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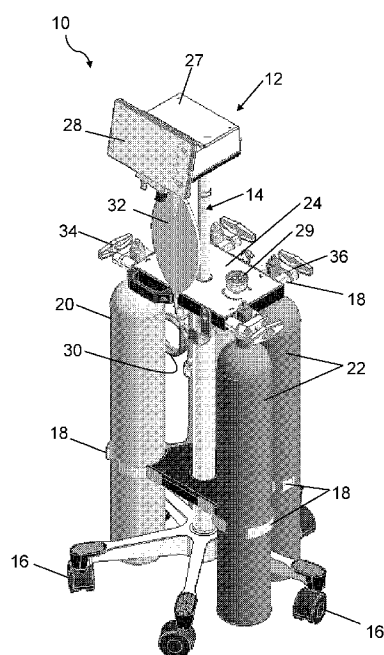


FIG. 1

(57) Abstract: A gas distribution system for a medical gas machine is configured to determine the amount of gas remaining in a gas tank, and display information associated with this determined amount of remaining gas to a user, such as a medical practitioner. The gas distribution system includes the gas tank containing the gas, a flow sensor arranged in a flow passage fluidly connected to the tank, and a controller operatively connected to the flow sensor. The controller is configured to track an amount of gas dispensed from the tank by integrating flow rate of the gas over time, as measured by the flow sensor. The controller determines the amount of the gas remaining in the tank by subtracting the dispensed amount of gas from an initial amount of gas in the tank, and sends information associated with the determined amount of gas remaining to a display for providing a notification.



METHOD FOR DETERMINING AND PROVIDING REMAINING CAPACITY OF GAS SUPPLY IN GAS MACHINE FOR ANESTHESIA AND ANALGESIA

Related Applications

5 This application claims the benefit of U.S. Provisional Application No. 63/080,041 filed September 18, 2020, which is hereby incorporated herein by reference.

Technical Field

10 The present disclosure relates to a gas machine and method that determines a remaining capacity of gas supply, and provides information associated with the determined amount of gas to a user, such as an amount or percentage of gas remaining and/or an estimated amount of time remaining before the gas supply is depleted; and more particularly relates to a continuous-
15 flow gas machine and method used in the administration of anesthetic or analgesic gas.

Background

 A gas machine for anesthesia is a device used to administer to a patient,
20 continuously or intermittently, a general inhalation anesthetic and to maintain a patient's ventilation. Typically in an anesthetic machine, the anesthetic agent is vaporized by a vaporizer, which is then carried to the patient by a carrier gas mixture that commonly includes oxygen and nitrous oxide.

 A gas machine for analgesia is a device used to administer to a patient an
25 analgesic agent, such as a nitrous oxide-oxygen mixture, which typically contains a maximum concentration of 70 percent nitrous oxide. Generally, an analgesia machine is simpler than an anesthetic machine, as it typically does not feature the additional medical ventilator, because the patient remains fully conscious but is less sensitive to due to the administration of the analgesic
30 agent.

Summary

One issue that is present in conventional gas machines, such as the type described above, is the inability of the user administering the gas (e.g., doctor or dentist) to know accurate information about the amount of gas remaining in the gas tank(s) connected to the machine. This is particularly problematic for mobile cart-mounted systems where the gas tanks provide a relatively small capacity of gas, or in systems where at least one of the gases is contained partially in liquid form and is therefore difficult to continuously and accurately monitor by pressure alone.

By way of non-limiting example, many standard gas tanks in the form of pressurized cylinders are letter-coded to indicate a standardized amount of pre-filled gas in the cylinder. For example, a full E-size oxygen gas cylinder contains approximately 660 liters of oxygen at a pressure of 2,200 psi. As oxygen is dispensed from the cylinder, the pressure will start to decay, and the remaining amount of oxygen can be estimated by reading the cylinder pressure with a pressure gauge and multiplying the pressure reading by a fudge factor of 0.3. This method is impractical to use with a gas machine, however, because the gas machine typically is not exposed to the full pressure range of the gas cylinder. Rather, a gas machine typically operates with a gas supply at a pressure between 45 and 75 psi.

Another problem that is encountered with gas machines involves the use of gases such as nitrous oxide. A full E-size nitrous oxide gas cylinder contains approximately 1,600 liters of nitrous oxide at a pressure of 750 psi. However, nitrous oxide is present in the cylinder in both liquid and gas forms. The pressure of the cylinder remains constant at 750 psi until all the liquid is depleted and the remaining gas is used. Then the pressure falls drastically, leaving the user administering the gas with the time-sensitive decision of whether to continue with the operation. One way to accurately estimate the amount of nitrous oxide gas remaining is to weigh the cylinder, however this is impractical for a gas machine.

An aspect of the present disclosure provides a unique system and method of determining the amount of gas remaining in a gas tank, and displaying information associated with this determined amount of remaining gas to a suitable party. Providing this information and knowing about the amount of gas

or time remaining can help healthcare providers prepare for switching gas tanks during a procedure, or can help plan for ordering additional gas supplies, for example.

According to an aspect, a gas distribution system includes at least one
5 gas tank containing at least one gas, at least one flow sensor arranged in a flow passage fluidly connected to the at least one gas tank, and at least one controller operatively connected to the at least one flow sensor, the at least one controller being configured to: (i) track an amount of gas dispensed from the at least one gas tank by integrating flow rate of the gas over time, wherein the flow
10 rate is measured by the at least one flow sensor; (ii) determine the amount of the gas remaining in the at least one gas tank by subtracting the dispensed amount of the gas from an initial amount of the gas in the at least one gas tank; and (iii) send information associated with the determined amount of gas remaining in the at least one gas tank to an indicator for providing a notification.

15 According to another aspect, a gas distribution system includes: a gas distribution manifold comprising a first inlet for receiving a first gas from a first gas tank, and a second inlet for receiving a second gas from a second gas tank, the gas distribution manifold being configured to mix the first and second gases at a selected ratio and dispense the mixed gas via an outlet of the gas
20 distribution manifold; a first flow sensor and a first valve respectively arranged in a first flow passage fluidly connectable to the first gas tank; at least one controller operatively connected to the first flow sensor, the at least one controller being configured to: (i) track an amount of the first gas dispensed from the first tank by integrating flow rate of the first gas over time, wherein the flow
25 rate is measured by the first flow sensor; (ii) determine the amount of the first gas remaining in the first tank by subtracting the dispensed amount of the first gas from an initial amount of the first gas in the first gas tank; and (iii) send information associated with the determined amount of the first gas remaining in the first gas tank to an indicator for notifying a user.

30 According to another aspect, a method of determining an amount of gas remaining in a gas tank of a gas machine, includes: providing an initial amount of gas in the gas tank; dispensing an amount of gas from the gas tank; tracking the amount of gas dispensed by integrating flow rate over time, wherein the flow rate

is measured by a gas flow sensor; determining the amount of gas remaining in the gas tank by subtracting the amount of gas dispensed from the initial amount of gas in the gas tank; and sending information associated with the determined amount of gas remaining in the gas tank to an indicator for notifying a user.

5 The following description and the annexed drawings set forth certain illustrative embodiments of the invention. These embodiments are indicative, however, of but a few of the various ways in which the principles of the invention may be employed. Other objects, advantages and novel features according to aspects of the invention will become apparent from the following detailed
10 description when considered in conjunction with the drawings.

Brief Description of the Drawings

The annexed drawings, which are not necessarily to scale, show various aspects of the invention.

15 Fig. 1 is a perspective view of an exemplary gas distribution system including an exemplary portable gas machine according to an aspect of the present disclosure.

Fig. 2 is an exemplary schematic diagram of the gas distribution system including components embodied in the portable gas machine shown in Fig. 1.

20 Fig. 3 is an exemplary flow chart showing an exemplary method of operating the gas distribution system.

Figs. 4-8 show exemplary display views for a user interface of the gas distribution system.

Detailed Description

25 The principles and aspects according to the present disclosure have particular application to a system and method for determining and providing the remaining capacity of gas supply in a gas machine for anesthesia or analgesia, and will thus be described below chiefly in this context. Such machines may be
30 particularly advantageous for delivering anesthetic or analgesic gas in medical and dental applications. It also understood, however, that the principles and aspects according to the present disclosure may be applicable to other gas

distribution systems for other applications where such technology as described herein may be desirable.

Referring to Figs. 1 and 2, an exemplary embodiment of a gas distribution system 10 is shown. Fig. 1 shows the gas distribution system 10 including a portable gas machine 12. Fig. 2 shows an exemplary schematic diagram of the gas distribution system 10 including components embodied in the portable gas machine 12.

In the illustrated embodiment, the portable gas machine 12 includes a cart 14 having wheels 16 and holders 18 (e.g., mounts or straps) for suspending first gas tank(s) 20 and second gas tank (s) 22. The portable gas machine 12 may be used in the medical field as an analgesic gas machine, and the first gas tank(s) 20 may contain a first gas, such as oxygen, while the second gas tank(s) 22 may contain a second gas, such as nitrous oxide. The tanks 20, 22 may be any suitable type or size, such as E-size pressurized gas cylinders in the illustrated embodiment, in which the oxygen tanks 20 will contain 660 liters of oxygen (O_2) when full, and the nitrous oxide tanks 22 will contain 1,600 liters of nitrous oxide (N_2O) when full.

Also mounted to the cart 14 (also called an E-stand) is a housing 24 having a gas distribution manifold 26 (Fig. 2), a computer 27 with a user interface 28, and other components or accessories for administering the gas(es) or gas mixture to the patient P (Fig. 2). These other components and/or accessories may include, for example, one or more pressure gauges 29, suitable tubing 30 for administering the gas or gas mixture, a reservoir bag 32, a respirator (not shown), or the like.

Referring particularly to Fig. 2, the gas tanks 20 and 22 are shown operatively coupled to the gas distribution manifold 26 via respective fluid flow passages 34 and 36, which may include suitable connectors, conduits, tubing, or the like. One or more valves 38, 40 may be included in each of the respective fluid flow passages 34, 36. For example, the one or more valves 38, 40 may be manually-operated valves provided at an outlet of the gas tanks 20, 22 as is customary with such gas tanks.

As shown in the illustrated embodiment, the gas distribution manifold 26 of the system 10 includes at least one first inlet 42 for receiving the first gas

(e.g., oxygen) from the first gas tank(s) 20, and at least one second inlet 44 for receiving a second gas (e.g., nitrous oxide) from the second gas tank(s) 22. The gas distribution manifold 26 is configured to mix the first and second gases at a selected ratio and dispense the mixed gas via at least one outlet 46 of the gas distribution manifold 26. Generally, the gas distribution manifold 26 may be any suitable apparatus having suitable fluid flow passages 48, 49 and/or 50 for fluidly connecting the inlets 42, 44 to the outlet 46. In the illustrated embodiment, the gas distribution manifold 26 is contained within or forms a part of the housing 24 of the gas machine 12. To provide suitable mixing of the first and second gases, the gas distribution manifold 14 may include a suitable mixing region or mixer 52 (passive or active), such as a T-connection or chamber, fluidly connected to the fluid flow passages 48, 49, 50 between the inlets 42, 44 and outlet 46.

To measure the flow rate and enable tracking of the amount of each gas dispensed from the respective tanks 20, 22, the gas distribution system 12 includes a first flow sensor 54 arranged in the first fluid flow passage 48 that is fluidly connected to the first gas tank 20, and a second flow sensor 56 arranged in the second fluid flow passage 49 that is fluidly connected to the second gas tank 22. The first and second flow sensors 54, 56 may be any suitable sensor or combination of sensors configured to measure flow rate. The first and second flow sensors 54, 56 may be the same or may be different. In exemplary embodiments, each of the first and second flow sensors 54, 56 is a mass flow sensor that is configured to measure the mass flow rate of each gas. As is well-known to those having ordinary skill in the art, the flow rate using a mass flow sensor is calculated by measuring the amount of mass of a substance passing through the device for a given amount of time. In other embodiments, each of the first and second flow sensors 54, 56 is a volumetric flow sensor that is configured to measure the volumetric flow rate of each gas. In volumetric flow sensors, the flow rate is calculated by measuring the volume of a substance through the device over a given period. Because gas changes its density with temperature and pressure, mass flow sensors may provide a more accurate measurement and may be preferred in exemplary embodiments.

In exemplary embodiments, the gas distribution system 10 further includes one or more valves for selectively controlling flow through the first fluid

flow passage 48 and/or the second fluid flow passage 49. In the illustrated embodiment, the system 10 includes a first electronically-operable valve 58 arranged in the first fluid flow passage 48, and a second electronically-operable valve 60 arranged in the second fluid flow passage 49. The first and second valves 58, 60 may be located in the distribution manifold 26 or the housing 24 downstream of the respective inlets 42, 44 and upstream of the respective flow sensors 54, 56, as shown; or the valves 58, 60 may be located at any other suitable location, including outside of the manifold 26, outside of the housing 24, upstream of the respective inlets 42, 44, downstream of the flow sensors 54, 56, etc.

As shown in the illustrated embodiment, the gas distribution system 10 also includes a controller 62 that is operatively coupled to the first and second flow sensors 54, 56, and is operatively coupled to the first and second valves 58, 60. In exemplary embodiments, the controller 62 is part of the computer 27.

The controller 62 receives information associated with the gas flow rates measured by the flow sensors 54, 56, and may be configured to selectively control (e.g., open, close, modulate, etc.) gas flow across the valves 58, 60. The controller 62 may include any suitable apparatus, device(s), or machine(s) for receiving, processing and sending data, which may include suitable control circuitry configured to carry out various control operations, as described in further detail below. As such, the controller 62 may include by way of example, multiple controllers, electronic processor(s), such as a CPU, microcontroller(s), or microprocessor(s). The controller 62 also may include, in addition to hardware, code that creates an execution environment for a computer program to implement the features described herein. The code may be stored in a non-transitory computer readable medium of the computer 27, such as random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), or any other suitable medium.

Turning to Fig. 3, a flow chart showing an exemplary method of operating the gas distribution system 10, which may include an exemplary logic implemented by the controller 62, is shown.

The operation may begin with step 110 in which information associated with the initial amount of gas in each gas tank 20, 22 is provided. In exemplary

embodiments, this information is provided by the user via the user interface 28. Such information may include any suitable information about the amount of gas in the tank(s) 20, 22, such as the initial volume or mass of gas in the tank. Such information may be provided in any suitable manner, such as by selecting the
 5 standard type of gas tank (e.g., E-size), or by manually entering the initial amount of gas in each tank 20, 22, or both (e.g., selecting the type of tank and then manually editing the amount).

At step 112, the user (e.g., via the user interface 28) selects a total flow rate to the patient P and the ratio of gases to be delivered. Based upon this
 10 input, the controller 62 then calculates the flow rate of each gas that is needed to deliver the desired ratio. As an example of a nitrous oxide and oxygen gas machine, the user may choose to enter 10 Liters Per Minute (LPM) of total flow rate and 50% of oxygen. In such case, the gas machine provides a mixed gas flow of 5 Liters Per Minute of nitrous oxide and 5 Liters Per Minute of oxygen.
 15 As is apparent in the illustrated embodiment, the controller 62 receives information from each flow sensor 54 and 56 about the amount of gas flow through each passage 48 and 49 that is delivered to the mixing region (e.g., mixer) 52, and can automatically control the opening or closing amount of each valve 58, 60 in response to this information to achieve the desired total flow rate
 20 through the outlet 46 and the ratio of each gas.

At step 114, the controller 62 tracks the amount of each gas dispensed from the respective tanks 20, 22 by integrating the flow rate of each gas over time. This flow rate is measured by the respective flow sensors 54, 56 which is communicated to the controller 62. The amount of gas dispensed over the time
 25 period T can be obtained using the following formula:

$$V_{dispensed} = \int_0^T f(t)dt$$

Where V is volume, and $f(t)$ represents the gas flow rate at any given time. The controller 62 may store this information in a non-transitory computer readable medium of the computer 27.

30 At step 116, the controller 62 determines the amount of the gas remaining in each tank 20, 22 by subtracting the dispensed amount of each gas (as calculated in step 114) from the initial amount of each gas in each tank 20, 22

(as provided in step 110). For example, where the full tank volume is known by a standard and is selected, the amount of gas remaining can be estimated at any time by subtracting the total amount of gas dispensed from the full tank gas volume:

$$V_{remaining} = V_{full} - V_{dispensed}$$

where “V” is volume, with V_{full} representing the full tank gas volume.

At step 118, the controller 62 is configured to send information associated with the determined amount of gas remaining in each gas tank to an indicator. The indicator may include any suitable device or combination of devices for notifying the user (e.g., administrator of the gas) about this information. Such an indicator may include, but is not limited to, visual, audible, or tactile indicators. For example, the visual indicator may include a display panel, a counter, a beacon, or the like, which may be incorporated into the user interface 28. The information associated with the determined amount of gas remaining may include, but is not limited to, a percentage of gas remaining in each tank, a volume amount of gas remaining in each tank, a mass amount of gas remaining in each tank, an estimated amount of time remaining until the gas in each tank is depleted based upon the measured flow rate, an icon, beacon or series of lights indicating such information, or the like. In the case of estimating the time remaining before gas supply runs out, based on current flow rates used during delivery of the gases, the following formula may be used:

$$t_{remaining} = V_{remaining} / \text{current flow rate}$$

where “t” is time and “V” is volume.

Turning to Figs. 4-8, exemplary display views for the user interface 28 are shown. In the illustrated embodiment, the displays are on a touch-screen display which the operator can use to operate the gas distribution system 10.

Fig. 4 shows an exemplary main screen 210, or home screen, where the administrator (e.g., doctor or dentist) can select the total flow rate (section 212) and the ratio of gases to be delivered (section 214) according to step 112 described above. The main screen 210 also shows the individual flow rate of each gas (section 216).

Fig. 5 shows an embodiment of a display screen 217 that indicates information about the amount of gas dispensed from each gas tank. This screen

217 can be accessed by touching the tank icon 218 at the top of the screen. As shown in this embodiment, the total volume of oxygen dispensed is shown in section 220, and the total volume of nitrous oxide dispensed is shown in section 222. This screen 217 also includes a settings icon 224 which displays a
5 configuration window as shown in Fig. 6.

The configuration window 225 in Fig. 6 includes settings for enabling the user to provide information associated with the initial amount of gas in each gas tank according to step 110 described above. For example, as shown at section 226, the user can select the standard cylinder size based on options listed in a
10 drop-down menu. When the standard cylinder size is selected, a value is pre-filled into section 228 based on user selection. In this section, there also are +/- buttons that the user can use to make further adjustments. Each time +/- button is pressed, volume is incremented/decremented by an amount, such as 10. The configuration window 225 in Fig. 6 also includes a toggle switch 229 that enables
15 display of information about the amount of gas remaining in each gas tank.

The user interface 28 further allows the user to indicate when a full tank has been connected to the device, such as by selecting the reset buttons 230a and 230b (Fig. 5). The controller 62 may also automatically detect when a gas supply runs out and is then restored during administration of the gases, which
20 would indicate that the gas tank has been replaced. In such instance, the user interface 28 may prompt the user to confirm that the gas tank has been replaced.

Fig. 7 shows an embodiment of a display screen 231 that indicates the information about the remaining amount of gas in each tank according to step 118 described above. This screen 231 may be accessed by switching the toggle
25 switch 229 in Fig. 6. In this embodiment, the information includes a volume amount of gas remaining in each tank (as shown at sections 232a and 232b). In this embodiment, the information also includes an estimated amount of time remaining until the gas in each tank is depleted based upon the measured or selected flow rate (as shown at sections 234a and 234b). This information is
30 exemplary, and it is understood that fewer or greater sources of information may be displayed. It also is understood that the display of information for one gas (e.g., oxygen) may be configured differently than the information for the other gas (e.g., nitrous), or the information may be the same.

Fig. 8 shows another embodiment of a display screen 240 that indicates the information about the remaining amount of gas in each tank according to step 118 described above. This display screen 240 is similar to display screen 231, except that the information includes a percentage of gas remaining in the gas tanks, as shown at section 242.

An exemplary gas distribution system such as for a medical gas machine has been described herein which provides a useful method of determining the amount of gas remaining in a gas tank, and displaying information associated with this determined amount of remaining gas to a user.

While exemplary forms of the gas distribution system have been described above, it should be apparent to those having ordinary skill in the art that alternative configurations also could be employed. For example, although shown as incorporating a gas machine 12 for mixing two gases, it is understood that the gas distribution system 10 may take other suitable forms, including non-portable forms or may be used with a system containing only one gas, or more than two gases. In addition, although the valve(s) 58, 60 operatively coupled to the controller 62 are shown contained in the housing 24 and fluidly connected to fluid flow passages 48, 49, it is understood that the one or more of the valve(s) 58, 60 could be located outside of the housing 24, such as in fluid flow passages 34, 36, or could replace valve(s) 38, 40. Likewise, the flow sensor(s) 54, 56 could be located outside of the housing 24, such as in fluid flow passages 34, 36. The flow sensor(s) 54, 56 also could be located upstream of the valve(s) 58, 60. It also is understood that the indicator or display does not need to be connected to the machine 10 or computer 27, but could be a remote indicator or display, such as a smart phone or the like.

According to one aspect of the present disclosure, a gas distribution system includes: a gas distribution manifold comprising a first inlet for receiving a first gas from a first gas tank, and a second inlet for receiving a second gas from a second gas tank, the gas distribution manifold being configured to mix the first and second gases at a selected ratio and dispense the mixed gas via an outlet of the gas distribution manifold; a first flow sensor and a first valve respectively arranged in a first flow passage fluidly connectable to the first gas tank; at least one controller operatively connected to the first flow sensor, the at least one

controller being configured to: track an amount of the first gas dispensed from the first tank by integrating flow rate of the first gas over time, wherein the flow rate is measured by the first flow sensor; determine the amount of the first gas remaining in the first tank by subtracting the dispensed amount of the first gas from an initial amount of the first gas in the first gas tank; and send information
5 associated with the determined amount of the first gas remaining in the first gas tank to an indicator for notifying a user.

Embodiments may include one or more of the following additional features, separately or in any combination.

10 In some embodiments, the information associated with the determined amount of the first gas remaining includes an amount of the first gas remaining in units of volume or mass.

In some embodiments, the information associated with the determined amount of the first gas remaining includes a percentage of the first gas
15 remaining relative to the initial amount.

In some embodiments, the information associated with the determined amount of the first gas remaining includes an estimated amount of time remaining until the first gas in the first gas tank is depleted based upon the measured flow rate of the first gas.

20 In some embodiments, a second flow sensor and a second valve are respectively arranged in a second flow passage fluidly connectable to the second gas tank, and the at least one controller is operatively connected to the second flow sensor, the at least one controller being configured to: track an amount of the second gas dispensed from the second tank by integrating flow
25 rate of the second gas over time, wherein the flow rate is measured by the second flow sensor; determine the amount of the second gas remaining in the second tank by subtracting the dispensed amount of the second gas from an initial amount of the second gas in the first gas tank; and send information associated with the determined amount of the second gas remaining in the
30 second gas tank to the indicator for notifying the user.

In some embodiments, the gas distribution system includes the indicator, the indicator including a display.

In some embodiments, the first flow sensor and/or the second flow sensor

is a mass flow sensor.

In some embodiments, the first flow sensor and/or the second flow sensor is a volumetric flow sensor.

In some embodiments, the first flow sensor and/or the second flow sensor
5 is downstream of the respective first valve and/or second valve.

In some embodiments, further comprising a user interface, wherein the user interface is configured to enable a user to select a type of gas tank for determining the initial amount of the first gas and/or the second gas, and/or the user interface being configured to enable the user to manually enter the initial
10 amount of the first gas and/or the second gas.

In some embodiments, the user interface is configured to enable the user to select the flow rate of the first gas, the flow rate of the second gas, and/or the selected ratio between the first and second gas.

In some embodiments, the at least one controller is configured to
15 automatically adjust the first valve and/or the second valve based upon the selected flow rate and/or the selected ratio.

In some embodiments, including a portable medical gas machine that includes a first holder for holding the first gas tank containing the first gas, and a second holder for holding the second gas tank containing the second gas,
20 wherein the portable medical gas machine includes a cart or stand on which the gas distribution manifold, the first valve, the first flow sensor, and the indicator are operatively mounted.

In some embodiments, further comprising the first gas tank and the second gas tank, wherein the first gas is nitrous oxide and the second gas is
25 oxygen.

According to another aspect, a gas distribution system includes: at least one gas tank containing at least one gas; at least one flow sensor arranged in a flow passage fluidly connected to the at least one gas tank; at least one controller operatively connected to the at least one flow sensor, the at least one
30 controller being configured to: track an amount of gas dispensed from the at least one gas tank by integrating flow rate of the gas over time, wherein the flow rate is measured by the at least one flow sensor; determine the amount of the gas remaining in the at least one gas tank by subtracting the dispensed amount

of the gas from an initial amount of the gas in the at least one gas tank; and send information associated with the determined amount of gas remaining in the at least one gas tank to an indicator for providing a notification.

Embodiments may include one or more of the foregoing or following
5 additional features, separately or in any combination.

According to another aspect, a method of determining an amount of gas remaining in a gas tank of a gas machine, includes: providing an initial amount of gas in the gas tank; dispensing an amount of gas from the gas tank; tracking the amount of gas dispensed by integrating flow rate over time, wherein the flow rate
10 is measured by a gas flow sensor; determining the amount of gas remaining in the gas tank by subtracting the amount of gas dispensed from the initial amount of gas in the gas tank; and sending information associated with the determined amount of gas remaining in the gas tank to an indicator for notifying a user.

Embodiments may include one or more of the foregoing or following
15 additional features, separately or in any combination.

In some embodiments, the gas flow sensor is a mass flow sensor.

In some embodiments, the gas flow sensor is a volumetric flow sensor.

In some embodiments, the providing the initial amount of gas is preselected based on a type of the gas tank, or is manually entered by a user.

20 In some embodiments, the dispensing includes selecting the flow rate of the dispensed gas.

In some embodiments, the selecting the flow rate of the dispensed gas includes adjusting a valve in a fluid passage that is fluidly connected to an outlet of the gas tank.

25 In some embodiments, the adjusting the valve includes automatically adjusting the valve by a controller based upon a comparison of the measured flow rate to a setpoint flow rate value.

In some embodiments, the gas in the gas tank is a first gas in a first gas tank, the method further comprising: providing an initial amount of a second gas
30 in a second gas tank; dispensing an amount of the second gas from the second gas tank at a selected ratio with the dispensing of the first gas from the first gas tank; tracking the amount of the second gas dispensed by integrating flow rate over time, wherein the flow rate is measured by a gas flow sensor; determining

the amount of gas remaining by subtracting the amount of gas dispensed from the initial amount of gas; displaying on a visual display the determined amount of gas remaining and/or an estimated time remaining until the determined amount of gas remaining is completely depleted based upon the measured flow rate.

5 In some embodiments, the controller, the valve, and the gas flow sensor are part of a gas machine.

 In some embodiments, the gas machine is a continuous-flow anesthesia or analgesia gas machine, and wherein the gas nitrous oxide.

 As used herein, an “operative connection,” or a connection by which
10 entities are “operatively connected,” is one in which the entities are connected in such a way that the entities may perform as intended. An operative connection may be a direct connection or an indirect connection in which an intermediate entity or entities cooperate or otherwise are part of the connection or are in between the operatively connected entities. An operative connection or coupling
15 may include the entities being integral and unitary with each other.

 An “operative connection,” or a connection by which entities are “operatively connected,” also is one in which signals, physical communications, or logical communications may be sent or received. Typically, an operative connection includes a physical interface, an electrical interface, or a data
20 interface, but it is to be noted that an operative connection may include differing combinations of these or other types of connections sufficient to allow operative control. For example, two entities can be operatively connected by being able to communicate signals to each other directly or through one or more intermediate entities like a processor, operating system, a logic, software, or other entity.
25 Logical or physical communication channels can be used to create an operative connection.

 It is understood that embodiments of the subject matter described in this specification can be implemented in combination with digital electronic circuitry, controllers, processors, computer software, firmware, and/or hardware. For
30 example, embodiments may be implemented in a gas distribution system that uses one or more modules of computer program instructions encoded on a non-transitory computer-readable medium for execution by, or to control the operation of, data processing apparatus.

In the flow diagram(s), blocks may denote "processing blocks" that may be implemented with logic. The processing blocks may represent a method step or an apparatus element for performing the method step. A flow diagram does not depict syntax for any particular programming language, methodology, or style (e.g., procedural, object-oriented). Rather, a flow diagram illustrates functional information one skilled in the art may employ to develop logic to perform the illustrated processing. It will be appreciated that in some examples, program elements like temporary variables, routine loops, and so on, are not shown. It will be further appreciated that electronic and software applications may involve dynamic and flexible processes so that the illustrated blocks can be performed in other sequences that are different from those shown or that blocks may be combined or separated into multiple components.

"Logic," as used herein, includes but is not limited to hardware, firmware, software or combinations of each to perform a function(s) or an action(s), or to cause a function or action from another logic, method, or system. For example, based on a desired application or needs, logic may include a software controlled microprocessor, discrete logic like an application specific integrated circuit (ASIC), a programmed logic device, a memory device containing instructions, or the like. Logic may include one or more gates, combinations of gates, or other circuit components. Logic may also be fully embodied as software. Where multiple logical logics are described, it may be possible to incorporate the multiple logical logics into one physical logic. Similarly, where a single logical logic is described, it may be possible to distribute that single logical logic between multiple physical logics.

Algorithmic descriptions and representations used herein are the means used by those skilled in the art to convey the substance of their work to others. An algorithm or method is here, and generally, conceived to be a sequence of operations that produce a result. The operations may include physical manipulations of physical quantities. Usually, though not necessarily, the physical quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated in a logic and the like. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols,

characters, terms, numbers, or the like. It should be borne in mind, however, that these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities.

Unless specifically stated otherwise, it is appreciated that throughout the
5 description, terms like processing, computing, calculating, determining,
displaying, or the like, refer to actions and processes of a computer system,
logic, processor, or similar electronic device that manipulates and transforms
data represented as physical (electronic) quantities. It will be appreciated that
the processes may be implemented using various programming approaches like
10 machine language, procedural, object oriented or artificial intelligence
techniques. In one example, methodologies are implemented as processor
executable instructions or operations provided on a computer-readable medium.
Thus, in one example, a computer-readable medium may store processor
executable instructions operable to perform a method. The computer-readable
15 medium may be a hard-drive, a machine-readable storage device, a memory
device, or a combination of one or more of them.

The controller may include all apparatus, devices, and machines for
processing data, including by way of example a programmable processor, a
computer, or multiple processors or computers. The controller may include, in
20 addition to hardware, code that creates an execution environment for the
computer program in question. The computer program (also referred to as
software or code), may be deployed in any form, including as a stand-alone
program or as a module, component, subroutine, or other unit suitable for use in
a computing environment. The computer program may be deployed to be
25 executed on one computer or on multiple computers that are located at one site
or distributed across multiple sites and interconnected by a communication
network. The processor may include all apparatus, devices, and machines
suitable for the execution of a computer program, which may include, by way of
example, both general and special purpose microprocessors, and any one or
30 more processors of any kind of digital computer. Generally, the processor will
receive instructions and data from a read-only memory or a random access
memory or both. The computer may include, or be operatively coupled to
receive data from or transfer data to, or both, one or more mass storage devices

for storing data. Devices suitable for storing computer program instructions and data include all forms of non-volatile memory, media and memory devices, including by way of example semiconductor memory devices. The processor and the memory can be supplemented by, or incorporated in, special purpose
5 logic circuitry.

To provide for interaction with a user, embodiments may be implemented using a computer having a display device and an input device. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback, e.g., visual
10 feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input. Embodiments may include a computing system that includes a back-end component (e.g., as a data server), or that includes a middleware component (e.g., an application server), or that includes a front-end component (e.g., a client computer having a
15 graphical user interface through which a user can interact with an implementation of the subject matter described in this specification), or any combination of one or more such back-end, middleware, or front-end components. The components of the system can be interconnected by any form or medium of digital data communication.

20 It is to be understood that terms such as "top," "bottom," "upper," "lower," "left," "right," "front," "rear," "forward," "rearward," and the like as used herein may refer to an arbitrary frame of reference, rather than to the ordinary gravitational frame of reference.

It is to be understood that all ranges and ratio limits disclosed in the
25 specification and claims may be combined in any manner. It is to be understood that unless specifically stated otherwise, references to "a," "an," and/or "the" may include one or more than one, and that reference to an item in the singular may also include the item in the plural.

The term "about" as used herein refers to any value which lies within the
30 range defined by a variation of up to $\pm 10\%$ of the stated value, for example, $\pm 10\%$, $\pm 9\%$, $\pm 8\%$, $\pm 7\%$, $\pm 6\%$, $\pm 5\%$, $\pm 4\%$, $\pm 3\%$, $\pm 2\%$, $\pm 1\%$, $\pm 0.01\%$, or $\pm 0.0\%$ of the stated value, as well as values intervening such stated values.

The phrase “and/or” should be understood to mean “either or both” of the elements so conjoined, i.e., elements that are conjunctively present in some cases and disjunctively present in other cases. Other elements may optionally be present other than the elements specifically identified by the “and/or” clause,
5 whether related or unrelated to those elements specifically identified unless clearly indicated to the contrary. Thus, as a non-limiting example, a reference to “A and/or B,” when used in conjunction with open-ended language such as “comprising” can refer, in one embodiment, to A without B (optionally including elements other than B); in another embodiment, to B without A (optionally
10 including elements other than A); in yet another embodiment, to both A and B (optionally including other elements); etc.

The word “or” should be understood to have the same meaning as “and/or” as defined above. For example, when separating items in a list, “or” or “and/or” shall be interpreted as being inclusive, i.e., the inclusion of at least one,
15 but also including more than one, of a number or list of elements, and, optionally, additional unlisted items. Only terms clearly indicated to the contrary, such as “only one of” or “exactly one of,” may refer to the inclusion of exactly one element of a number or list of elements. In general, the term “or” as used herein shall only be interpreted as indicating exclusive alternatives (i.e. “one or the
20 other but not both”) when preceded by terms of exclusivity, such as “either,” “one of,” “only one of,” or “exactly one of.”

The transitional words or phrases, such as “comprising,” “including,” “carrying,” “having,” “containing,” “involving,” “holding,” and the like, are to be understood to be open-ended, i.e., to mean including but not limited to.

25 Although the invention has been shown and described with respect to a certain embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In particular regard to the various functions performed by the above described elements
30 (components, assemblies, devices, compositions, etc.), the terms (including a reference to a “means”) used to describe such elements are intended to correspond, unless otherwise indicated, to any element which performs the specified function of the described element (i.e., that is functionally equivalent),

even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiment or embodiments of the invention. In addition, while a particular feature of the invention may have been described above with respect to only one or more of several illustrated
5 embodiments, such feature may be combined with one or more other features of the other embodiments, as may be desired and advantageous for any given or particular application.

Claims

What is claimed is:

1. A gas distribution system, comprising:
 - 5 a gas distribution manifold comprising a first inlet for receiving a first gas from a first gas tank, and a second inlet for receiving a second gas from a second gas tank, the gas distribution manifold being configured to mix the first and second gases at a selected ratio and dispense the mixed gas via an outlet of the gas distribution manifold;
 - 10 a first flow sensor and a first valve respectively arranged in a first flow passage fluidly connectable to the first gas tank;
at least one controller operatively connected to the first flow sensor, the at least one controller being configured to:
track an amount of the first gas dispensed from the first tank by
15 integrating flow rate of the first gas over time, wherein the flow rate is measured by the first flow sensor;
determine the amount of the first gas remaining in the first tank by
subtracting the dispensed amount of the first gas from an initial amount of the first gas in the first gas tank; and
20 send information associated with the determined amount of the first gas remaining in the first gas tank to an indicator for notifying a user.
2. The gas distribution system according to claim 1, wherein the
information associated with the determined amount of the first gas remaining
25 includes an amount of the first gas remaining in units of volume or mass.
3. The gas distribution system according to claim 1, or any other
preceding claim, wherein the information associated with the determined amount
of the first gas remaining includes a percentage of the first gas remaining relative
30 to the initial amount.
4. The gas distribution system according to claim 1, or any other
preceding claim, wherein the information associated with the determined amount

of the first gas remaining includes an estimated amount of time remaining until the first gas in the first gas tank is depleted based upon the measured flow rate of the first gas.

- 5 5. The gas distribution system according to claim 1, or any other preceding claim, wherein a second flow sensor and a second valve are respectively arranged in a second flow passage fluidly connectable to the second gas tank, and the at least one controller is operatively connected to the second flow sensor, the at least one controller being configured to:
- 10 track an amount of the second gas dispensed from the second tank by integrating flow rate of the second gas over time, wherein the flow rate is measured by the second flow sensor;
- determine the amount of the second gas remaining in the second tank by subtracting the dispensed amount of the second gas from an initial amount of the
- 15 second gas in the first gas tank; and
- send information associated with the determined amount of the second gas remaining in the second gas tank to the indicator for notifying the user.

6. The gas distribution system according to claim 1, or any other
- 20 preceding claim, wherein the gas distribution system includes the indicator, the indicator including a display.

7. The gas distribution system according to claim 5, or any other preceding claim, wherein the first flow sensor and/or the second flow sensor is a
- 25 mass flow sensor.

8. The gas distribution system according to claim 5, or any other preceding claim, wherein the first flow sensor and/or the second flow sensor is a volumetric flow sensor.

30

9. The gas distribution system according to claim 5, or any other preceding claim, wherein the first flow sensor and/or the second flow sensor is downstream of the respective first valve and/or second valve.

10. The gas distribution system according to claim 5, or any other preceding claim, further comprising a user interface, wherein the user interface is configured to enable a user to select a type of gas tank for determining the initial
5 amount of the first gas and/or the second gas, and/or the user interface being configured to enable the user to manually enter the initial amount of the first gas and/or the second gas.

11. The gas distribution system according to claim 10, or any other
10 preceding claim,
wherein the user interface is configured to enable the user to select the flow rate of the first gas, the flow rate of the second gas, and/or the selected ratio between the first and second gas, and
wherein the at least one controller is configured to automatically adjust the
15 first valve and/or the second valve based upon the selected flow rate and/or the selected ratio.

12. The gas distribution system according to claim 1, or any other preceding claim, including a portable medical gas machine that includes a first
20 holder for holding the first gas tank containing the first gas, and a second holder for holding the second gas tank containing the second gas, wherein the portable medical gas machine includes a cart or stand on which the gas distribution manifold, the first valve, the first flow sensor, and the indicator are operatively
mounted.

25

13. The gas distribution system according to claim 1, or any other preceding claim, further comprising the first gas tank and the second gas tank, wherein the first gas is nitrous oxide and the second gas is oxygen.

30 14. A method of determining an amount of gas remaining in a gas tank of a gas machine, comprising:
providing an initial amount of gas in the gas tank;
dispensing an amount of gas from the gas tank;

tracking the amount of gas dispensed by integrating flow rate over time,
wherein the flow rate is measured by a gas flow sensor;

determining the amount of gas remaining in the gas tank by subtracting
the amount of gas dispensed from the initial amount of gas in the gas tank; and

5 sending information associated with the determined amount of gas
remaining in the gas tank to an indicator for notifying a user.

15. The method according to claim 14, wherein the gas flow sensor is
a mass flow sensor.

10

16. The method according to claim 14 or claim 15, wherein the gas
flow sensor is a volumetric flow sensor.

17. The method according to any one of claims 14-16, wherein the
15 providing the initial amount of gas is preselected based on a type of the gas
tank, or is manually entered by a user.

18. The method according to any one of claims 14-17, wherein the
dispensing includes selecting the flow rate of the dispensed gas.

20

19. The method according to claim 18, or any other preceding claim,
wherein the selecting the flow rate of the dispensed gas includes adjusting a
valve in a fluid passage that is fluidly connected to an outlet of the gas tank.

25 20. The method according to claim 19, or any other preceding claim,
wherein the adjusting the valve includes automatically adjusting the valve by a
controller based upon a comparison of the measured flow rate to a setpoint flow
rate value.

30 21. The method according any one of claims 14-20,
wherein the gas in the gas tank is a first gas in a first gas tank, the
method further comprising:
providing an initial amount of a second gas in a second gas tank;

dispensing an amount of the second gas from the second gas tank at a selected ratio with the dispensing of the first gas from the first gas tank;

tracking the amount of the second gas dispensed by integrating flow rate over time, wherein the flow rate is measured by a gas flow sensor;

5 determining the amount of gas remaining by subtracting the amount of gas dispensed from the initial amount of gas;

displaying on a visual display the determined amount of gas remaining and/or an estimated time remaining until the determined amount of gas remaining is completely depleted based upon the measured flow rate.

10

22. The method according to claim 20, or any other preceding claim, wherein the controller, the valve, and the gas flow sensor are part of a gas machine.

15 23. The method according to claim 18, or any other preceding claim, wherein the gas machine is a continuous-flow anesthesia or analgesia gas machine, and wherein the gas nitrous oxide.

24. A gas distribution system comprising:
20 at least one gas tank containing at least one gas;
at least one flow sensor arranged in a flow passage fluidly connected to the at least one gas tank;

at least one controller operatively connected to the at least one flow sensor, the at least one controller being configured to:

25 track an amount of gas dispensed from the at least one gas tank by integrating flow rate of the gas over time, wherein the flow rate is measured by the at least one flow sensor;

determine the amount of the gas remaining in the at least one gas tank by subtracting the dispensed amount of the gas from an initial amount of the gas in
30 the at least one gas tank; and

send information associated with the determined amount of gas remaining in the at least one gas tank to an indicator for providing a notification.

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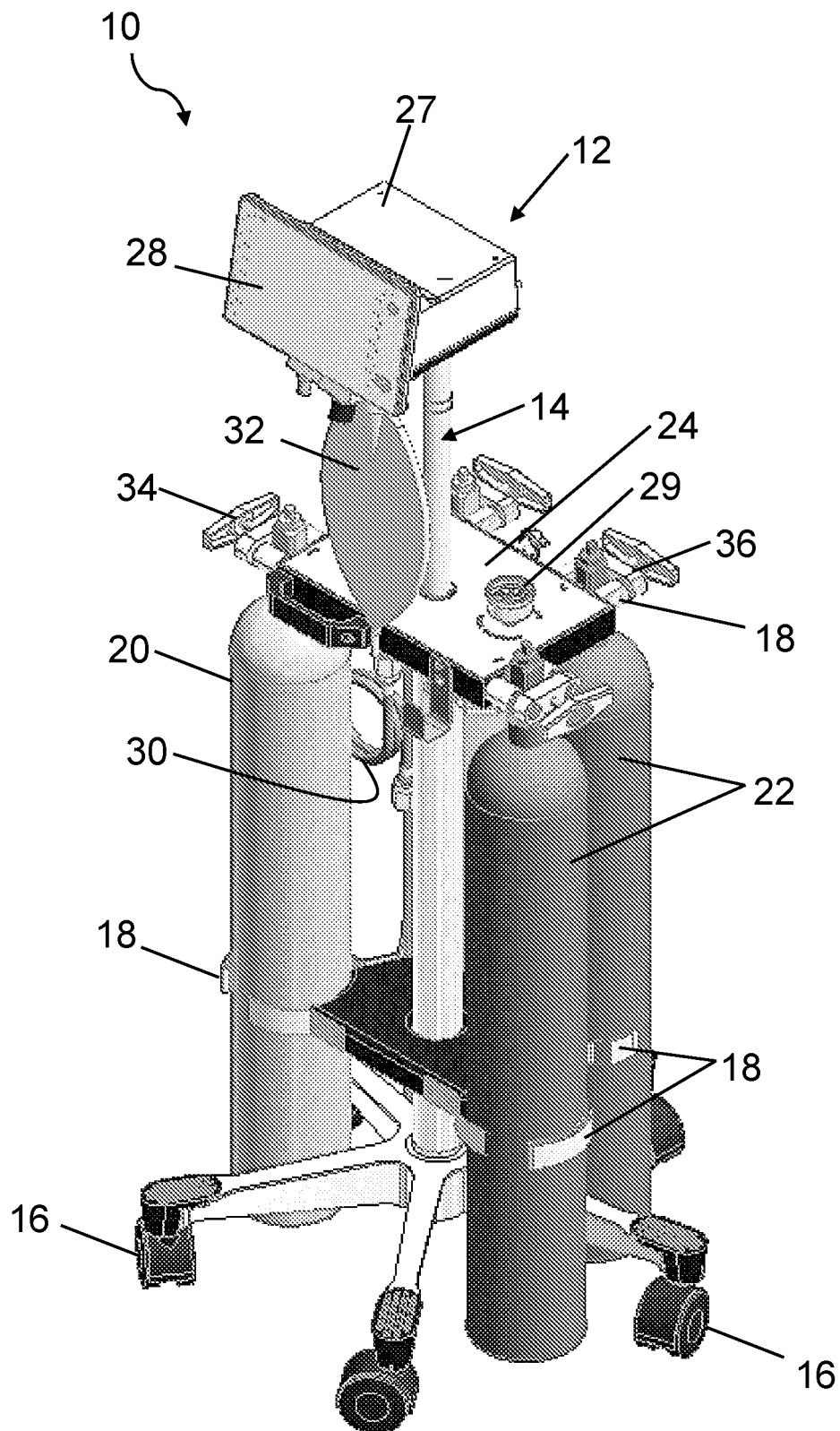


FIG. 1

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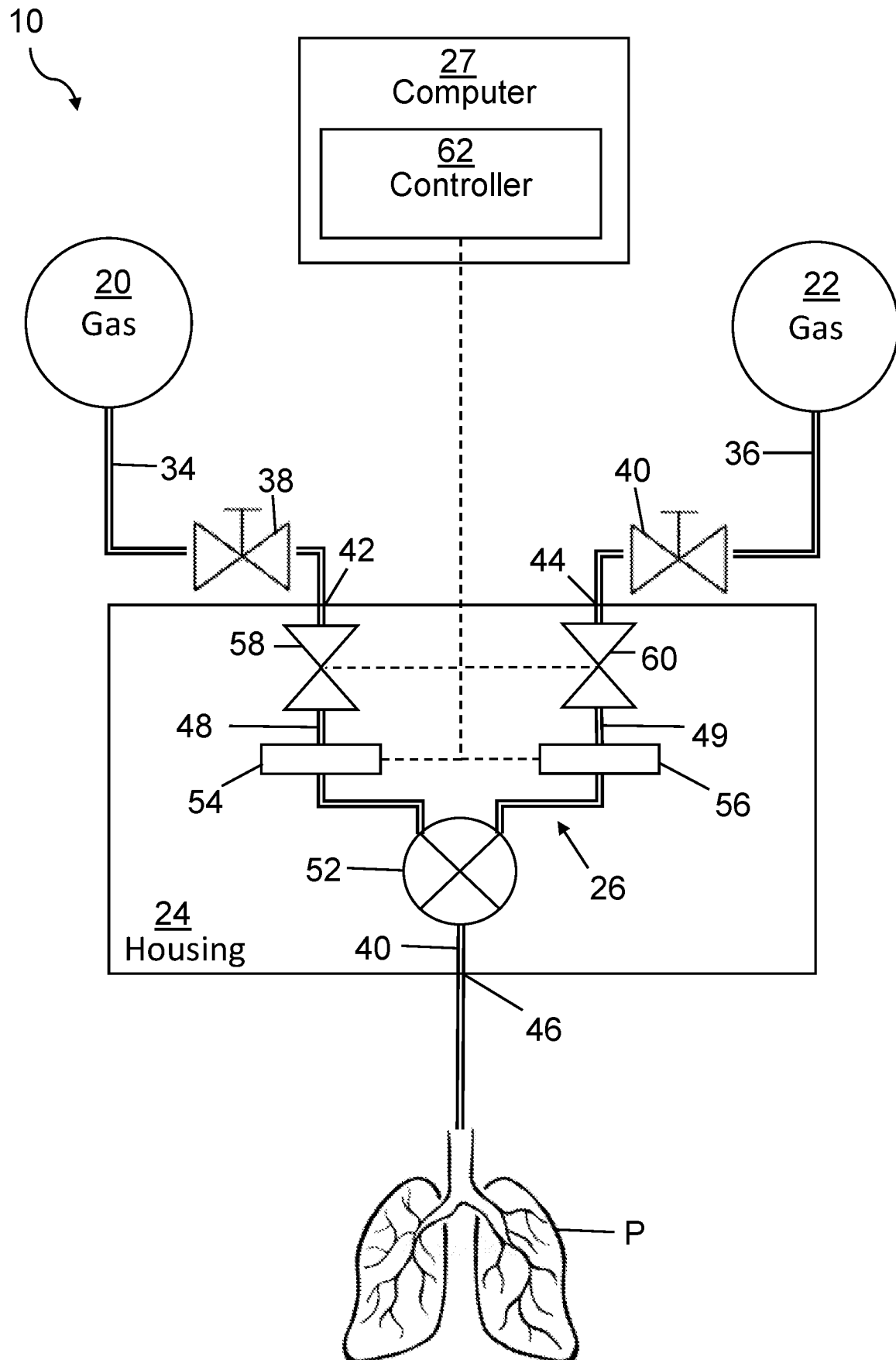


FIG. 2

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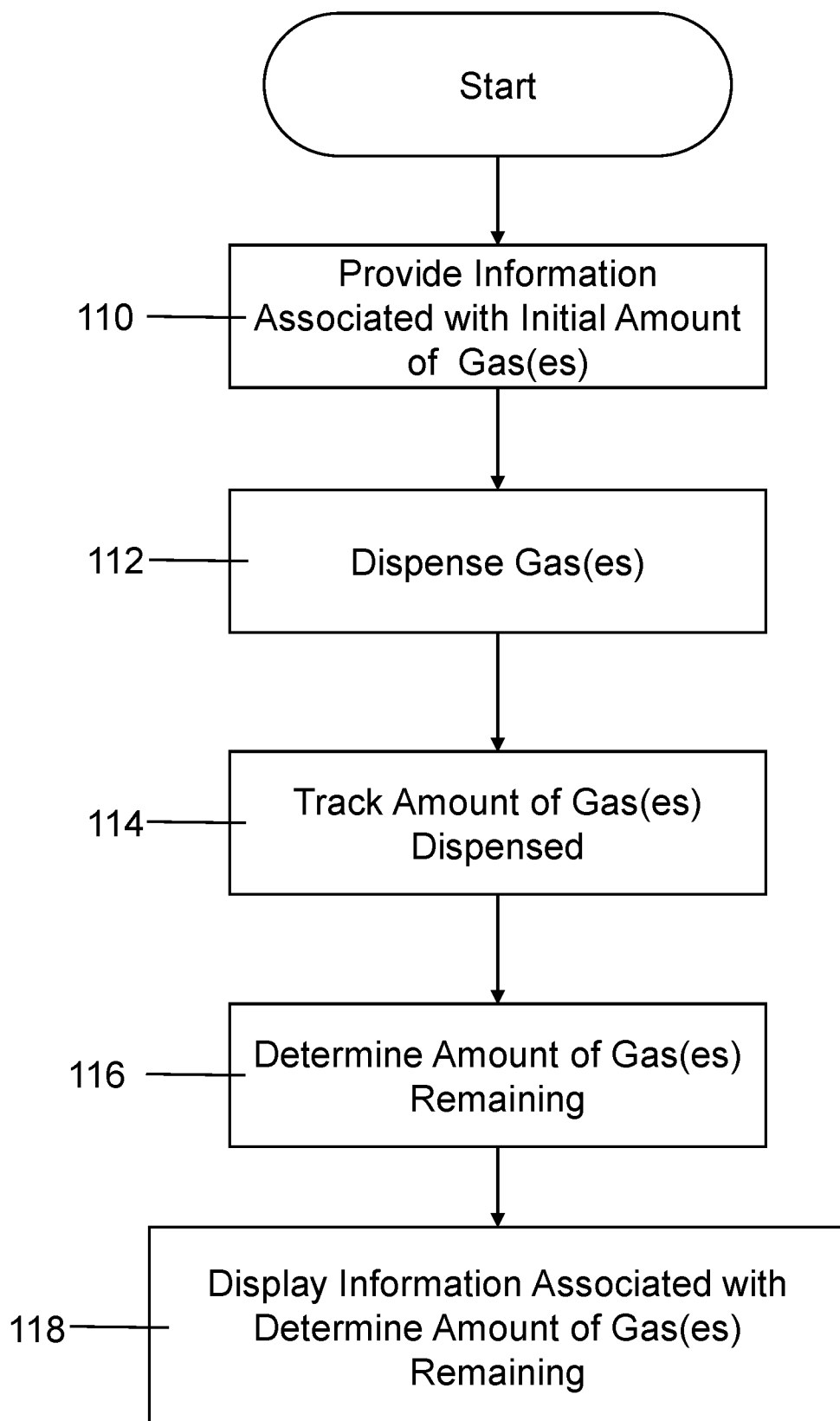


FIG. 3

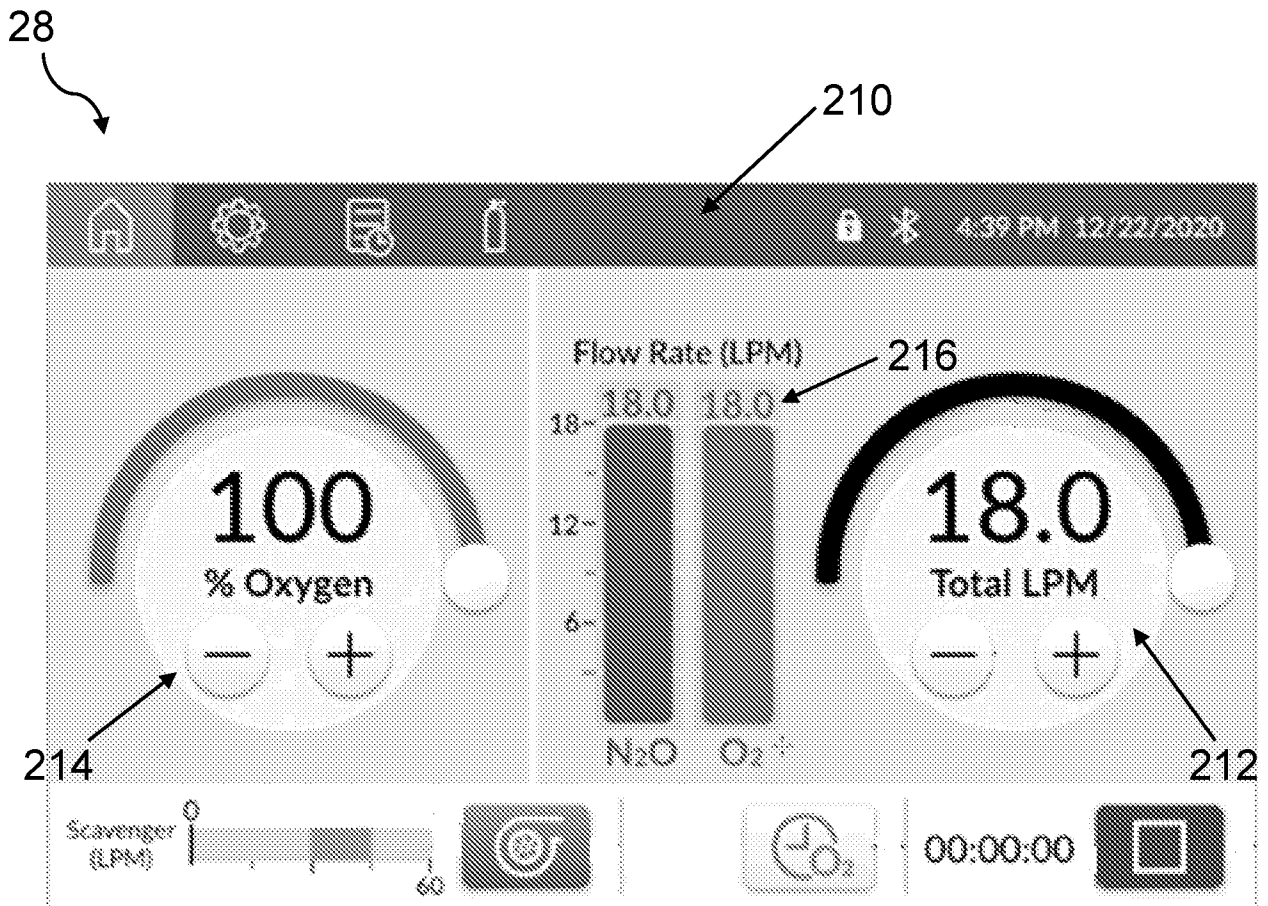


FIG. 4

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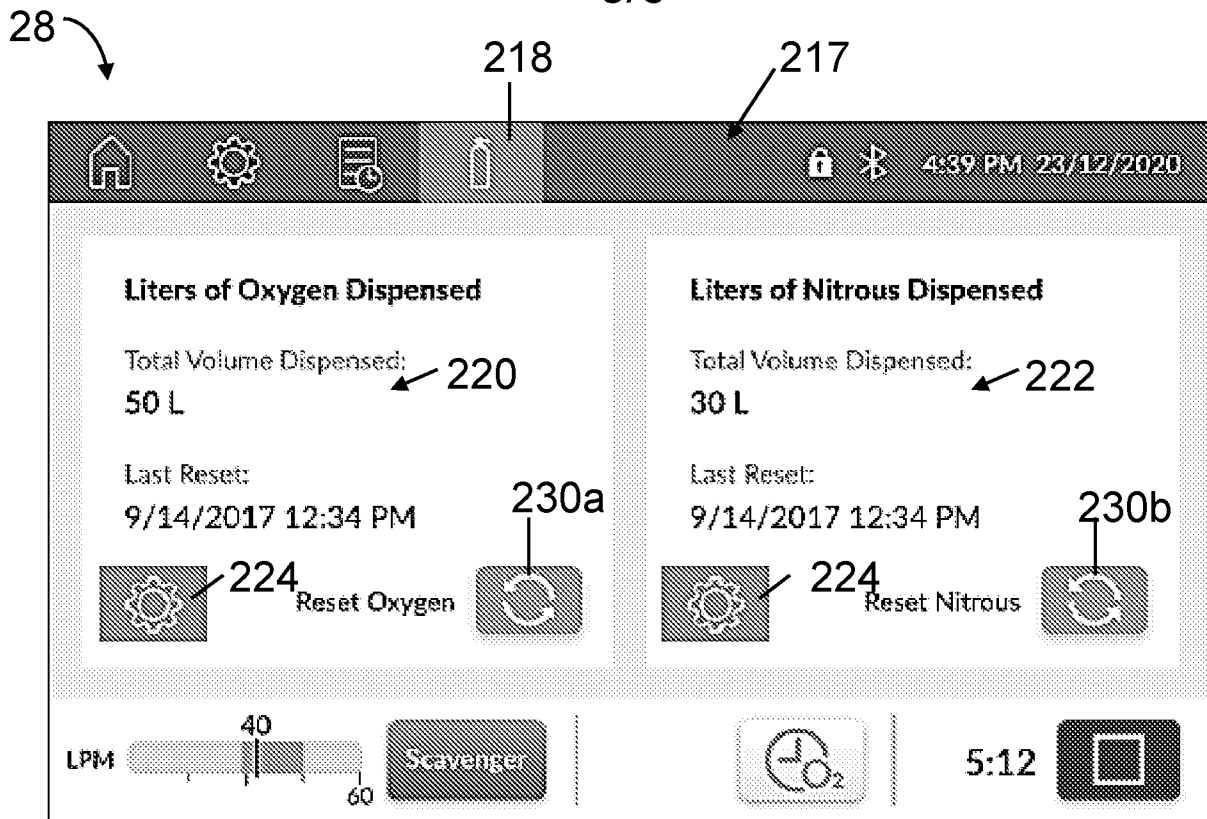


FIG. 5

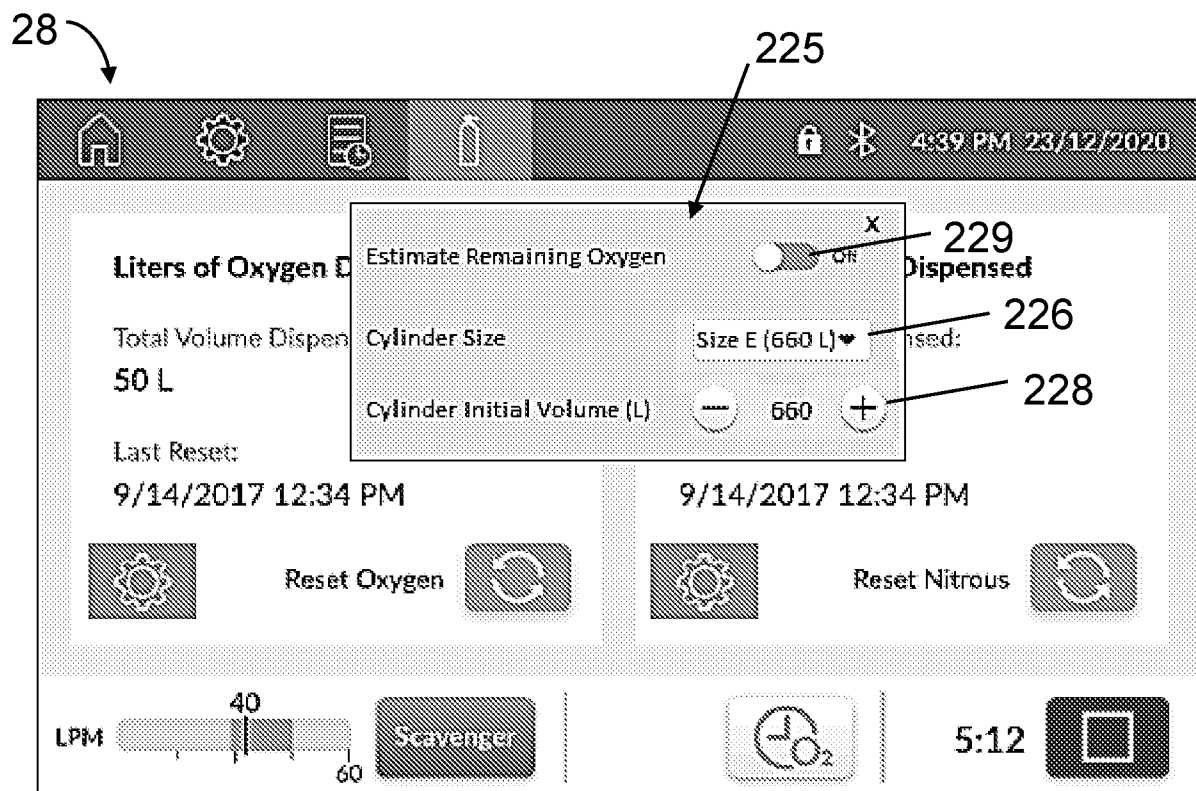


FIG. 6

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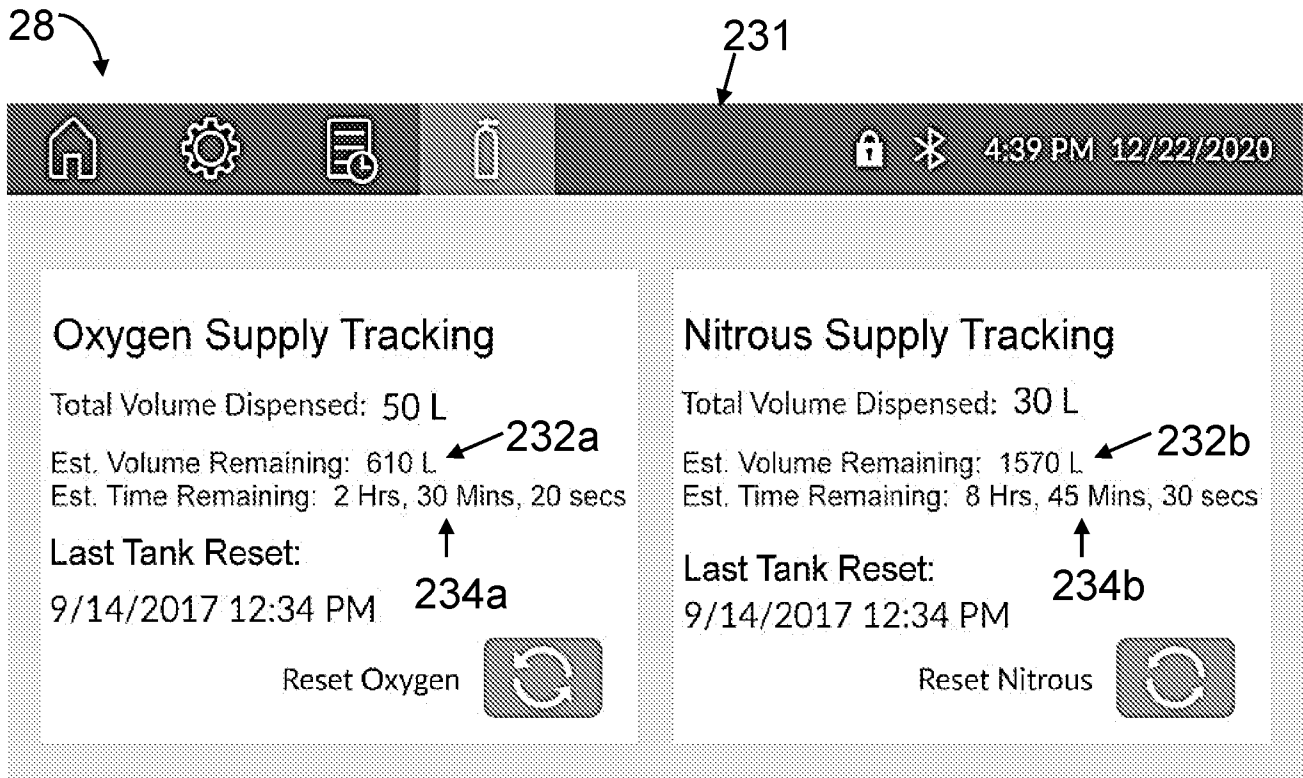


FIG. 7

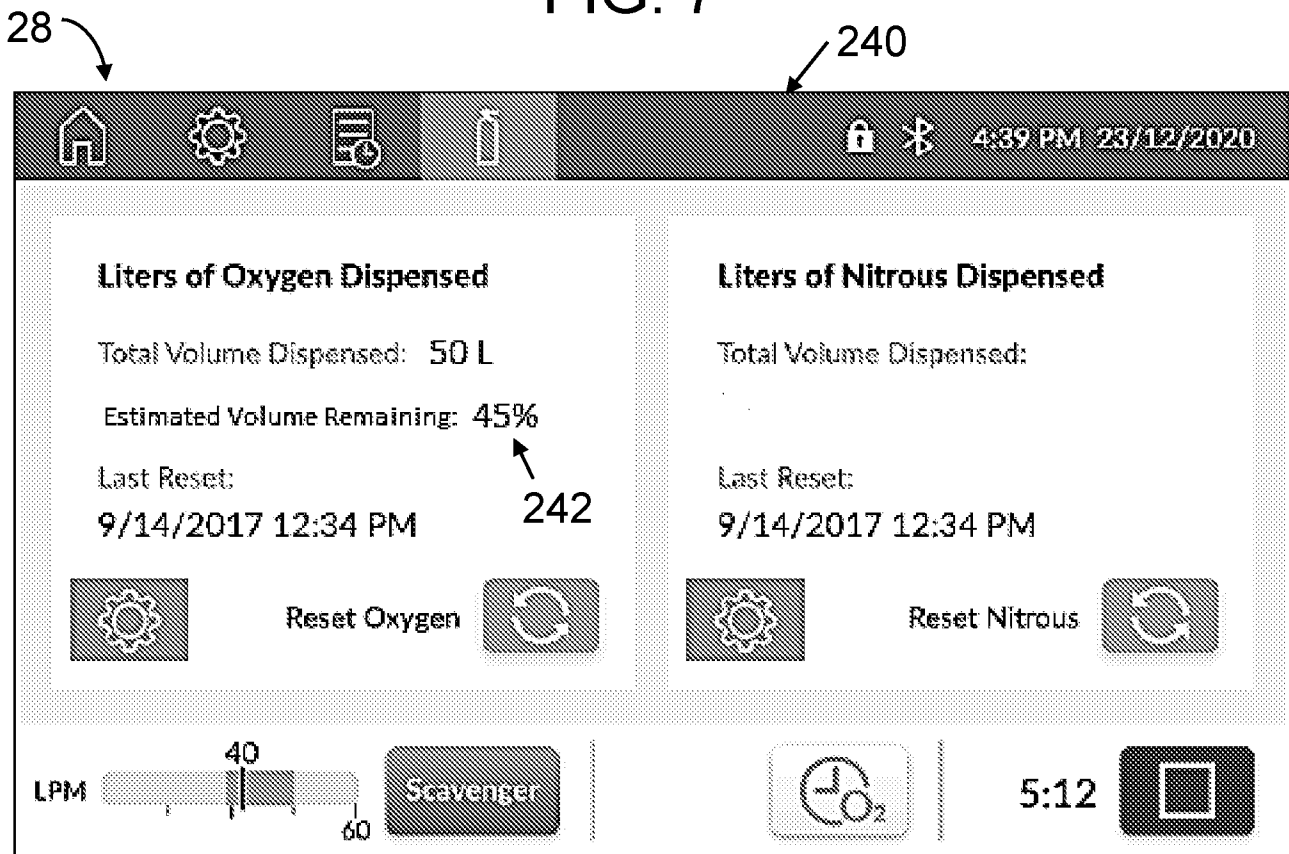


FIG. 8

International application No
PCT/US2021/050158

A. CLASSIFICATION OF SUBJECT MATTER INV. A61M16/00 A61M16/10 A61M16/12 F17C13/02 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 A62C A62B F17C				
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	JP 2007 309778 A (YAMATAKE CORP) 29 November 2007 (2007-11-29)	1-10, 14-17, 21		
Y	figure 1 and 4 paragraph [0007] paragraph [0021] - paragraph [0025] paragraph [0032] -----	1-24		
Y	US 2018/339279 A1 (BALDUS FABIAN [DE]) 29 November 2018 (2018-11-29) figure 1B figures 2A-B paragraph [0033] - paragraph [0034] paragraph [0071] - paragraph [0081] paragraph [0097] paragraph [0106] ----- -/--	1-24		
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.				
* Special categories of cited documents : <table border="0"> <tr> <td> "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 </td> <td> "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 </td> </tr> </table>			"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
"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 3 December 2021		Date of mailing of the international search report 05/01/2022		
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Cecchini, Stefano		

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2021/050158

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 9 408 995 B2 (AHEARN DAVID J [US]) 9 August 2016 (2016-08-09) figures 4-6 figure 32 column 5, line 29 - line 36 -----	1-24

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2021/050158

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 2018339279 A1	29-11-2018	EP 3088032 A1	02-11-2016
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US 9408995 B2	09-08-2016	US 2015075525 A1	19-03-2015
		US 2017100553 A1	13-04-2017