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(71) Applicant (for all designated States except US): **NELL-COR PURITAN BENNETT LLC** [US/US]; 6135 Gunbarrel Avenue, Boulder, Colorado 80301 (US).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **GRABOI, Daniel, G.** [US/US]; 1314 Desert Rose Way, Encinitas, California 92024 (US).

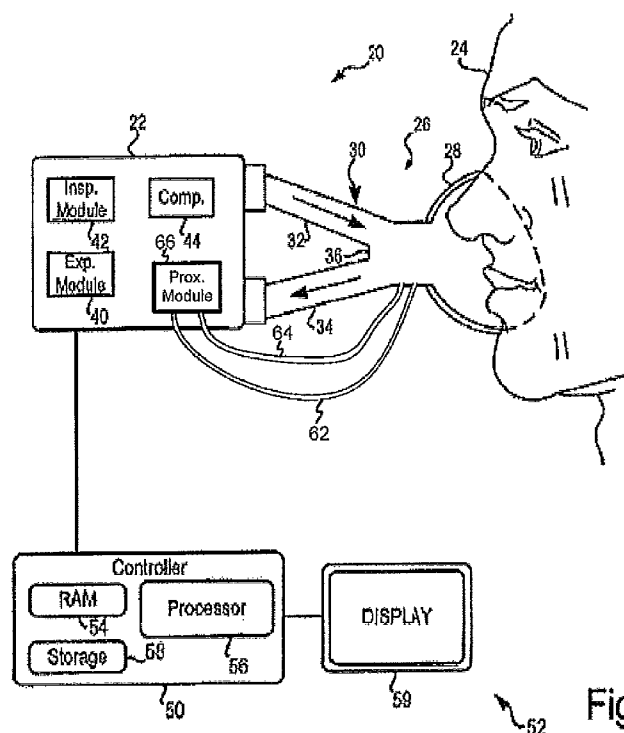
(74) Agent: **DOUGHERTY, Thomas, A.**; Attn: IP Legal, 6135 Gunbarrel Avenue, Boulder, Colorado 80301 (US).

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(54) Title: VENTILATOR WITH CONTROLLED PURGE FUNCTION



(57) Abstract: This disclosure describes systems and methods for purging narrow diameter sensor tubing in a ventilation system. Among other aspects, this disclosure describes ventilation systems in which a sensor tube purge module utilizes a ventilator-generated signal to synchronize the purging of sensor tubes with the delivery of respiratory therapy. Through the signal, purging is prevented from occurring during inspiration and during events such as ventilation maneuvers. Purging may be further improved by monitoring the pressure of the gas used to purge the sensor tubes in order to prevent purges being performed when the pressure is too high or too low. One way to achieve this is by purging the sensor tubes using gas discharged from an accumulator, in which the pressure in the accumulator is monitored and controlled by the sensor tube purging module.

Fig. 1



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VENTILATOR WITH CONTROLLED PURGE FUNCTION

Related Applications

This application claims the benefit of U.S. Provisional Application No. 61/094,377 filed September 4, 2008 and U.S. Provisional Application No. 61/169,976 filed April 16, 2009, which applications are hereby incorporated herein by reference.

Introduction

Medical ventilators may determine when a patient takes a breath in order to synchronize the operation of the ventilator with the natural breathing of the patient. In some instances, detection of the onset of inhalation and/or exhalation may be used to trigger one or more actions on the part of the ventilator.

In order to accurately detect the onset of inhalation and/or exhalation, and/or obtain a more accurate measurement of inspiratory and expiratory flow/volume, a flow or pressure sensor may be located close to the patient. For example, to achieve accurate and timely non-invasive signal measurements, differential-pressure flow transducers may be placed at the patient wye proximal to the patient. However, the ventilator circuit and particularly the patient wye is a challenging environment to make continuously accurate measurements. The harsh environment for the sensor is caused, at least in part, by the condensations resulting from the passage of humidified gas through the system as well as secretions emanating from the patient. Over time, the condensate material can enter the sensor tubes and/or block its ports and subsequently jeopardize the functioning of the sensor.

Summary

This disclosure describes systems and methods for purging narrow diameter sensor tubing, occasionally referred to as "sensor lines", in a ventilation system. Among other aspects, this disclosure describes ventilator systems in which the purging of sensor lines is synchronized to a ventilator-generated signal. Through the signal, purging is prevented from occurring during inspiration and during events such as ventilation maneuvers. Purging is further improved by monitoring the pressure of the gas used to purge the sensor lines in order to prevent purges being performed when the pressure is too high or too low.

There are times during ventilator operation that it would be undesirable to purge. For example, the operator may want to perform maneuvers such as an inspiratory pause, an expiratory pause, or a respiratory mechanics maneuver such as NIF, P100 and Vital Capacity. In such cases, the operator may push a button on the ventilator user interface to initiate the maneuver. However, the operator has requested a maneuver which should not be contaminated with a purge.

For example, in some situations, it may be desirable to purge only during a patient exhalation. This acts to prevent or help prevent an inhalation of material expelled during the purge, and reduces the maximum inflation of the lungs which would occur if purging occurred at the end of inspiration when the lungs are at their peak inflation point. Furthermore, it can be desirable, and in some cases preferred to begin to purge not at the very beginning of exhalation, but later in exhalation when the lungs are partially deflated.

In the current Puritan Bennett 840 ventilator, the shortest exhalation phase is about two hundred milliseconds (200 ms). Especially in such cases, fine control over when the purge of the proximal flow sensor package starts is desirable. Since the ventilator is in control of when the exhalation valve opens and the exhalation phase begins, it can know this point in time sooner and with higher precision than does a proximal flow sensor package. Use of a hardware "purge enable" signal sourced at the ventilator to control the start of purging can help guarantee precision timing for purging.

In some embodiments of the systems and methods described herein, the possibility of a poorly timed purge may be reduced or eliminated by adding a "purge enable" hardware signal sourced by the ventilator and sent to the microprocessor on the proximal flow sensor package. In some embodiments, coupling this hardware signal with suitable software commands reduces the possibility of an ill-timed purge, and results in negligible patient impact. Such additional software commands may include one or more commands directed to (1) setting target accumulator pressures and/or pressure tolerances, (2) setting a purge delay time; (3) providing low pressure (PEEP) information to the proximal sensor package; (4) recording and/or transmitting purge duration; and (5) establishing purge abort criteria.

In part, this disclosure describes a pressure support system with means for synchronizing the purging of a sensor tube with the delivery of gas to the patient by the

ventilation system. The system includes a pressure generating system adapted to generate a flow of breathing gas; a ventilation system including a patient circuit adapted to control delivery of the flow of breathing gas; at least one circuit sensor in fluid communication with the patient circuit via one or more sensor tubes; and a sensor tube
5 purge module adapted to discharge gas through the sensor tube into the patient circuit based on a signal received from the ventilation system. In an embodiment of the system, the signal received is a purge-enable signal and the sensor tube purge module discharges gas based on the purge-enable signal, that is only when the purge-enable signal indicates that a purge is allowed by the ventilator.

10 In addition, this disclosure also describes a pressure support system having a ventilation system controlling the flow of breathing gas in a patient circuit; a sensor in fluid communication with the patient circuit via one or more sensor tubes; and a sensor tube purge module adapted to discharge gas through the sensor tube into the ventilation system based on the flow of breathing gas in the patient circuit.

15 In yet another aspect of this disclosure, it describes a pressure support system having a pressure generating system adapted to generate a flow of breathing gas; a ventilation system including a patient circuit; a sensor in fluid communication with the patient circuit via a sensor tube; and a sensor tube purge module having a controller, an accumulator from which gas is discharged through the one or more sensor tubes, and an
20 accumulator pressure monitoring device, wherein the sensor tube purge module is adapted to discharge gas from the accumulator through the sensor tube into the patient circuit.

This disclosure further describes a method of purging a sensor tube connecting a sensor to a gas transport circuit. The method includes monitoring a pressure or flow in
25 the gas transport circuit using the sensor and discharging a volume of gas through the sensor tube into the gas transport circuit based at least in part on the monitored pressure or flow in the gas transport circuit. In the event that the gas transport circuit is a patient circuit attached to a breathing patient, the method may further include determining a current phase of a breathing cycle of the patient from the monitored pressure or flow and
30 discharging the volume of gas through the sensor tube into the patient circuit based at least in part on the current phase of the breathing cycle of the patient, such as

discharging only when the current phase of the breathing cycle is not an inhalation phase.

Yet another aspect, this disclosure describes a ventilation system adapted to generate a purge control signal for use by a sensor tube purge module thereby controlling, at least in part, when the sensor tube purge module purges the sensor tubes. The ventilator may allow control of purging by user's through the ventilator's interface in which case compliance with and execution of the user-specific purge conditions controlled by the ventilator through the purge control signal transmitted to the purge system.

Still a further aspect of this disclosure is the sensor tube purge module adapted to discharge gas through a sensor tube into a gas transport circuit. In this aspect, the sensor tube purge module includes a pressure generating system adapted to discharge a volume of gas through the sensor tube into the gas transport circuit; and a controller controlling the discharge of gas from the pressure generating system, the controller further adapted to communicate with a ventilation system that controls the flow of gas in the gas transport circuit.

These and various other features as well as advantages will be apparent from a reading of the following detailed description and a review of the associated drawings. Additional features are set forth in the description that follows and, in part, will be apparent from the description, or may be learned by practice of the described embodiments. The benefits and features will be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the systems and methods for controlled purging of sensor lines.

Brief Description of the Drawings

The following drawing figures, which form a part of this application, are illustrative of embodiments systems and methods described below and are not meant to limit the scope of the invention in any manner, which scope shall be based on the claims appended hereto.

FIG. 1 illustrates an embodiment of a ventilator connected to a human patient.

FIG. 2 illustrates an embodiment of a proximal sensor module that includes a sensor tube purging system.

FIG. 3 illustrates an embodiment of a method of purging a sensor tube
5 connecting a patient circuit of a medical ventilator to a sensor.

FIG. 4 illustrates an embodiment of a method of operating a purge system with an accumulator.

Detailed Description

10 Although the techniques introduced above and discussed in detail below may be implemented for a variety of medical devices, the present disclosure will discuss the implementation of these techniques in the context of a medical ventilator for use in providing ventilation support to a human patient. The reader will understand that the technology described in the context of a medical ventilator for human patients could be
15 adapted for use with other systems such as ventilators for non-human patients and general gas transport systems in which sensor tubes in challenging environments may require periodic or occasional purging.

Medical ventilators are used to provide a breathing gas to a patient who may otherwise be unable to breathe sufficiently. In modern medical facilities, pressurized air
20 and oxygen sources are often available from wall outlets. Accordingly, ventilators may provide pressure regulating valves (or regulators) connected to centralized sources of pressurized air and pressurized oxygen. The regulating valves function to regulate flow so that respiratory gas having a desired concentration of oxygen is supplied to the patient at desired pressures and rates. Ventilators capable of operating independently of external
25 sources of pressurized air are also available.

While operating a ventilator, it is desirable to monitor the rate at which breathing gas is supplied to the patient. Accordingly, systems typically have interposed flow and/or pressure sensors. The sensors may be connected to or in communication with the inspiratory limb and the expiratory limb of the ventilator and/or patient circuit. In some
30 cases, it is desirable to provide a flow sensor and/or pressure sensor near the wye of the patient circuit, which connects the inspiratory limb and the expiratory limb near the

patient interface (e.g., an endotracheal tube, mask, or the like). Such a sensor package may be referred to as a proximal sensor system, device or module.

During operation, the patient circuit can acquire exhaled condensate from the patient and/or condensate from the action of a humidifier in the patient circuit. For circuits containing a proximal flow sensor package which measures flow using the principle of differential pressure, the presence of such liquid or viscous material in either or both of the lines used to sense differential pressure can reduce sensor performance. One approach to address this issue involves sending a puff, pocket, or discharge of air down each of the differential pressure sensing tubes. Such a discharge, which may also be referred to as a single, or individual, purge of the tube, may help remove or prevent unwanted condensate or the like from the tubes and/or from the proximal flow sensor package. Depending on the embodiment, purging is performed using a sensor tube purge system or module which may be integral with the proximal sensor module or a separate and independent system.

FIG. 1 illustrates an embodiment of a ventilator **20** connected to a human patient **24**. Ventilator **20** includes a pneumatic system **22** (also referred to as a pressure generating system **22**) for circulating breathing gases to and from patient **24** via the ventilation tubing system **26**, which couples the patient to the pneumatic system via physical patient interface **28** and ventilator circuit **30**. Ventilator circuit **30** could be a two-limb or one-limb circuit for carrying gas to and from the patient. In a two-limb embodiment as shown, a wye fitting **36** may be provided as shown to couple the patient interface **28** to the inspiratory limb **32** and the expiratory limb **34** of the circuit **30**.

The present systems and methods have proved particularly advantageous in invasive settings, such as with endotracheal tubes. However, condensation and mucus buildup do occur in a variety of settings, and the present description contemplates that the patient interface may be invasive or non-invasive, and of any configuration suitable for communicating a flow of breathing gas from the patient circuit to an airway of the patient. Examples of suitable patient interface devices include a nasal mask, nasal/oral mask (which is shown in FIG. 1), nasal prong, full-face mask, tracheal tube, endotracheal tube, nasal pillow, etc.

Pneumatic system **22** may be configured in a variety of ways. In the present example, system **22** includes an expiratory module **40** coupled with an expiratory limb

34 and an inspiratory module 42 coupled with an inspiratory limb 32. Compressor 44 or another source or sources of pressurized gas (e.g., pressured air and/or oxygen controlled through the use of one or more gas regulators) is coupled with inspiratory module 42 to provide a source of pressurized breathing gas for ventilatory support via inspiratory limb
5 32.

The pneumatic system may include a variety of other components, including sources for pressurized air and/or oxygen, mixing modules, valves, sensors, tubing, accumulators, filters, etc. Controller 50 is operatively coupled with pneumatic system 22, signal measurement and acquisition systems, and an operator interface 52 may be
10 provided to enable an operator to interact with the ventilator (e.g., change ventilator settings, select operational modes, view monitored parameters, etc.). Controller 50 may include memory 54, one or more processors 56, storage 58, and/or other components of the type commonly found in command and control computing devices.

The memory 54 is computer-readable storage media that stores software that is
15 executed by the processor 56 and which controls the operation of the ventilator 20. In an embodiment, the memory 54 comprises one or more solid-state storage devices such as flash memory chips. In an alternative embodiment, the memory 54 may be mass storage connected to the processor 56 through a mass storage controller (not shown) and a communications bus (not shown). Although the description of computer-readable media
20 contained herein refers to a solid-state storage, it should be appreciated by those skilled in the art that computer-readable storage media can be any available media that can be accessed by the processor 56. Computer-readable storage media includes volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information such as computer-readable instructions, data
25 structures, program modules or other data. Computer-readable storage media includes, but is not limited to, RAM, ROM, EPROM, EEPROM, flash memory or other solid state memory technology, CD-ROM, DVD, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed
30 by the processor 56.

As described in more detail below, controller 50 issues commands to pneumatic system 22 in order to control the breathing assistance provided to the patient by the

ventilator. The specific commands may be based on inputs received from patient 24, pneumatic system 22 and sensors, operator interface 52 and/or other components of the ventilator. In the depicted example, operator interface includes a display 59 that is touch-sensitive, enabling the display to serve both as an input user interface device and output device.

In addition to general control commands, the controller 50 also communicates with the proximal sensor module 66. The information provided allows purges performed of the sensor tubes 62, 64 to be synchronized with the overall operation of the ventilator 20. For example, the controller 50 may be programmed so that purges will or will not occur during specific phases of the patient's breathing cycle, during specific periods within a phase (e.g., not at the beginning or end of a phase) or during specific maneuvers. These specific periods may be predetermined by the manufacturer, the hospital or adjusted by each user via the display and ventilator's user interface. For example, in an embodiment purge control parameters are stored in the memory of the ventilator 22 which can be revised through a user interfacing with the controller 50. Alternatively such parameters may be transmitted to the purge system for storage and use at a later time when determining from a purge control signal whether purging is allowed at any given instant. This allows an operator to control purging through the ventilator's interface.

The ventilator 20 is also illustrated as having a proximal sensor module (the "Prox. Module" in FIG. 1) 66. The proximal sensor module 66 includes at least one sensor, such as a pressure sensor, that is connected to some location in the patient circuit 30 or patient interface 28 by one or more sensor tubes 62, 64. In the embodiment shown, two sensor tubes 62, 64 connect the proximal sensor module 66 to a location in the wye fitting 36. As is known in the art, for the differential pressure measurement system to operate, a resistance to flow is placed between the flow outlets of the two sensor tubes 62, 64. In alternative embodiments, sensor tubes may connect to the ventilator tubing system 26 at any location including any limb of the circuit 30 and the patient interface 28. It should be noted that regardless of where the sensor tubes connect to the tubing system 26, because it is assumed that there is very little or no leakage from the tubing system 26 all gas discharged through the sensor tubes into the ventilator tubing system 26 will ultimately be discharged from the ventilator through the patient circuit 30 and

expiratory module **40**. The use of sensor tubes as part of various different measurement systems is known in the art.

In the embodiment shown, the proximal sensor module **66** includes a sensor tube purging system that purges the sensor tubes by occasionally discharging gas through the sensor tubes into the patient circuit **30**. The sensor tube purging system and functions are discussed in greater detail below.

Although FIG. 1 illustrates an embodiment have two sensor tubes **62**, **64** and one proximal sensor module **66**, any number of sensor tubes may be used depending on the number and types of proximal sensors. For example, in some embodiments module **66** couples to three (3) tubes, with two (2) tubes used for a differential pressure sensor function and the third tube used for an alternative function such as gas composition analysis, orientation or other alternative sensors, or the like. All of the sensors may be housed in a single proximal sensor module **66** or they may be separated into different modules **66**.

Furthermore, a proximal sensor module **66** may be integrated into the ventilator **20** as shown, or may be a completely independent module. If independent, the proximal flow module **66** may be adapted to detect the current phase of a patient's breathing cycle in order to synchronize the purging of the sensor tubes with specific breathing phases, such as the inspiratory phase or the exhalation phase or other conditions such as respiratory maneuvers or user-initiated purging (e.g., a user-generated "purge now" command).

FIG. 2 illustrates an embodiment of a proximal sensor module that includes a sensor tube purge system in addition to a proximal sensor that prevents purges from occurring during points in the ventilation cycle in which purges are undesirable. The proximal sensor module **202** may be implemented as an independent, stand-alone module, e.g., as a separate card either inside the ventilator or within a separate housing associated with the proximal flow sensor. Alternatively, the proximal sensor module **202** may be integrated with components of the ventilator or another device, e.g., built into a ventilator control board. In yet another embodiment, the sensor tube purge system may be implemented independently from the proximal sensor **204**, for example as an in-line module between the sensor and the patient circuit, in which case the module of FIG. 2 would not include the proximal sensor **204**.

In the embodiment shown, a proximal sensor module **202** is illustrated having a differential pressure or flow sensor **204** connected to two sensor tubes **206, 208** that are subsequently attached to the ventilator tubing system (not shown). Sensor tubes used in conjunction with proximal sensors may have relatively small internal diameters. For
5 example, tube diameters may be less than about 10 millimeters (mm), less than about 1 mm, or even smaller. Such sensor tubes are prone to blockage and, also because of their small diameters, are relatively more detrimentally affected by inner surface contamination even when not completely occluded.

In the embodiment shown, the differential pressure sensor **204** is connected to
10 each sensor tube **206, 208** by a corresponding valve **210, 212**. The valves **210, 212** are also connected to a pressurized vessel **214**, sometimes also referred to as an accumulator **214**, and operate such that when a sensor tube **206, 208** is connected to the vessel **214** (thus allowing pressurized gas from the vessel to be discharged through the sensor tube to the ventilator circuit) the associated sensor tube is not connected to the pressure
15 sensor **204**. This protects the sensor **204** from damage due to the abrupt change in pressure caused when the sensor tube is purged. In another embodiment, when performing an individual purge of either sensor tube of a differential pressure sensor, the sensor may also be disconnected from the both sensor tubes. In yet another embodiment, the differential pressure sensor may always be connected to the sensor tubing regardless
20 of whether the tubes are being purged or not. In this embodiment, the sensor **204** may or may not be disabled (turned off) to prevent damage or the recording of spurious pressure measurements.

In the embodiment shown, the purge module in the proximal sensor module **202** includes the accumulator **214**, a pump **216** (or alternatively a source of pressurized gas
25 and a regulator) for charging the accumulator **214** with gas obtained from an external source (e.g., ambient), a pressure sensor **218** for monitoring the pressure in the accumulator **214**, the aforementioned valves **210, 212** and a purge controller **220** that controls the functions of the purge module. The accumulator **214** may be any appropriate size and rated to any appropriate pressure. In an embodiment, because the
30 volumes and pressures necessary to purge the typically small-diameter sensor tubes are relatively small and cost and size are always important design factors, the accumulator **214** may have a volume between about five (5) milliliters (ml) to about 20 milliliters. In

a specific embodiment, the accumulator **214** volume is between about 10 ml and about 12 ml. In some embodiments, accumulator **214** is rated to hold and/or maintain pressures between about two (2) pounds per square inch (PSI) and about thirty (30) pounds per square inch, with ratings of up to about 3 psi, up to about 6 psi and up to about 8 psi used in various embodiments depending on pump size. The pump **216** may be of any type and may receive filtered air or any other gas, including respiratory gas obtained directly from the ventilator.

For example, in an embodiment, when power is applied to the pump **216**, gas from the gas source is pumped under pressure into the accumulator **214**. When power is removed from the pump **216**, the pump contains a suitable structure such that the pressure built up in the accumulator **214** does not discharge back through the pump. Such structure provides the function of a check valve without requiring an extra component.

In the embodiment shown, the accumulator pressure sensor **218** is provided to obtain information concerning the pressure within the vessel **214**. From this information, the amount of gas used during purging can be determined. Depending on the embodiment, the raw pressure data may be provided to the ventilator for use in calculating the gas flow through the patient circuit or may be provided to the purge controller **220**, which calculates the purge volume and provides that data to the ventilator. Such a calculation would be performed based on the pressure changes observed during the purge cycle and previously determined data characterizing the volume, compliance and other parameters of the purge module as is known in the art.

In the embodiment shown, the purge controller **220** controls the purging of the sensor tubes **206**, **208** by controlling the opening and closing of the valves **210**, **212** and the pressurizing of the accumulator **214** by the pump **216**. In an embodiment, the purge controller **220** includes a microprocessor executing software stored either on memory within the processor or in a separate memory cache. The purge controller **220** may or may not be involved in the transmission of sensor data from the circuit sensor **204** to other devices or components such as the ventilator, e.g., the circuit sensor **204** may directly output its data signal to the ventilator.

As discussed above, the controller **220** may also communicate with other systems. For example, in an embodiment the controller **220** interfaces between the

ventilator and the sensor tube purge system to provide information to the ventilator such as the status of the purge system (e.g., currently discharging, time since last discharge, time/duration of last discharge, time until next discharge, currently in a purge cycle, time since last purge cycle, purge failure error due to possible occlusion of a sensor tube, component failure, etc.) and the amount of purge gas delivered into the patient circuit. The controller **220** may also receive information from external sources such as modules of the ventilator, in particular information concerning the current breathing phase of the patient so that the purge system can synchronize its operations with the delivery of gas to the patient, and user interfaces. The information received may include user-selected or predetermined values for various parameters such as the purge cycle interval (e.g., perform a purge cycle every 10 minutes), accumulator pressure, between-discharges delay period, individual purge/discharge interval, a purge-enable signal (e.g., a signal indicating that the proximal sensor module **202** is free to initiate a purge cycle), a purge-disable signal (e.g., a signal indicating that the proximal sensor module **202** should not initiate a purge cycle), etc. The information received may further include directions such as a ventilator-generated purge command or an operator command to perform a purge at the next opportunity (e.g., an automatic or manual purge command). The controller **220** may also include an internal timer so that individual purges can be performed at a user or manufacturer specified interval.

Depending on the embodiment, the controller **220** may also monitor the pressure in the accumulator **214** (via the vessel pressure sensor **218**) when controlling the pump **216** so that specified pressures are obtained at different points in the purge cycle. In an alternative embodiment, the controller **220** may rely on timing to control the operation of the purge system, for example such as when there is no sensor **218** provided, by opening and closing valves and operating the pump for specified lengths of time.

In an embodiment, the proximal sensor module **202** may be independent of the ventilator in that it determines based on its own internal logic (which may take into account data from the ventilator, directly from the sensor **204**, the accumulator sensor **218** or other sources) when to perform purges of the sensor tubes. In an alternative embodiment, the proximal sensor module **202** may be less than independent of the ventilator or, even, purely a slave to the commands provided by the ventilator and containing little or no internal decision making or processing capabilities.

In an alternative embodiment (not shown), alternative systems for providing pressured gas for purging may be used. For example, in an embodiment the pump **216** and accumulator **214** may be replaced with a regulator (not shown) and a valve that regulates pressure from an external pressurized gas source. Many other systems for providing pressurized gas are known in the art. Although the systems described herein are expedient given the current design constraints encountered by the inventors, any suitable pressurized gas system may be used and are considered within the scope of this disclosure.

In an alternative embodiment, the module **202** does not include a vessel pressure sensor **218** and does not have the ability to measure the pressure in the accumulator **214**. In this case, control of the pump **216** and knowledge of the pump's specifications and the accumulator size may be used to determine the amount of gas injected during an individual purge event or the full purge cycle into the patient circuit.

As discussed above, in some embodiments of the proximal sensor module **202**, a pressure sensor **218** is added to provide pressure readings from the accumulator **214**. Additionally, in some embodiments the repeatability of purges is improved by charging the accumulator **214** to a fixed target pressure (measured with the pressure sensor **218**), and using a variable amount of time for charging. In this manner, input from the pressure sensor **218** can be used to track the accumulator pressure and adjust the pumping time necessary to create the desired pressure. In still other embodiments, pump performance is trended over time. In this manner, an alert may be sent to the operator or the ventilator, may be displayed on the ventilator graphical user interface (GUI), or the like, to indicate the pump performance. Such a trend can be used, for example, to schedule maintenance to replace the pump **216** in a timely fashion.

After the accumulator **214** is charged, the accumulator **214** can discharge if left alone for a period of time due to slow leakage through the valves and manifold seals. In an embodiment, the extent of this leakage and the health of the system may be determined by using the pressure sensor **218** in communication with the accumulator circuit.

Some pumps **216** require relatively high power, and may have problems operating at elevated temperatures. Such high temperatures may exist, for example, in the ventilator card cage containing the proximal flow sensor control card when the

ventilator card cage is operating under high ambient temperature conditions. In some embodiments, a pump **216** capable of operation in such temperature ranges is used.

FIG. 3 illustrates an embodiment of a method of purging a sensor tube connecting a patient circuit of a medical ventilator to a sensor. The embodiment illustrated in method **300** in simple terms can be described as synchronizing the purging of sensor tubes with the operation of the ventilator or, alternatively, the breathing cycle of the patient. This is done by determining that all of the purge system's internal conditions necessary for performing a purge are met as well as receiving an indication from the ventilator either that the ventilator's conditions for purging are also met or from which that can be ascertained.

The general method **300** shown starts with an initialization operation **302**. This may take the form of a startup command or may simply be caused by an operator turning on the ventilator or sensor tube purge system. In yet another embodiment, the initialization operation **302** may be caused by the receipt of a purge control signal from the ventilator or other source or the detection of flow in the patient circuit by the sensor tube purge system.

In the embodiment shown, upon initiation a monitoring operation **304** is performed in which a timer or counter is utilized to determine the elapsed time or number of breaths (depending on the type of interval being used). During the monitoring operation the timer counts down until the interval expires as illustrated by the determination operation **304**. Upon expiration of the interval, this internal purge system condition is met.

The method now begins the process of determining if the ventilator condition(s) for allowing a purge are met by performing a check purge control signal operation **308**. In the embodiment shown, the purge control signal is received from the ventilator and may take any number of different forms, e.g., a purge-enable signal indicating that purges can be performed at the present time or a purge-disable signal indicating the opposite condition, from which the purge system can ultimately determine whether the ventilator allows a purge at the time of the analysis.

In an alternate embodiment, the purge control signal may need to be interpreted against some additional information to determine if the ventilator condition is met. For example, the ventilator may provide a signal indicative of the current phase of the

patient's breathing cycle which the purge system then must analyze against its internally-stored setting to determine if the current phase is one in which a purge is allowed. The purge system may have been previously set to allow purges only when the current phase is not the inhalation phase and, in this embodiment, if the purge control signal indicates a phase other than inhalation, the ventilator condition is met and a purge is performed. In yet another embodiment, the purge control signal may be an indication of the current flow in the patient circuit and may be compared to a flow condition known to the purge system in order to determine if a purge is allowed. In yet another embodiment a purge control signal may be a signal indicating the performance of a recruitment maneuver or a patient disconnect condition.

In an embodiment, a ventilator may transmit a variety of different purge control signals over time. Such signals may be transmitted to multiple different recipients including the purge system and may conform to a standard. Furthermore, signals may be simple analog or digital signals or may be complex signals, such as codes indicative of different states of the ventilator or different commands, which must be processed and identified by the purge system before they can be interpreted and the determination made as to whether purge is allowed by the ventilator or not.

In an embodiment, the purge control signal from the ventilator may be a signal directly or indirectly based on the data received from the very sensor for which the tubes will be purged. In this embodiment, it may be of even more importance to the ventilator when purges occur as the sensor may not be available to provide its normal data during a purge.

A purge control signal generated by the ventilator may take into account the expected duration of a purge event and adjust the timing of the signal accordingly to ensure that a purge does not extend into an undesirable portion of the ventilator's operation, e.g., the purge extends into a patient's inhalation even though started during the previous exhalation phase. Alternatively, such management may be performed by the purge system by tracking when purge control signals change.

In yet another embodiment, the purge control signal may be obtained directly from the sensor attached to the sensor tubes to be purged or from some other sensor instead of from the ventilator's control or communication system. In an embodiment, the purge system may interpret the sensor data directly to determine what the current

phase is of the patient's breathing cycle or may simply be looking for specific flow or pressure condition, e.g., a sudden drop or rise or a stable period for a certain duration, and when that condition is detected a purge is allowed.

5 The act of analyzing the information provided by the ventilator is illustrated by the determination operation **310**. In the embodiment shown, if, after analysis, it is determined that a purge is not allowed the system returns to the check operation **308**, thereby creating a loop that waits for the ventilator condition to change to purge being allowed.

10 If the ventilator condition is met, however, a purge is performed as illustrated in the gas discharge operation **312**. This may include discharge of gas from an accumulator or from some other source under control of the purge system. As part of this operation **312**, data may be recorded, e.g., the time of the discharge, the duration, the volume discharged, etc. and some or all of the data may be transmitted to the ventilator.

15 After the purge of the tube or tubes, the timer is reset in a reset operation **314** and the flow returns to the monitoring operation **304** so the flow is repeated until the purge system is shutdown, such as in response to some external command or event.

FIG. 3 illustrates a method that checks a purge system condition and a ventilator condition to determine when to purge sensor lines. The ventilator is thus able to prevent purges from being performed at inopportune times such as during inhalation and during recruitment maneuvers. In this way, the purge system can synchronize its operation with the ventilator and the ventilation of the patient.

20 In alternative embodiments, the various operations may be reordered or adjusted and new operations (such as checking additional purge system conditions and/or ventilator conditions) added so that the method's flow is altered even though the goal of the method, synchronization and preventing purges from being performed during specific conditions, is still achieved. For example, in an alternative embodiment the timer may be reset if the purge is not allowed by the ventilator.

25 In another embodiment of a method of purging sensor lines, other conditions may be evaluated such as determining whether the pressure in the accumulator is within a specific range suitable for performing a purge.

FIG. 4 illustrates this embodiment of a method of operating a purge system with an accumulator. In this embodiment, the operations with like reference numbers are the

same as those described with reference to FIG. 3, with the addition of several operations related to determining the condition of the accumulator.

In the embodiment shown, the accumulator is pressurized in a charge operation 407. This operation could occur at any time, although in an embodiment it is intentionally charged at or near the time at which a purge is to be performed in order to extend the life of valves and other equipment that degrade faster when the accumulator is pressurized.

A determination operation 408 then tests the pressure condition of the accumulator to determine when it has sufficient pressure for a purge to be performed. When there is enough pressure in the accumulator, the condition is met and, in the embodiment shown, the pump is disabled and flow proceeds to the check purge control signal operation 308.

In the embodiment shown, until the accumulator is fully pressurized the charge accumulator operation 407 continues. However, as illustrated by the determination operation 409, if after some predetermined amount of time the desired pressure is not reached an alarm operation 410 is performed in which an alarm or notification is transmitted as described above. Other methods and operations related to assessing the performance of the accumulator may also be used or substituted in the determination operation 409.

In some embodiments, adding a pressure sensor to the accumulator, and coupling the use of this sensor signal with suitable new software commands, adds the ability to do one or more of the following: (a) assess and/or guarantee that purging is working properly; (b) monitor the health of the purge pump and provide user feedback if pump replacement is required; (c) produce more repeatable purges over the time, even as pump performance degrades; and (d) confirm that leakage in the accumulator manifold circuit is within acceptable limits.

Those skilled in the art will recognize that the methods and systems of the present disclosure may be implemented in many manners and as such are not to be limited by the foregoing exemplary embodiments and examples. In other words, functional elements being performed by a single or multiple components, in various combinations of hardware and software or firmware, and individual functions, can be distributed among software applications at either the client or server level or both. In

this regard, any number of the features of the different embodiments described herein may be combined into single or multiple embodiments, and alternate embodiments having fewer than or more than all of the features herein described are possible.

Functionality may also be, in whole or in part, distributed among multiple components, 5 in manners now known or to become known. Thus, myriad software/hardware/firmware combinations are possible in achieving the functions, features, interfaces and preferences described herein. Moreover, the scope of the present disclosure covers conventionally known manners for carrying out the described features and functions and interfaces, and those variations and modifications that may be made to the hardware or software or 10 firmware components described herein as would be understood by those skilled in the art now and hereafter.

While various embodiments have been described, various changes and modifications may be made which are well within the scope of the present disclosure. For example, in an embodiment the operation of the sensor tube purge system may be 15 entirely controlled by the ventilator such that the purge system performs no logic other than to await a command to purge from the ventilator. In addition, the methods described above could be altered in many different ways to change the order of the operations and add additional condition checks in order to adjust the performance of the system to meet differing design and cost criteria. Numerous other changes may be made 20 which will readily suggest themselves to those skilled in the art and which are encompassed in the spirit of the disclosure and as defined in the appended claims.

Claims

What is claimed is:

1. A pressure support system comprising:
a pressure generating system adapted to generate a flow of breathing gas;
5 a ventilation system including a patient circuit adapted to control delivery of the flow of breathing gas;
at least one circuit sensor in fluid communication with the patient circuit via one or more sensor tubes; and
a sensor tube purge module adapted to discharge gas through the sensor tube into
10 the patient circuit based on a signal received from the ventilation system.
2. The system of claim 1 wherein the signal received is a purge-enable signal and the sensor tube purge module discharges gas based on the purge-enable signal and one or more conditions determined by the sensor tube purge module.
3. The system of claim 2 wherein the one or more conditions are selected from
15 an elapsed time since a last discharge of gas through the sensor tube, a monitored gas pressure, an indication of a breathing cycle of a patient connected to the patient circuit, a user-generated command to discharge gas, and an elapsed number of breaths since the last discharge of gas through the sensor tube.
4. The system of claim 2 wherein when the purge-enable signal indicates that a
20 purge can be performed, the sensor tube purge module discharges gas based one or more conditions determined by the sensor tube purge module.
5. The system of claim 2 wherein when the purge-enable signal indicates that a purge can not be performed, the sensor tube purge module does not discharge gas.
6. The system claim 1 wherein the sensor tube purge module transmits
25 information to the ventilation system after each discharge indicative of the amount of gas discharged into the patient circuit.
7. The system of claim 6 wherein the information transmitted is selected from one or more of a volume of gas discharged, an indication that a discharge was performed, a discharge duration, and a pressure associated with the discharged gas.
- 30 8. The system of claim 1 wherein the sensor tube purge module further comprises:

an accumulator from which gas is discharged through the one or more sensor tubes; and

an accumulator pressure monitoring device.

9. The system of claim 8 wherein the sensor tube purge module discharges gas based on the signal received from the ventilation system and the accumulator pressure.

10. The system of claim 1 wherein the signal received is a purge command signal directing the sensor tube purge module to discharges gas and, in response, the sensor tube purge module discharges gas upon a next detection of the end of patient inspiration.

11. The system of claim 1 wherein the signal received is a recruitment maneuver signal indicating when the ventilation system is performing a recruitment maneuver and the sensor tube purge module does not discharge gas when the recruitment maneuver signal indicates that a recruitment maneuver is ongoing.

12. A pressure support system comprising:
a ventilation system controlling the flow of breathing gas in a patient circuit;
a sensor in fluid communication with the patient circuit via one or more sensor tubes; and

a sensor tube purge module adapted to discharge gas through the sensor tube into the ventilation system based on the flow of breathing gas in the patient circuit.

13. The system of claim 12 wherein the sensor tube purge module monitors the patient's breathing via the sensor and discharges gas through a sensor tube only during a predetermined phase of a patient's breathing cycle as determined by the sensor tube purge module.

14. The system of claim 12 wherein the ventilation system monitors the patient's breathing and the sensor tube purge module discharges gas through a sensor tube only during a predetermined phase of a patient's breathing cycle as determined by the ventilation system.

15. The system of claim 14 wherein the ventilation system transmits a signal to the sensor tube purge module indicative of the patient's breathing cycle.

16. The system of claim 14 wherein the ventilation system transmits a signal to the sensor tube purge module indicative of the predetermined phase of the patient's breathing cycle.

17. A pressure support system comprising:

a pressure generating system adapted to generate a flow of breathing gas;

a ventilation system including a patient circuit;

a sensor in fluid communication with the patient circuit via a sensor tube; and

5 a sensor tube purge module having a controller, an accumulator from which gas is discharged through the one or more sensor tubes, and an accumulator pressure monitoring device, wherein the sensor tube purge module is adapted to discharge gas from the accumulator through the sensor tube into the patient circuit.

18. The system of claim 17 wherein the sensor tube purge module charges the
10 accumulator to a predetermined pressure prior to discharging gas from accumulator through the sensor tube into the ventilation system.

19. The system of claim 17 wherein the sensor tube purge module monitors changes in the accumulator pressure over time.

20. The system of claim 17 wherein the sensor tube purge module transmits an
15 alarm notification based on the monitored changes in pressure during a time period when the sensor tube purge module is not actively discharging gas through the sensor tube.

21. The system of claim 17 wherein the sensor tube purge module transmits information derived from an output the accumulator pressure monitoring device for display by the ventilation system.

20 22. The system of claim 17 wherein the sensor tube purge module further comprises:

a pump that pressurizes the accumulator.

23. The system of claim 17 wherein the sensor tube purge module further comprises:

25 a regulator connected to an external source of pressurized gas that pressurizes the accumulator.

24. The system of claim 17 wherein the ventilation system monitors a patient's breathing cycle and the sensor tube purge module discharges gas through a sensor tube only during a predetermined phase of a patient's breathing cycle.

30 25. A method of purging a sensor tube connecting a sensor to a gas transport circuit comprising:

monitoring a pressure or flow in the gas transport circuit using the sensor; and

discharging a volume of gas through the sensor tube into the gas transport circuit based at least in part on the monitored pressure or flow in the gas transport circuit.

26. The method of claim 25 wherein the gas transport circuit is a patient circuit connected to a breathing patient and the method further comprises:

5 determining a current phase of a breathing cycle of the patient from the monitored pressure or flow; and

discharging the volume of gas through the sensor tube into the patient circuit based at least in part on the current phase of the breathing cycle of the patient.

10 27. The method of claim 26 wherein the discharging operation further comprises:

discharging only when the current phase of the breathing cycle is not an inhalation phase.

28. The method of claim 26 further comprising:

15 discharging the volume of gas through the sensor tube into the patient circuit based on the current phase of the breathing cycle of the patient and a condition based on a last discharge of gas through the sensor tube.

29. The method of claim 28 wherein the condition based on a last discharge of gas through the sensor tube is selected from a time period since the last discharge of gas and a number of breaths since the last discharge of gas.

20 30. The method of claim 25 wherein the gas transport circuit is a patient circuit connected to a breathing patient and the method further comprises:

25 monitoring a signal provided by a ventilation system controlling the flow of gas in the patient circuit, wherein signal is indicative of the flow of gas in the patient circuit and generated by the ventilation system based at least in part on the monitored pressure or flow in the gas transport circuit; and

discharging the volume of gas through the sensor tube into the patient circuit based at least in part on the signal from the ventilation system.

31. The method of claim 25 wherein the signal is selected from a purge-enable signal, a recruitment maneuver signal, a signal indicating a condition of the ventilator, 30 and a signal indicating a phase of a patient's breathing cycle.

32. The method of claim 25 further comprising:

transmitting information identifying the volume of gas discharged through the sensor tube into the gas transport circuit.

33. A ventilation system adapted to generate a purge control signal to a sensor tube purge module thereby controlling, at least in part, when the sensor tube purge module purges the sensor tubes.

34. The system of claim 33 wherein the purge control signal indicates to the sensor tube purge module when a purge of the sensor tubes can be performed.

35. The system of claim 33 wherein the purge control signal indicates to the sensor tube purge module when to purge the sensor tube.

36. The system of claim 33 wherein the purge control signal indicates to the sensor tube purge module when purging of the sensor tube is not allowed.

37. A sensor tube purge module adapted to discharge gas through a sensor tube into a gas transport circuit comprising:

a pressure generating system adapted to discharge a volume of gas through the sensor tube into the gas transport circuit; and

a controller controlling the discharge of gas from the pressure generating system, the controller further adapted to communicate with a ventilation system that controls the flow of gas in the gas transport circuit.

38. The sensor tube purge module of claim 37 wherein the controller is adapted to receive one or more signals from the ventilation system, wherein the signals are selected from a signal indicating when discharge of gas through the sensor tubes is not allowed, a signal indicating when discharge of gas through the sensor tubes is allowed, and a signal indicating when to discharge gas through the sensor tubes.

39. The sensor tube purge module of claim 37 wherein the controller is adapted to transmit information to the ventilation system based on the discharge of gas through the sensor tubes, wherein the information is selected from one or more of a volume of gas discharged, an indication that a discharge was performed, a discharge duration, and a pressure associated with the discharged gas.

40. The sensor tube purge module of claim 37 further comprising:
a sensor attached to the sensor tubes, wherein the sensor monitors pressure or flow in the gas transport circuit and transmits information indicative of the pressure or flow to the ventilator.

41. A pressure support system comprising:
a ventilation system adapted to deliver respiratory gas to a patient; and
a sensor tube purge means for synchronizing the purging of a sensor tube with
the delivery of gas to the patient by the ventilation system.

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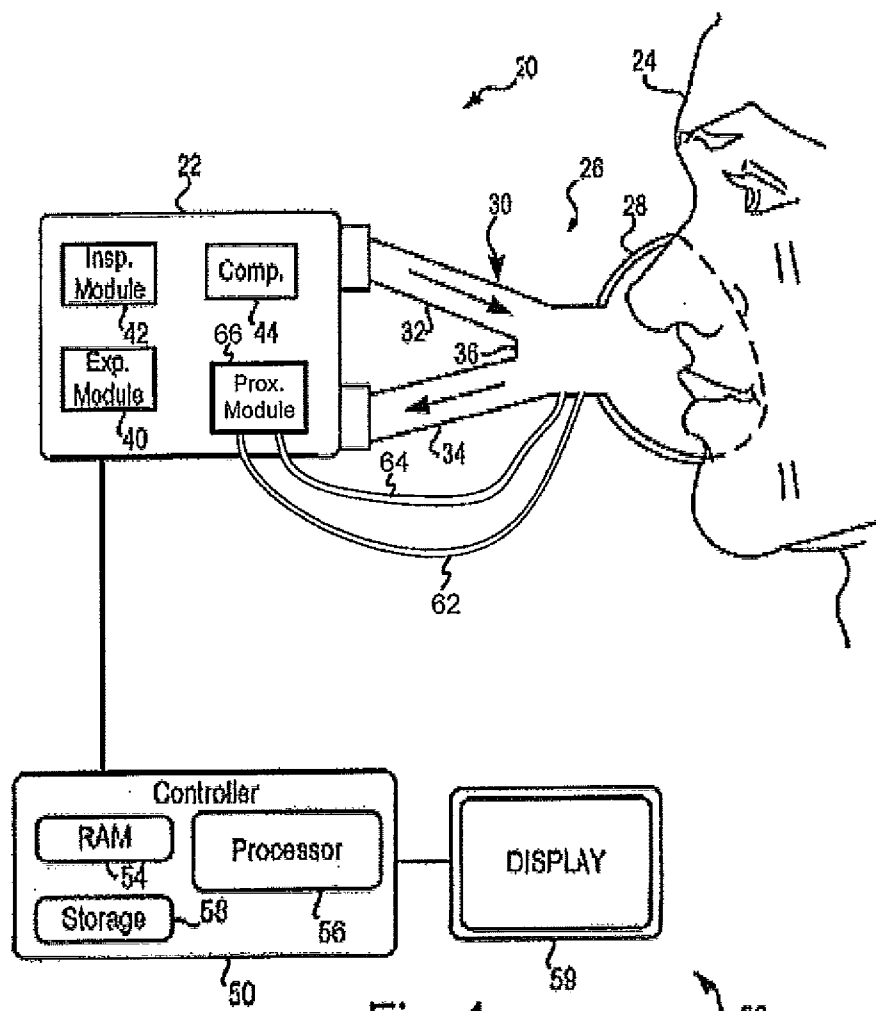


Fig. 1

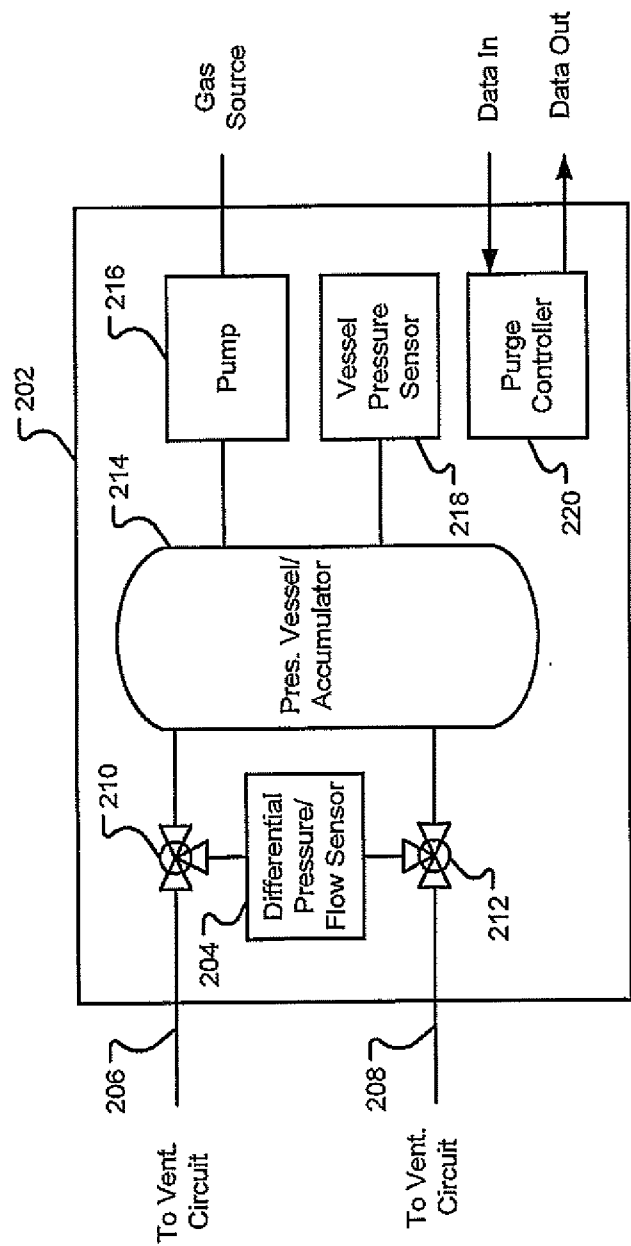


FIG. 2

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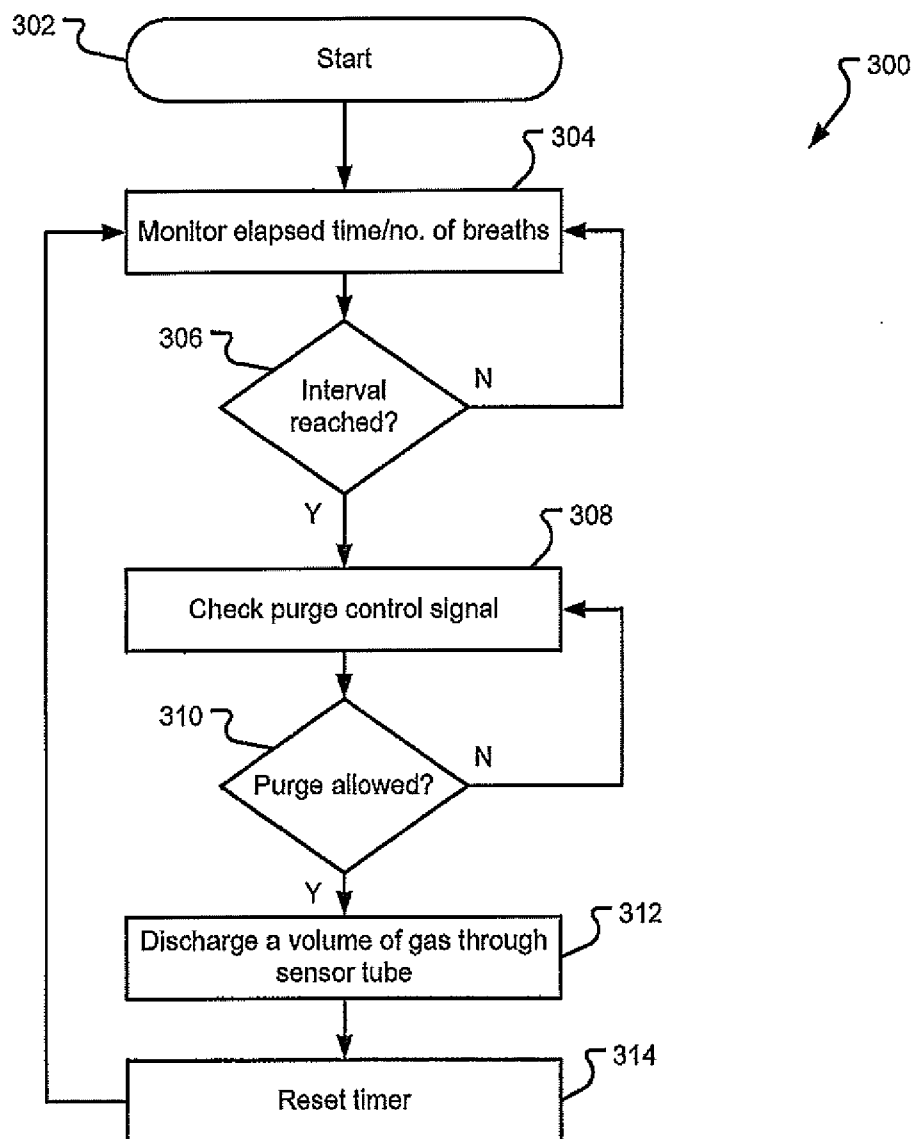


FIG. 3

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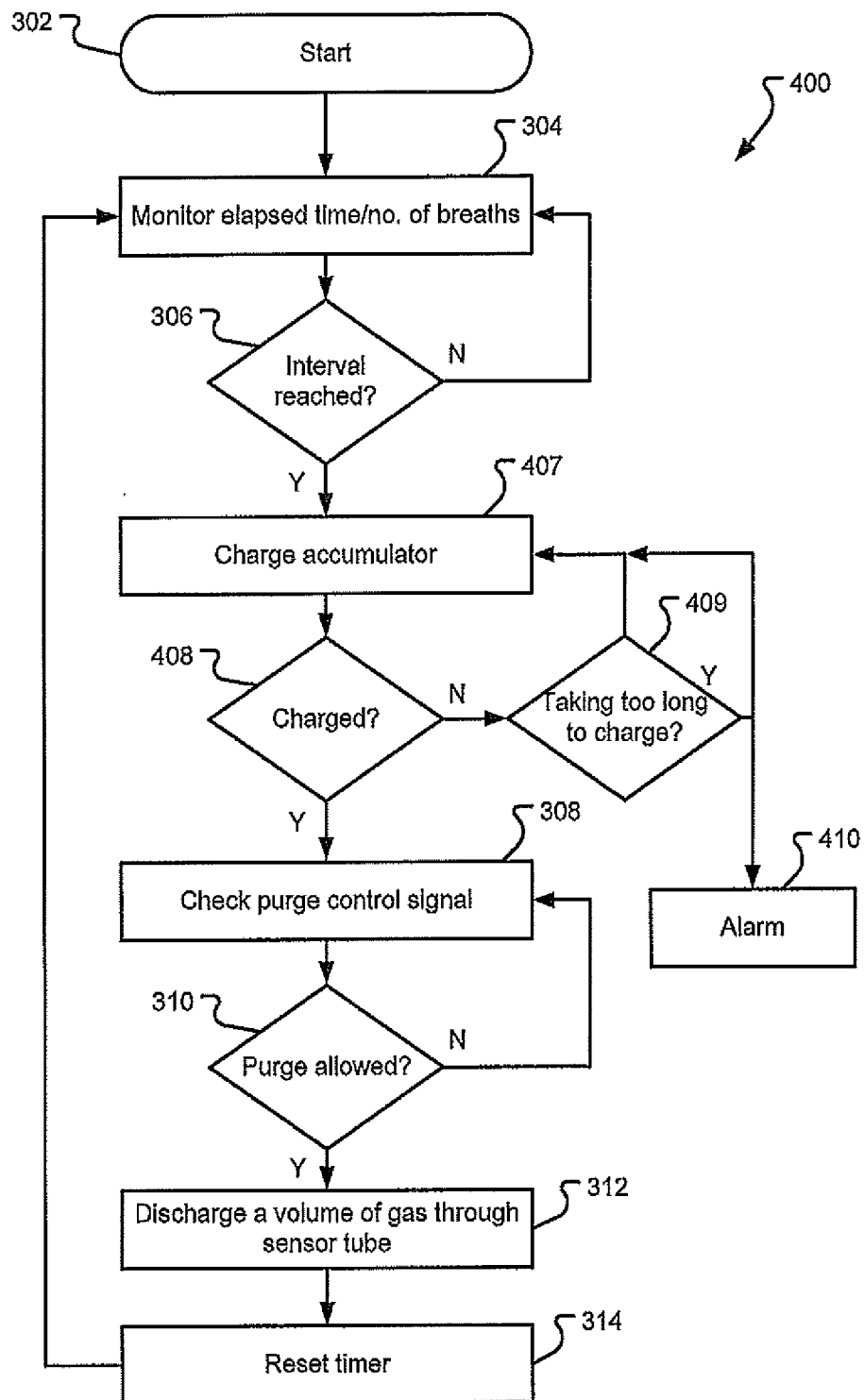


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/055889

A. CLASSIFICATION OF SUBJECT MATTER

INV. A61M16/00 G01F15/12 G01F1/37

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 G01F

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 practical, 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 6 203 502 B1 (HILGENDORF EDWIN J [US] ET AL) 20 March 2001 (2001-03-20) column 10, line 15 - column 11, line 38; figure 5 column 16, line 12 - column 16, line 63 column 16, line 63 - column 17, line 6	1-41
X	US 2004/003814 A1 (BANNER MICHAEL J [US] ET AL) 8 January 2004 (2004-01-08) paragraph [0005]; figures paragraph [0008] paragraph [0013] paragraph [0014] paragraph [0039] - paragraph [0040]	1-41



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

20 November 2009

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26/11/2009

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NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Valfort, Cyril

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2009/055889

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6203502	B1	20-03-2001	NONE
US 2004003814	A1	08-01-2004	NONE