a flow of breathing gas therefrom for delivery to an airway of a patient 10 at relatively higher and lower pressures, i.e., generally equal to or above ambient atmospheric pressure. In the exemplary embodiment, gas flow generator 6 is capable of providing a flow of breathing gas ranging in pressure from 3-30 cmH2O. The pressurized flow of breathing gas from gas flow generator 6, generally indicated by arrow D, is delivered via a delivery conduit 12 to a patient interface device 14 of any known construction, which is typically worn by or otherwise attached to patient 10 to communicate the flow of breathing gas to the airway of patient 10. Delivery conduit 12 and patient interface device 14 are typically collectively referred to as a patient circuit.

[20] Pressure support system 2 shown in FIG. 1 is what is known as a single-limb system, meaning that the patient circuit includes only delivery conduit 12 connecting patient 10 to pressure support system 2. As such, an exhaust vent is provided in patient interface device 14 for venting exhaled gases from the system. It should be noted that the exhaust vent can be provided at other locations in addition to or instead of in patient interface device 14, such as in delivery conduit 12. It should also be understood that the exhaust vent can have a wide variety of configurations depending on the desired manner in which gas is to be vented from pressure support system 2.

[21] The present invention also contemplates that pressure support system 2 can be a two-limb system, having a delivery conduit and an exhaust conduit connected to patient 10. In a two-limb system (also referred to as a dual-limb system), the exhaust conduit carries exhaust gas from patient 10 and includes an exhaust valve at the end distal from patient 10. The exhaust valve in such an embodiment is typically actively

controlled to maintain a desired level or pressure in the system, which is commonly known as positive end expiratory pressure (PEEP).

[22] In the illustrated embodiment, pressure support system 2 includes a pressure controller in the form of a valve 16 provided in an internal delivery conduit 18 provided in pressure generating device base unit 4 of pressure support system 2. Valve 16 controls the pressure of the flow of breathing gas from gas flow generator 6 that is delivered to patient 10. For present purposes, gas flow generator 6 and valve 16 are collectively referred to as a pressure generating system because they act in concert to control the pressure and/or flow of gas delivered to patient 10. However, it should be apparent that other techniques for controlling the pressure of the gas delivered to patient 10, such as varying the blower speed of gas flow generator 6, either alone or in combination with a pressure control valve, are contemplated by the present invention. Thus, valve 16 is optional depending on the technique used to control the pressure of the flow of breathing gas delivered to patient 10. If valve 16 is eliminated, the pressure generating system corresponds to gas flow generator 6 alone, and the pressure of gas in the patient circuit is controlled, for example, by controlling the motor speed of gas flow generator 6.

[23] Pressure support system 2 further includes a gauge pressure sensor 17 that measures the gauge pressure of the flow of breathing gas being output by the pressure generating system, and a flow sensor 20 that measures the flow (i.e., flow rate) of the breathing gas within delivery conduit 18 and delivery conduit 12. In the particular embodiment shown in FIG. 1, pressure sensor 17 and flow sensor 20 are interposed in line with delivery conduit 18, most preferably downstream of valve 16. Gauge pressure sensor 17 generates a pressure signal, P_{GAUGE}, that is provided to a controller 22 (described herein). Flow sensor 20 generates a flow signal, $Q_{MEASURED}$, that is provided to controller 22 and is used by controller 22 to determine the flow of gas at patient 10 ($Q_{PATIENT}$). In an alternative implementation, the locations of gauge pressure sensor 17 and flow sensor 20 are reversed from how they are shown in FIG. 1, since flow sensors

innately have pressure drop over them, and therefore it may be advantageous to measure pressure at the very outlet of pressure generating device base unit 4.

[24] Techniques for calculating $Q_{PATIENT}$ based on $Q_{MEASURED}$ are well known, and take into consideration the pressure drop of the patient circuit, known leaks from the system, i.e., the intentional exhausting of gas from the circuit as described herein, and unknown (unintentional) leaks from the system, such as leaks at the mask/patient interface. The present invention contemplates using any known or hereafter developed technique for calculating total leak flow Q_{LEAK}, and using this determination in calculating $Q_{PATIENT}$ based on $Q_{MEASURED}$ (and for other purposes as described elsewhere herein). Examples of such techniques are taught by U.S. Patent Nos. 5,148,802; 5,313,937; 5,433,193; 5,632,269; 5,803,065; 6,029,664; 6,539,940; 6,626,175; and 7,011,091, the contents of each of which are incorporated by reference into the present invention.

[25] Of course, other techniques for measuring and/or estimating the respiratory flow of patient 10 are contemplated by the present invention, such as, without limitation, measuring the flow directly at patient 10 or at other locations along delivery conduit 12, measuring patient flow based on the operation of gas flow generator 6, measuring patient flow using a flow sensor upstream of valve 16, and estimating flow based a parameter such as motor current.

[26] Also, pressure at the outlet of pressure generating device base unit 4 can be estimated using a number of methods known to one skilled in the art, including using blower speed, blower speed and barometric pressure, or blower speed, barometric pressure, and outlet flow.

[27] Controller 22 includes a processing portion which may be, for example, a microprocessor, a microcontroller or some other suitable processing device, and a memory portion that may be internal to the processing portion or operatively coupled to the processing portion and that provides a storage medium for data and software executable by the processing portion for controlling the operation of pressure support system 2, including compensating for the pressure drop over the patient circuit based on a

barometric pressure measured within the air flow path as described in greater detail herein.

[28] An input/output device 24 is provided for setting various parameters used by airway pressure support system 2, as well as for displaying and outputting information and data to a user, such as a clinician or caregiver.

[29] In the exemplary embodiment, patient interface device 14 includes a patient sealing assembly 28, which in the illustrated embodiment is a nasal mask. However, other types of patient sealing assemblies, such as, without limitation, a nasal/oral mask, a nasal cushion, nasal pillows, a cradle cushion or a full face mask, which facilitate the delivery of the flow of breathing gas to the airway of a patient may be substituted for patient sealing assembly 28 while remaining within the scope of the present invention. In the non-limiting exemplary embodiment, patient sealing assembly 28 includes a cushion 30 coupled to a frame member 32. In the illustrated embodiment, cushion 30 is defined from a unitary piece of soft, flexible, cushiony, elastomeric material, such as, without limitation, silicone, an appropriately soft thermoplastic elastomer, a closed cell foam, or any combination of such materials. Also in the illustrated embodiment, frame member 32 is made of a rigid or semi-rigid material, such as, without limitation, an injection molded thermoplastic or silicone, and includes a faceplate portion 34 to which cushion 30 is fluidly attached. A fluid coupling conduit 36 having an exhaust vent is coupled to an opening in faceplate portion 34 to allow the flow of breathing gas from pressure generating device base unit 4 to be communicated to an interior space defined by cushion 30, and then to the airway of a patient. Other options patient sealing assembly 28 are available within the scope of the disclosed concept, such as an implementation wherein the mask does not have a solid frame at all, but instead consists of flexible silicone tubing through which the air is routed from a connection on the crown of the head down two tubes on the side of the face toward the nose.

[30] Frame member 32 also includes a forehead support member 38 that is coupled to the faceplate portion 34 by a connecting member 40. A forehead cushion 42 is

coupled to the rear of forehead support member 38. In the exemplary embodiment, forehead cushion 42 is made of a material that is similar to the material of cushion 30.

[31] Patient interface device 14 also includes a headgear component 44 for securing patient interface device 14 to the head of patient 10. Headgear component 44 includes a back member 46, upper strap members 48 and lower strap members 49. In the exemplary embodiment, upper strap members 48 and lower strap members 49 each include a hook and loop fastening system, such as VELCRO®, provided on the end thereof to allow headgear component 44 to be secured in a known manner. It will be understood that the described hook and loop fastening arrangement is meant to be exemplary only, and that other selectively adjustable fastening arrangements are also possible within the scope of the present invention.

[32] Pressure support system 2 further includes a barometric pressure sensor 29 that is provided in the airflow path of pressure support system 2 proximate to patient 10. As seen in FIG. 1, in the exemplary embodiment, barometric pressure sensor 29 is shown as being provided inside faceplate portion 34 of patient interface device 14, although it will be understood that this is meant to be exemplary only and that barometric pressure sensor 29 may be positioned in other portions of the airflow path such as within conduit 12 or within other parts of patient interface device 14, such as cushion 30 or fluid coupling conduit 36. Barometric pressure sensor 29 may be any type of known or hereafter developed sensor device suitable for measuring the barometric pressure within the airflow path of pressure support system 2. Barometric pressure sensor 29 is coupled to controller 22 by a suitable wired and/or wireless connection to enable a signal, $P_{BAROMETIC}$, generated by barometric pressure sensor 29 to be communicated to controller 22.

[33] In the illustrated, non-limiting exemplary embodiment of the present invention, airway pressure support system 2 essentially functions as a CPAP pressure support system, and, therefore, includes all of the capabilities necessary in such systems in order to provide appropriate CPAP pressure levels to patient 10. This includes receiving the necessary parameters, via input commands, signals, instructions or other

information, for providing appropriate CPAP pressure, such as maximum and minimum CPAP pressure settings. It should be understood that this is meant to be exemplary only, and that other pressure support methodologies, including, but not limited to, BiPAP AutoSV, AVAPS, Auto CPAP, and BiPAP Auto, are within the scope of the present invention.

[34] As discussed briefly elsewhere herein, the disclosed concept provides a methodology for controlling the pressure generating system (gas flow generator 6 and valve 16 in the illustrated example) of pressure support system 2 in order to compensate for the pneumatic resistance that is present in the patient circuit comprising delivery conduit 12 and patient interface device 14 at any particular time that, rather than being based on a gauge pressure that is measured proximate to patient 10, is based on a barometric pressure that is measured proximate to patient 10. Furthermore, the disclosed concept may be used to estimate either the entire pressure drop of the patient circuit or a portion thereof (i.e., the pressure drop of the patient circuit can contain any of a number of components with known pressure drops and/or known leaks such that a combination of one or more estimated pressure drops (estimated as described herein) and one or more known pressure drops may be employed to determine pressure compensation). For example, in the case of a patient circuit including a flexible headgear portion having a variable resistance tubing positioned after a leak port of the patient circuit, the pressure drop of the variable resistance tubing may be estimated using an estimated/known pressure at the leak port, an estimated patient flow, and the measured barometric pressure.

[35] In particular, according to the disclosed concept, the outlet pressure generated by gas flow generator 6 and output from pressure generating device base unit 4 (Poutlet) is controlled based upon the following equation:

$$Poutlet = Pptset + Pdropcalc,$$

wherein Pptset is the desired patient pressure set point (i.e., desired pressure to be delivered to the airway of patient 10 through patient interface device 14) stored by pressure generating device 4, and wherein Pdropcalc is a feedforward term calculated based upon 2 coefficients, A and B (determined as described below) and the total flow,

$Q_{MEASURED}$, currently being generated by the pressure generating system. According to an aspect of the disclosed concept, Pdropcalc is determined according to the following equation:

$$Pdropcalc = A*Q_{MEASURED}^2 + B*Q_{MEASURED}.$$

[36] In addition, according to a further aspect of the disclosed concept, the coefficients A and B required for the above calculation may be determined by collecting data and performing modeling of the pressure drop over the patient circuit using certain known equations as described below. In particular, the following two equations are known:

$$Pdiff = A*Q_{MEASURED}^2 + B*Q_{MEASURED} + C,$$

$$Pdrop = Pdiff + C,$$

[37] wherein Pdiff is the difference between the gauge pressure of the gas being output by the pressure generating system as measured by gauge pressure sensor 17 and represented by the signal P_{GAUGE} and the barometric pressure in the airflow path at patient interface device 14 as measured by barometric pressure sensor 29 and represented by the signal $P_{BAROMETRIC}$, and wherein Pdrop is the pressure drop over the patient circuit comprising delivery conduit 12 and patient interface device 14. The coefficients A, B and C may derived by collecting and/or determining data comprising the values of $Q_{MEASURED}$, P_{GAUGE}, $P_{BAROMETRIC}$, and Pdiff (P_{GAUGE} - $P_{BAROMETRIC}$) over time, generating a Pdiff-$Q_{MEASURED}$ curve based on the data, and deriving the constants A, B and C from the curve fit (e.g., without limitation, least squares estimator (LSE) curve fit) of the Pdiff-$Q_{MEASURED}$ curve.

[38] FIG. 2 is a flowchart showing a method that may be implemented in pressure support system 2 for compensating for the pressure drop across the patient circuit due to the pneumatic resistance thereof according to an exemplary embodiment of the disclosed concept. In the exemplary embodiment, the method is implemented in a number of routines stored in the memory of controller 22 and executable by the processor of controller 22. The method of FIG. 2 begins at step 50, wherein current values for

$Q_{MEASURED}$, P_{GAUGE}, $P_{BAROMETRIC}$, and Pdiff are obtained as described herein and stored. Then, at step 52, a determination is made as to whether the number of breaths since the A and B coefficients has last been updated is equal to a predetermined update threshold. In essence, step 52 ensures that the values of the A and B coefficients get updated periodically, e.g. every breath or every several breaths. If the answer at step 52 is yes, then, at step 54, the A and B coefficients are updated as described elsewhere herein using the collected and stored data. If, however, the answer at step 52 is no, or following the performance of step 54 if appropriate, the method proceeds to step 56. At step 56, the current value for Pdropcalc is determined as described herein (Pdropcalc = $A*Q_{MEASURED}^2 + BQ_{MEASURED)}$ using the updated A and B coefficients and the current $Q_{MEASURED}$ value. Then, at step 58, the value for Poutlet is determined using the stored Pptset and the determined Pdropcalc as described herein (Poutlet = Pptset + Pdropcalc). Also at step 58, once the current value for Poutlet is determined as just described, the pressure generating system of pressure generating device 4 is controlled to output a pressure equal to Poutlet. As will be appreciated, outputting a pressure equal to Poutlet will compensate for the current pneumatic resistance of the patient circuit so as to cause a pressure equal to Pptset to be actually delivered to patient 10.

[39] In alternative embodiments, the outlet pressure of the pressure generating system (Poutlet) may be controlled using the pressure drop equation above using only the square term (i.e., B=0). Furthermore, other governing equations may also be used to determine the pressure drop (e.g., an equation that uses $Q_{MEASURED}$ raised to a different power other than 2).

[40] In an alternative embodiment, shown in FIG. 3, the pressure generating device 4 may have a second barometric pressure sensor 29′ (in addition to first barometric pressure sensor 29 and gauge pressure sensor 17) for generating a signal $P_{BAROMETRIC'}$ indicative of the barometric pressure within the gas flow within pressure generating device base unit 4. In such a case, the gauge pressure being delivered to the patient can be determined by the difference of the two barometric pressure sensor readings, wherein the

zero offset between the two barometric pressure sensors can be estimated in the same fashion as described above.

[41] Thus, the disclosed concept provides a system and method wherein the pressure drop in a patient circuit caused by the pneumatic resistance of the patient circuit may be compensated for using a smaller and less expensive barometric pressure sensor as compared to a larger, more expensive gauge pressure sensor proximate the patient.

[42] In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" or "including" does not exclude the presence of elements or steps other than those listed in a claim. In a device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. In any device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain elements are recited in mutually different dependent claims does not indicate that these elements cannot be used in combination.

[43] Although the invention has been described in detail for the purpose of illustration based on what is currently considered to be the most practical and preferred embodiments, it is to be understood that such detail is solely for that purpose and that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover modifications and equivalent arrangements that are within the spirit and scope of the appended claims. For example, it is to be understood that the present invention contemplates that, to the extent possible, one or more features of any embodiment can be combined with one or more features of any other embodiment.

What is Claimed is:

1. A pressure support system (2) for delivering a flow of breathing gas to an airway of a patient (10), comprising:

a pressure generating system (6, 16) structured to generate the flow of breathing gas;

a patient circuit including a patient interface device (14), the patient circuit being coupled to the pressure generating system and structured to carry the flow of breathing gas;

a barometric pressure sensor (29) coupled to the patient circuit within a gas flow path of the patient circuit, wherein the barometric pressure sensor is structured to generate a barometric pressure signal indicative of a barometric pressure within the gas flow path proximate the patient; and

a control system (22) structured to control an outlet pressure generated by the pressure generating system based on at least the barometric pressure signal in a manner that compensates for a pressure drop across the patient circuit due to a pneumatic resistance of the patient circuit.

2. The pressure support system according to claim 1, wherein the pressure generating system is provided within a pressure generating base unit (4), wherein the pressure generating base unit includes a flow sensor (20) structured to generate a flow signal ($Q_{MEASURED}$) indicative of a total flow rate being generated by the pressure generating system and a base unit pressure sensor (17) structured to generate a base unit pressure signal, and wherein the control system is structured to control the outlet pressure based on the barometric pressure signal, the flow signal and the base unit pressure signal in a manner that compensates for the pressure drop across the patient circuit due to the pneumatic resistance of the patient circuit.

3. The pressure support system according to claim 2, wherein the base unit pressure sensor is a gauge pressure sensor and wherein the base unit pressure signal is a gauge pressure signal indicative of a gauge pressure being generated by the pressure generating system.

4. The pressure support system according to claim 3, wherein the flow signal is $Q_{MEASURED}$, the barometric pressure signal is $P_{BAROMETRIC}$, and the gauge pressure signal is P_{GAUGE}, wherein the control system is structured to determine the outlet pressure (Poutlet) as a function of $Q_{MEASURED}$, $P_{BAROMETRIC}$, and P_{GAUGE}.

5. The pressure support system according to claim 4, wherein the control system is structured to determine the outlet pressure (Poutlet) according to the following equation: Poutlet = Pptset + Pdropcalc, wherein Pptset is a desired patient pressure set point, wherein Pdropcalc = $A*Q_{MEASURED}^2 + B*Q_{MEASURED}$, and wherein A and B are coefficients derived using a plurality of collected and stored values of $Q_{MEASURED}$, $P_{BAROMETRIC}$, and P_{GAUGE}.

6. The pressure support system according to claim 5, wherein Pdiff is a difference between P_{GAUGE} and $P_{BAROMETRIC}$, wherein A and B are derived by generating a Pdff-$Q_{MEASURED}$ curve using the collected and stored values of $Q_{MEASURED}$, $P_{BAROMETRIC}$, and P_{GAUGE} and deriving A and B from a curve fit of the Pdff-$Q_{MEASURED}$ curve.

7. The pressure support system according to claim 6, wherein the curve fit is a least squares estimator curve fit.

8. The pressure support system according to claim 6, wherein the controller is structured to update A and B periodically.

9. The pressure support system according to claim 1, wherein the barometric pressure sensor is directly connected to the patient interface device.

10. The pressure support system according to claim 1, wherein the pressure generating system is provided within a pressure generating base unit (4), the pressure support system further comprising a second barometric pressure sensor (29') provided within the pressure generating base unit and within a gas flow path of the pressure generating base unit, wherein the second barometric pressure sensor is structured to generate a second barometric pressure signal indicative of a barometric pressure within the pressure generating base unit, and wherein the control system is structured to control the outlet pressure generated by the pressure generating system based on at least the barometric pressure signal and the second barometric pressure signal in a manner that compensates for a pressure drop across the patient circuit due to a pneumatic resistance of the patient circuit

11. A method of controlling a pressure support system (2) for delivering a flow of breathing gas to an airway of a patient (10), the pressure support system including a pressure generating system (6, 16) structured to generate the flow of breathing gas and a patient circuit including a patient interface device (14) structured to deliver the flow of breathing gas to an airway of the patient, the method comprising:

determining a barometric pressure within a gas flow path of the patient circuit proximate the patient; and

a controlling an outlet pressure of the pressure generating system based on at least the barometric pressure in a manner that compensates for a pressure drop across the patient circuit due to a pneumatic resistance of the patient circuit.

12. The method according to claim 11, wherein the determining a barometric pressure comprises generating a barometric pressure signal indicative of the barometric pressure using a barometric pressure sensor provided within the gas flow path.

13. The method according to claim 12, wherein the pressure generating system is provided within a pressure generating base unit (4), wherein the pressure generating base unit includes a flow sensor (20), wherein the method includes generating a flow signal ($Q_{MEASURED}$) indicative of a total flow rate being generated by the pressure generating system, wherein the pressure generating base unit includes base unit pressure sensor (17), wherein the method includes generating a base unit pressure signal, and wherein the controlling comprises controlling the outlet pressure based on the barometric pressure signal, the flow signal and the base unit pressure signal in a manner that compensates for the pressure drop across the patient circuit due to the pneumatic resistance of the patient circuit.

14. The method according to claim 12, wherein the base unit pressure sensor is a gauge pressure sensor and wherein the base unit pressure signal is a gauge pressure signal indicative of a gauge pressure being generated by the pressure generating system.

15. The method according to claim 14, wherein the flow signal is $Q_{MEASURED}$, the barometric pressure signal is $P_{BAROMETRIC}$, and the gauge pressure signal is P_{GAUGE}, wherein the controlling includes determining the outlet pressure (Poutlet) as a function of $Q_{MEASURED}$, $P_{BAROMETRIC}$, and P_{GAUGE}.

16. The method according to claim 15, wherein the controlling includes determining the outlet pressure (Poutlet) according to the following equation: Poutlet = Pptset + Pdropcalc, wherein Pptset is a desired patient pressure set point, wherein Pdropcalc = $A*Q_{MEASURED}2 + B*Q_{MEASURED}$, and wherein A and B are coefficients derived using a plurality of collected and stored values of $Q_{MEASURED}$, $P_{BAROMETRIC}$, and P_{GAUGE}.

17. The method according to claim 15, wherein Pdiff is a difference between P_{GAUGE} and $P_{BAROMETRIC}$, wherein the method includes deriving A and B by generating a Pdff-$Q_{MEASURED}$ curve using the collected and stored values of $Q_{MEASURED}$, $P_{BAROMETRIC}$, and P_{GAUGE} and deriving A and B from a curve fit of the Pdff-$Q_{MEASURED}$ curve.

18. The method according to claim 17, wherein the curve fit is a least squares estimator curve fit.

19. The method according to claim 16, wherein the method includes updating A and B periodically.

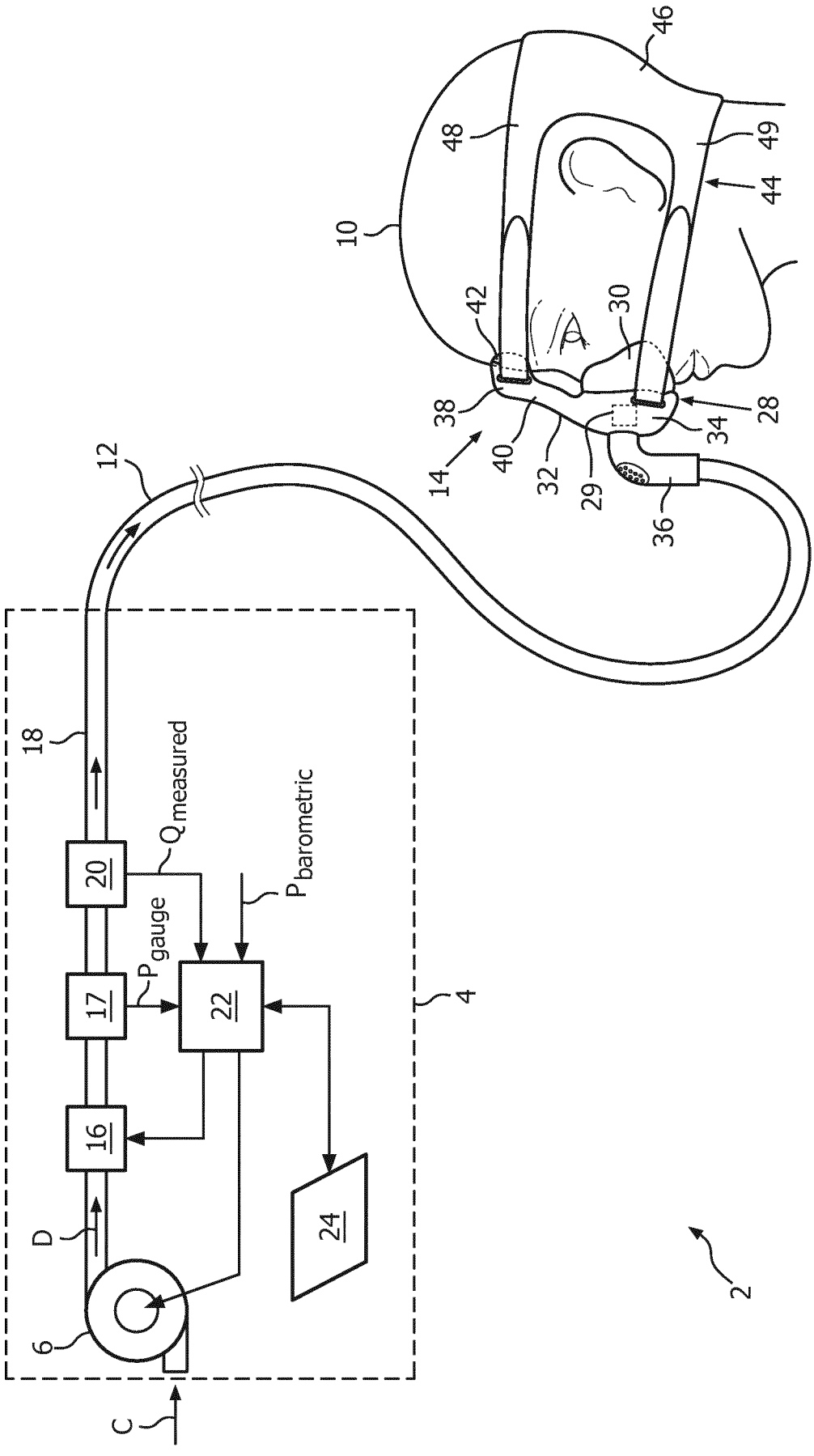

46
48
49
44
10
42
30
38
28
34
40
32
29
14
36
12
18
20
$Q_{measured}$
$P_{barometric}$
P_{gauge}
17
22
4
16
24
D
6
C
2

FIG. 1

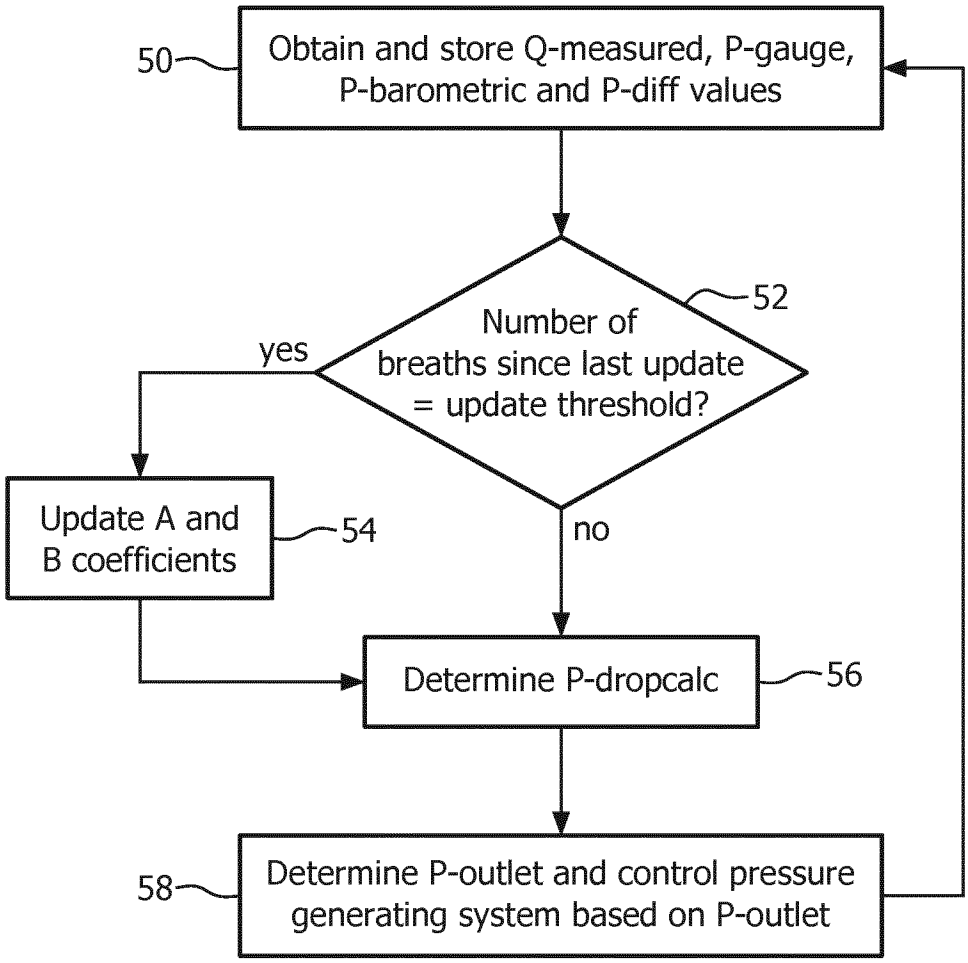
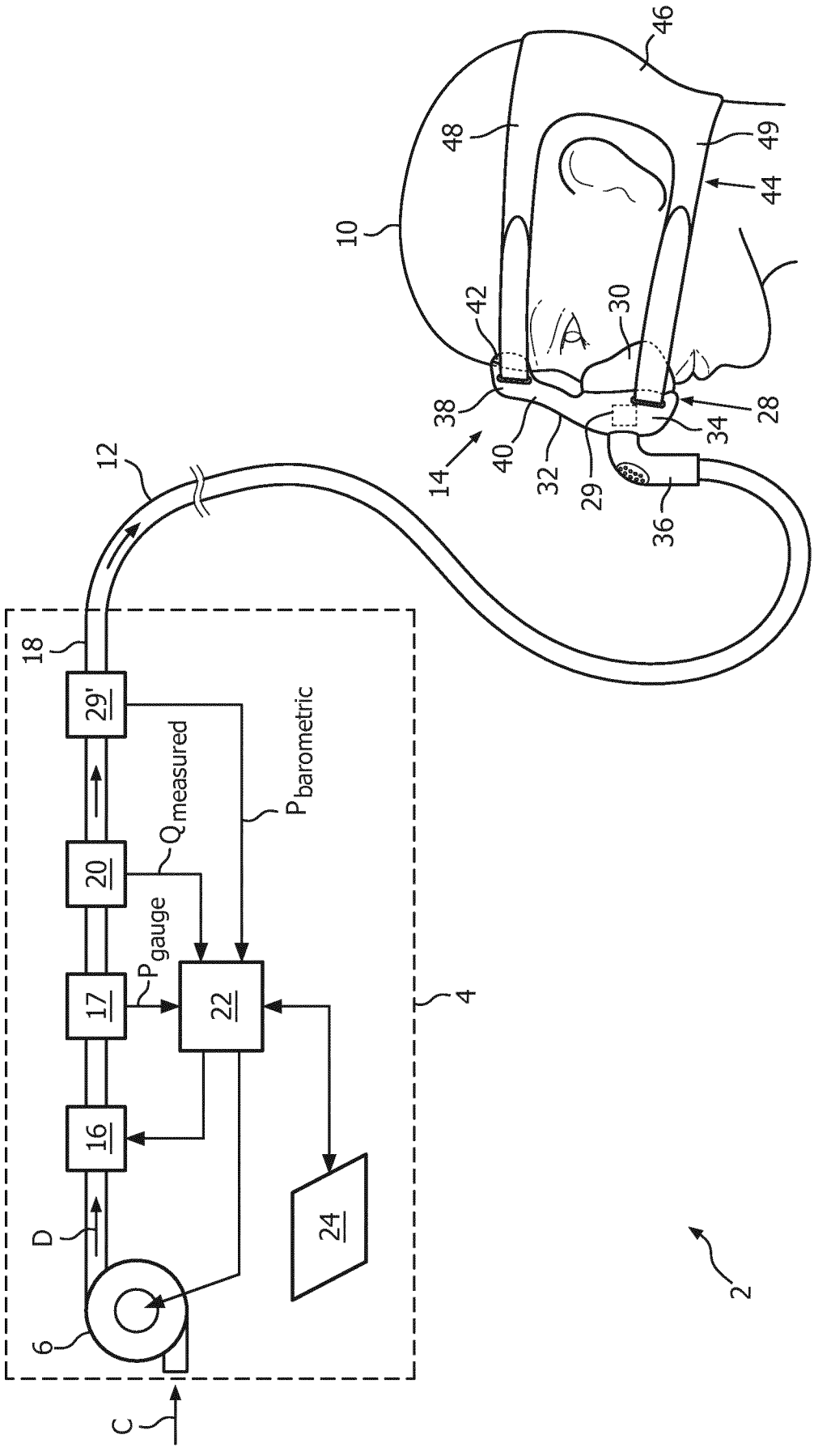

50
Obtain and store Q-measured, P-gauge, P-barometric and P-diff values
52
Number of breaths since last update = update threshold?
yes
no
Update A and B coefficients
54
Determine P-dropcalc
56
58
Determine P-outlet and control pressure generating system based on P-outlet

FIG. 2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42
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38
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34
40
32
29
14
36
12
18
29'
20
17
16
22
24
4
D
6
C
2
$P_{barometric}$
$Q_{measured}$
P_{gauge}

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/065384

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61M16/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61M

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/056006 A1 (SHELLY BENJAMIN IRWIN [US] ET AL) 7 March 2013 (2013-03-07) abstract; figure 1 paragraphs [0019], [0022], [0029], [0031] - [0034], [0041] - [0044]	1-10
X	WO 2014/057457 A2 (KONINKL PHILIPS NV [NL]) 17 April 2014 (2014-04-17) abstract; figure 1 paragraphs [0023] - [0028], [0043] - [0060]	1-10
X	US 2009/241952 A1 (NICOLAZZI PASCAL [FR] ET AL) 1 October 2009 (2009-10-01) figure 1 paragraphs [0025] - [0026], [0053] - [0060], [0069]	1-10

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 September 2016	11/10/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Moraru, Liviu

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/065384

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/227738 A1 (VIRR ALEXANDER [AU] ET AL) 13 September 2012 (2012-09-13) abstract; figure 6 paragraphs [0048] - [0051] -----	1-10
X	US 2010/078023 A1 (PERINE PHILIPPE [FR] ET AL) 1 April 2010 (2010-04-01) abstract; figure 1 paragraphs [0019], [0030], [0031], [0036] - [0040] -----	1-10
A	US 5 881 717 A (ISAZA FERNANDO J [US]) 16 March 1999 (1999-03-16) the whole document -----	1-10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2016/065384

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 11-19
because they relate to subject matter not required to be searched by this Authority, namely:

see FURTHER INFORMATION sheet PCT/ISA/210

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

Continuation of Box II.1

Claims Nos.: 11-19

Methods of providing ventilation to a subject as defined in claims 11-19 of the present application are methods for treatment of human or animal body by therapy. Indeed these methods are meant to provide breathing gas to a patient (see paragraph 34). Thus, claims 11-19 relate to subject-matter considered by this Authority to be covered by the provisions of Rules 39.1(iv) and 67.1(iv) PCT, and no international search report has been established with respect to the subject-matter of these claims (Article 17(2)(a)(i)PCT). Consequently, no opinion will be formulated with respect to novelty, inventive step and industrial applicability of the subject-matter of these claims (Article 34(4)(a)(i)PCT).

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2016/065384

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