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(54) Title: HIGH FLOW STEAM RESPIRATORY TREATMENT APPARATUS

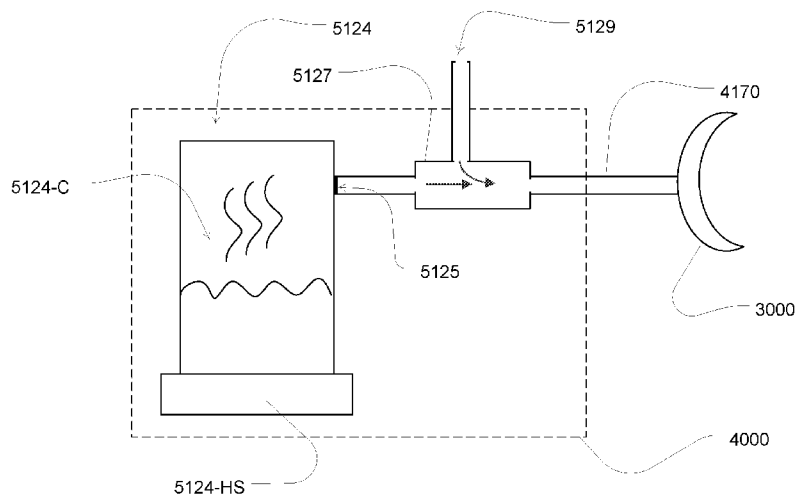


FIG. 5

(57) Abstract: A respiratory treatment apparatus generates a flow of breathable gas such as for a respiratory therapy. In an example, the apparatus may employ one or more steam cells. The steam cell may generate a flow of steam for the respiratory therapy. In some examples, the flow of steam from the steam cell may be applied to be mixer. The mixer may be configured to combine the steam from the mixer with air, such as ambient air. In some versions, the mixer may be a discrete component or integrally formed within a housing or chamber of the steam cell. Optionally, the mixer may include one or more venturi jets configured to accelerate the flow of steam and entrain the air for delivery as a breathable gas treatment for a patient or user.



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HIGH FLOW STEAM RESPIRATORY TREATMENT APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of the filing date of United States Provisional Patent Application No. 61/835,861 filed June 17, 2013, the disclosure of which is hereby incorporated herein by reference.

FIELD OF THE TECHNOLOGY

[0002] The present technology relates to methods and apparatus for generating respiratory therapy. More particularly, the technology relates to a respiratory therapy supplied to a patient generated with a high flow steam apparatus.

BACKGROUND OF THE TECHNOLOGY

[0003] CPAP treatment of SDB may involve the delivery of a pressurised breathable gas, usually air, to a patient's airways using a conduit and mask. Gas pressures employed for CPAP typically range from 4 cm H₂O to 28 cm H₂O, at flow rates of up to 180 L/min (measured at the mask), depending on patient requirements. The pressurised gas is said to act as a pneumatic splint for the patient's airway, preventing airway collapse, especially during the inspiratory phase of respiration. In a Bi-Level PAP device, a higher pressure is provided during an inspiration phase of the breathing cycle and a lower pressure is provided during an expiration phase of the breathing cycle in order to provide improved breathing comfort for the patient. In some CPAP devices, an expiratory pressure relief, which may be considered a drop in pressure of generally 1-3 cm H₂O from an inspiratory pressure treatment setting, is provided during an expiration phase compared to the inspiration phase.

[0004] CPAP apparatus typically include a flow generator that includes a blower for supplying pressurised

respiratory gas, such as air, to the patient via an air delivery tube leading to a patient interface, such as a nasal or oronasal mask, or nasal cushion or nasal pillows arrangement.

BRIEF SUMMARY OF THE TECHNOLOGY

[0005] One form of the present technology may involve an improved method and apparatus adapted to generate a flow of breathable gas for a user or patient.

[0006] In an example, a respiratory treatment apparatus may include one or more steam cells to generate a breathable gas therapy.

[0007] In some forms of the present technology, the generated therapy may include a flow of steam.

[0008] Some examples of the present technology may include a respiratory treatment apparatus to generate a flow of breathable gas. The apparatus may include a steam cell configured to generate a flow of steam. The apparatus may include a mixer coupled with the steam cell, the mixer configured to combine the flow of steam with a breathable gas. The apparatus may include a delivery circuit adapted to couple with the mixer. The delivery circuit may be configured to couple with a patient interface to provide steam heated breathable gas to the patient interface. In some cases, the flow of steam pressurizes the flow of breathable gas.

[0009] In some examples of the apparatus, the mixer may include an injector and an ejector. The mixer may include a mixing chamber between an injector and an ejector. The mixer may include a venturi jet. Optionally, the mixer may include a series of venturi jets. The mixer may include a circumferential series of venturi jets. The mixer may be integrated with the steam cell.

[0010] In some examples of the apparatus, the steam cell may include a heating coil heat source. The steam cell may include a combustible fuel heating source. Optionally, the apparatus may include a pressure sensor to detect a pressure level of a steam chamber of the steam cell. In some cases, the apparatus may include a temperature sensor to detect a temperature level of the steam cell. In some cases, a steam chamber of the steam cell may be coupled with a safety release valve. In some cases of the apparatus, a steam release port of the steam cell may be coupled with a proportional valve.

[0011] Optionally, the apparatus may include a hydro-filter. The hydro-filter may be configured to remove water from the steam heated breathable gas and permit transfer of the steam heated breathable gas. The apparatus may include a heat exchanger. The heat exchanger may be configured to condense water from the steam heated breathable gas. The apparatus may also include a liquid reservoir configured to collect water condensed from the steam heated breathable gas. The reservoir may be coupled with the steam cell to return the collected water to the steam cell.

[0012] In some cases, the apparatus may include a pump configured to pump water condensed from the steam heated breathable gas to the steam cell. The apparatus may include a pump configured to pump water condensed from the steam heated breathable gas to the steam cell upon detection of a presence of water with a water sensor. The apparatus may include a back flow conduit configured to return steam heated breathable gas to the mixer. In some cases, the apparatus may include a back flow conduit configured with a valve to selectively return steam heated breathable gas to a mixer in accordance with a detection of temperature with a temperature sensor.

[0013] In some cases, the apparatus may include a controller, such as one including a processor. The controller may be configured to control an operational parameter of the steam cell. In some cases, the controller may control a heat source of the steam cell in accordance with a detected pressure of the steam cell. In some cases, the controller may control a heat source of the steam cell in accordance with a detected temperature of the steam cell. In some cases, the controller may control a proportional valve to set a pressure level released from the steam cell. In some cases, the controller may control a change to a pressure level released from the steam cell in accordance with detection of a physiological parameter of a patient. In some cases, the controller may control a change to a pressure level released from the steam cell in accordance with detection of a respiratory cycle. In some cases, the controller may control a change to a pressure level released from the steam cell in accordance with detection of a sleep disordered breathing event.

[0014] In some cases, the apparatus may also include a steam turbine. The steam turbine may include a blower impeller. The steam turbine may include a liquid impeller. In some cases, the apparatus may include a venturi jet configured to direct a supply of steam from the steam cell to entrain a supply of water to the steam cell. In some cases, the apparatus may include a steam conduit configured with an exchanger material to exchange heat via the material. In some cases, the steam conduit may be proximate to a humidifier tank to warm a fluid of the tank. In some cases, the steam conduit may be proximate to a breathable gas supply conduit to warm a breathable gas of the breathable gas supply conduit.

[0015] Some examples of the present technology may involve a method for controlling a respiratory treatment apparatus. The method may involve generating a flow of steam from a steam cell. The method may also involve combining the flow of steam with a breathable gas in a mixer coupled with the steam cell to form steam heated breathable gas. In some cases of the method, a delivery circuit is adapted to couple with the mixer. The delivery circuit may be configured to couple with a patient interface to conduct the steam heated breathable gas to the patient interface. In some cases, the steam pressurizes the breathable gas.

[0016] In some versions of the method, the mixing may involve injecting the steam into a chamber and entraining the breathable gas with the steam through an ejector. In some cases, the mixer may include a mixing chamber between an injector and an ejector. Such a mixer may include a venturi jet, a series of venturi jets, and/or a circumferential series of venturi jets. Such a mixer may be integrated with the steam cell.

[0017] In some cases, the method may include heating water in the steam cell with a heating coil heat source and/or it may include heating water in the steam cell with a combustible fuel heating source. The method may include detecting a pressure level of a steam chamber of the steam cell with a pressure sensor. The method may include detecting a temperature level of the steam cell with a temperature sensor. In some cases, a steam chamber of the steam cell may be coupled with a safety release valve. In some cases, a steam release port of the steam cell may be coupled with a proportional valve.

[0018] Some versions of the method may involve filtering the steam heated breathable gas with a hydro-filter. The hydro-filter may remove water from the steam heated

breathable gas and permit transfer of the steam heated breathable gas. The method may also involve condensing water from the steam heated breathable gas with a heat exchanger. The method may also involve collecting water condensed from the steam heated breathable gas in a water reservoir coupled with the steam cell and may involve returning the collected water to the steam cell.

[0019] In some cases, the method may involve pumping water condensed from the steam heated breathable gas to the steam cell. In some cases, the method may involve pumping, with a pump, water condensed from the steam heated breathable gas to the steam cell upon detection of a presence of water with a water sensor. The method may also involve returning with a back flow conduit, steam heated breathable gas to the mixer. In some cases, the method may involve selectively returning with a back flow conduit and a valve the steam heated breathable gas to the mixer in accordance with a detection of temperature with a temperature sensor.

[0020] In some cases, the method may include controlling with a processor an operational parameter of the steam cell. In some cases, the method may involve controlling with a processor a heat source of the steam cell in accordance with a detected pressure of the steam cell. In some cases, the method may involve controlling with a processor a heat source of the steam cell in accordance with a detected temperature of the steam cell. In some cases, the method may involve controlling with a processor a proportional valve to set a pressure level released from the steam cell. In some cases, the method may involve controlling with a processor a change to a pressure level released from the steam cell in accordance with detection of a physiological parameter of a patient with a sensor. In some cases, the method may involve

controlling with a processor a change to a pressure level released from the steam cell in accordance with detection of a respiratory cycle with a sensor. In some cases, the method may involve controlling with a processor a change to a pressure level released from the steam cell in accordance with detection of a sleep disordered breathing event.

[0021] In some cases, the method may include directing steam from the steam cell at a steam turbine. In some cases, the steam turbine may include a blower impeller and/or a liquid impeller. In some cases, the method may involve entraining a supply of water to the steam cell with a venturi jet configured to direct a supply of steam from the steam cell. In some cases, the method may involve exchanging heat from a steam conduit configured with an exchanger material to exchange heat via the material. In some cases, the steam conduit may be proximate to a humidifier tank to warm a fluid of the tank. In some cases, the steam conduit may be proximate to a breathable gas supply conduit to warm a breathable gas of the breathable gas supply conduit.

[0022] Some cases of the present technology may include a respiratory treatment apparatus to generate a flow of breathable gas. The apparatus may include a steam cell configured to generate a flow of steam. The apparatus may include a turbine coupled with the steam cell, the turbine configured for operation in response to the flow of steam. The apparatus may also include a delivery circuit configured to couple with a patient interface to provide pressurized breathable gas to the patient interface. The breathable gas may be pressurized by operation of the turbine.

[0023] In some cases, the turbine of the apparatus may include an impeller assembly. The impeller assembly may

include a blower impeller and a steam impeller. In some cases, the apparatus may include a mixer to combine the flow of steam with a flow of air. In some cases, the apparatus may include a mixer to combine the flow of steam with a flow of air from a blower impeller. In some cases, the apparatus may include a liquid pump. The liquid pump may be configured to move a liquid by operation of the turbine. In some cases, the impeller assembly of the turbine may include a liquid impeller and a steam impeller. In some cases of the apparatus, a liquid pump of the apparatus may supply a liquid to the steam cell. In some cases, the liquid pump may supply a liquid to a humidifier tank coupled with the delivery circuit. The humidifier may be configured to humidify the breathable gas.

[0024] Any of the apparatus may include a controller and a sensor to sense a characteristic of the apparatus. The controller may set operation of the turbine in response to a signal from the sensor. The characteristic may be any one or more of turbine speed, breathable gas pressure, steam pressure, breathable gas temperature, steam temperature, breathable gas humidity, steam flow rate, breathable gas flow rate, liquid flow rate and fluid level. In some cases, a controller of the apparatus detects a flow rate of a supplied breathable gas with a flow sensor and regulates the flow of steam to the turbine to control the supplied breathable gas.

[0025] Some examples of the present technology may involve a method for controlling a respiratory treatment apparatus. The method may include generating a flow of steam in a steam cell of the apparatus. The method may include directing the flow of steam at a turbine coupled with the steam cell. The turbine may be configured for operation in response to the flow of steam. The method

may also include generating a pressurized breathable gas into a delivery circuit configured to couple with a patient interface. The breathable gas may be pressurized by operation of the turbine.

[0026] Optionally, in some such cases of the method, the turbine may include an impeller assembly. The impeller assembly may include a blower impeller and a steam impeller. The method may further include combining in a mixer the flow of steam with a flow of air. In some cases, the method may include combining in a mixer the flow of steam with a flow of air from a blower impeller coupled with the turbine.

[0027] In some cases, the method may include moving a liquid with a liquid pump by operation of the turbine. In some such methods, an impeller assembly of the turbine may include a liquid impeller and a steam impeller. The method may further include supplying a liquid to the steam cell with the liquid pump. In some cases, the method may include, with the liquid pump, supplying a liquid to a humidifier tank coupled with the delivery circuit. Such a humidifier may be configured to humidify the breathable gas.

[0028] In some version, the method may include, with a controller, setting an operation of the turbine in response to a signal from a sensor that senses a characteristic of the apparatus. The characteristic may be any one or more of turbine speed, breathable gas pressure, steam pressure, breathable gas temperature, steam temperature, breathable gas humidity, steam flow rate, breathable gas flow rate, liquid flow rate and fluid level. In some cases, the method may involve, with a controller, detecting a flow rate of a supplied breathable gas with a flow sensor and regulating the flow

of steam to the turbine to control the supplied breathable gas.

[0029] Of course, portions of the aspects may form sub-aspects of the present invention. Also, various ones of the sub-aspects and/or aspects may be combined in various manners and also constitute additional aspects or sub-aspects of the present technology.

[0030] Other features of the technology will be apparent from consideration of the information contained in the following detailed description, abstract, drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The above and other features and advantages of the present technology are further described in the detailed description which follows, with reference to the drawings, and by way of non-limiting exemplary embodiments of the present technology wherein:

[0032] Fig. 1 shows a typical system in accordance with the present technology. A patient 1000 wearing a patient interface 3000, receives a supply of air at positive pressure from a PAP device 4000. Air from the PAP device, which may optionally be humidified in a humidifier 5000, passes along an air circuit 4170 to the patient 1000;

[0033] Fig. 2 shows a patient interface in accordance with one form of the present technology;

[0034] Fig. 3a shows an example PAP device in accordance with one form of the present technology;

[0035] Fig. 3b shows a schematic diagram of the pneumatic circuit of a typical PAP device of Fig. 3a. The directions of upstream and downstream are indicated;

[0036] Fig. 3c shows a schematic diagram of the electrical components of the PAP device of Fig. 3a; and

[0037] Fig. 4 shows a humidifier.

[0038] Fig. 5 shows a schematic diagram illustrating an example steam flow system according to an aspect of the present technology;

[0039] Fig. 6 shows a schematic diagram illustrating example components of a further example steam flow system according to an aspect of the present technology;

[0040] Fig. 7 is an illustration of an example steam/air mixer for implementation in some embodiments of the present technology;

[0041] Fig. 8 is an illustration of an example steam cell incorporating steam/air mixer for implementation with some versions of the present technology;

[0042] Fig. 9 is an illustration of a portion of an example steam/air mixer that may be suitable for implementation with the embodiment of Fig. 8; and

[0043] Fig. 10 is a block diagram illustrating example components of a steam cell controller architecture for some embodiments of the present technology.

[0044] Fig. 11a is a perspective illustration of an example steam turbine component for implementation in some embodiments of the present technology.

[0045] Fig. 11b is an exploded perspective view of the example steam turbine component of Fig. 11a.

[0046] Fig. 11c is a bottom perspective illustration of a steam turbine component suitable for implementation in some embodiments of the present technology. The figure includes illustrative arrows added to indicate a path for a flow of steam moving through the component.

[0047] Fig. 11d is a top perspective illustration of the steam turbine component of Fig. 11c. The figure includes illustrative arrows added to indicate a path for a flow of air moving through the component.

[0048] Fig. 12a is a component diagram of a further example steam flow system showing example flow paths according to an aspect of the present technology.

[0049] Fig. 12b is a component diagram of a further example steam flow system showing additional example flow paths according to an aspect of the present technology.

[0050] Fig. 12c is a component diagram of a further example steam flow system showing yet further example flow paths according to an aspect of the present technology.

[0051] Fig. 12d is a component diagram of an example steam flow system showing still further flow paths according to an aspect of the present technology.

[0052] Fig. 12e is a component diagram illustrating another example steam flow system with example flow paths according to an aspect of the present technology.

DETAILED DESCRIPTION OF THE TECHNOLOGY

[0053] In this specification, the word "comprising" is to be understood in its "open" sense, that is, in the sense of "including", and thus not limited to its "closed" sense, that is the sense of "consisting only of". A corresponding meaning is to be attributed to the corresponding words "comprise," "comprised" and "comprises" where they appear.

[0054] The term "air" will be taken to include breathable gases, for example air with supplemental oxygen. It is also acknowledged that flow generators described herein may be designed to pump fluids other than air.

1.1 Treatment Systems

[0055] In one form, the present technology may form part of an apparatus (e.g., a PAP device 4000) for treating a respiratory disorder, such as that illustrated in Fig. 3a, 5 and 6. The apparatus may include a flow generator

such as one implemented with a blower or, as an alternative, with one or more steam cells configured to generate the pressurised respiratory gas, such as air with a flow of steam, to the patient 1000 via an air delivery tube leading to a patient interface 3000.

1.2 Therapy

[0056] In one form, the present technology may be configured to treat a respiratory disorder such as by applying positive pressure to the entrance of the airways of a patient 1000, such as to the nasal passages of the patient via one or both nares and/or the mouth. For example, the PAP device 4000 may generate a Nasal Continuous Positive Airway Pressure (CPAP) therapy to treat Obstructive Sleep Apnea (OSA) of the upper airway by pushing the soft palate and tongue forward and away from the posterior oropharyngeal wall.

[0057] Non-invasive ventilation (NIV) has been used to treat Cheyne-Stokes Respiration (CSR), Obesity Hyperventilation Syndrome (OHS), Chronic Obstructive Pulmonary Disease (COPD), Neuromuscular Disease (NMD) and Chest Wall disorders. In some cases of NIV, the pressure treatment may be controlled to enforce a target ventilation by measuring a tidal volume or minute ventilation, for example, and controlling the measure of ventilation to satisfy the target ventilation. Servo-controlling of the measure of ventilation, such as by a comparison of an instantaneous measure of ventilation and a long term measure of ventilation, may serve as a treatment to counteract CSR. In some such cases, the form of the pressure treatment delivered by an apparatus may be Pressure Support ventilation. Such a pressure treatment typically provides generation of a higher level of pressure during inspiration (e.g., an IPAP) and

generation of a lower level of pressure during expiration (e.g., an EPAP). In some cases, any of such therapies may be implemented with a high flow stream generated by the flow generator of the PAP device.

1.3 Patient interface 3000

[0058] As illustrated in Fig. 2, a non-invasive patient interface 3000 in accordance with one aspect of the present technology may include the following functional aspects: a seal-forming structure 3100, a plenum chamber 3200, a positioning and stabilising structure 3300 and a connection port 3600 for connection to air circuit 4170. In some forms a functional aspect may be provided by one or more physical components. In some forms, one physical component may provide one or more functional aspects. In use the seal-forming structure 3100 is arranged to surround an entrance to the airways of the patient so as to facilitate the supply of air at positive pressure or high flow to the airways.

1.4 PAP device 4000

[0059] As illustrated in Fig. 3a, 3b and 3c, a typical example PAP device 4000 may include mechanical and pneumatic components 4100, electrical components 4200 and may be programmed to execute one or more algorithms. The PAP device may have an external housing 4010 formed in two parts, an upper portion 4012 of the external housing 4010, and a lower portion 4014 of the external housing 4010. In alternative forms, the external housing 4010 may include one or more panel(s) 4015. The PAP device 4000 may include a chassis 4016 that supports one or more internal components of the PAP device 4000. In one form a pneumatic block 4020 is supported by, or formed as part of the chassis 4016. The PAP device 4000 may include a handle 4018.

[0060] The pneumatic path of the PAP device 4000 may optionally include an inlet air filter 4112, an inlet muffler 4122, a controllable pressure device 4140 capable of supplying air at positive pressure (such as a blower 4142 or suitably configured steam cell), and an outlet muffler 4124. One or more pressure sensors (e.g., pressure transducer 4272) and flow sensors (e.g., flow transducer 4274) may optionally be included in the pneumatic path.

[0061] The pneumatic block 4020 may form a portion of the pneumatic path that is located within the external housing 4010.

[0062] The PAP device 4000 has an electrical power supply 4210, one or more input devices 4220, a central controller 4230, a therapy device controller 4240, a therapy device 4245, one or more protection circuits 4250, memory 4260, optional transducers 4270, data communication interface 4280 and one or more output devices 4290. Electrical components 4200 may be mounted on a single Printed Circuit Board Assembly (PCBA) 4202. In an alternative form, the PAP device 4000 may include more than one PCBA 4202.

[0063] The central controller 4230 of the PAP device 4000 may be programmed to execute one or more algorithm modules, including in one implementation a pre-processing module, a therapy engine module, a pressure, temperature and/or steam control module, and a fault condition module. Thus, such processes may be implemented with the algorithms or processing of a digital processor. In such a case, the digital processor may include integrated chips, a memory and/or other control instruction, data or information storage medium. For example, programmed instructions encompassing the process methodologies may be coded on integrated chips in a memory or otherwise

form an application specific integrated chip (ASIC). Such instructions may also or alternatively be loaded as software or firmware using an appropriate data storage medium.

[0064] In what follows, the PAP device 4000 is referred to interchangeably as a ventilator.

1.4.1 PAP device mechanical & pneumatic components 4100

1.4.1.1 Air filter(s) 4110

[0065] A PAP device in accordance with some examples of the present technology may optionally include an air filter 4110, or a plurality of air filters 4110.

[0066] In one form, an inlet air filter 4112 is located at the beginning of the pneumatic path upstream of a blower 4142 such as seen in Fig. 3b or at an ambient air intake shown in Fig. 6.

[0067] In one form, an outlet air filter 4114, for example an antibacterial filter, may be located between an outlet of the pneumatic block 4020 and a patient interface 3000 as shown in Fig. 3b.

1.4.1.2 Muffler(s) 4120

[0068] In one form of the technology, an inlet muffler 4122 may optionally be located in the pneumatic path, such as upstream of a blower 4142. See Fig. 3b.

[0069] In one form of the technology, an outlet muffler 4124 may be located in the pneumatic path between the blower 4142 and a patient interface 3000. See Fig. 3b.

1.4.1.3 Pressure device 4140

[0070] In one form of the present technology, a pressure device 4140 for producing a flow of air at positive pressure is a controllable blower 4142 or one or more steam cell(s) 5124. For example, the blower may include

one or more impellers housed in a volute which may be driven by a brushless DC motor 4144 or a steam turbine 9002 as will be described later. In some cases as discussed in more detail herein, a steam cell pressure device may include a heating element and water chamber. The device may be configured to generate a supply of air, for example in a range up to about 120 litres/minute, at a positive pressure in a range from about 4 cmH₂O to about 20 cmH₂O, or in other forms up to about 30 cmH₂O.

[0071] The pressure device 4140 may be under the control of the therapy device controller 4240.

1.4.1.4 Transducer(s) 4270

[0072] In one form of the present technology, one or more transducers 4270 may be located upstream of the pressure device 4140. The one or more transducers 4270 are constructed and arranged to measure properties of the air at that point in the pneumatic path.

[0073] In one form of the present technology, one or more transducers 4270 are located downstream of the pressure device 4140, and upstream of the air circuit 4170. The one or more transducers 4270 are constructed and arranged to measure properties of the air at that point in the pneumatic path.

[0074] In one form of the present technology, one or more transducers 4270 are located proximate to the patient interface 3000.

1.4.1.5 Anti-spill back valve 4160

[0075] In one form of the present technology, an anti-spill back valve may optionally be located between the humidifier 5000 and the pneumatic block 4020. The anti-spill back valve is constructed and arranged to reduce the risk that water will flow upstream from the humidifier 5000, for example to the motor 4144.

1.4.1.6 Air circuit 4170

[0076] An air circuit 4170 in accordance with an aspect of the present technology is constructed and arranged to allow a flow of air or breathable gases between the pneumatic block 4020 and the patient interface 3000.

1.4.1.7 Oxygen delivery

[0077] In one form of the present technology, supplemental oxygen 4180 may be delivered to a point in the pneumatic path.

[0078] In one form of the present technology, supplemental oxygen 4180 is delivered upstream of the pneumatic block 4020.

[0079] In one form of the present technology, supplemental oxygen 4180 is delivered to the air circuit 4170.

[0080] In one form of the present technology, supplemental oxygen 4180 is delivered to the patient interface 3000.

1.4.2 PAP device electrical components 4200**1.4.2.1 Power supply 4210**

[0081] In one form of the present technology power supply 4210 is internal of the external housing 4010 of the PAP device 4000. In another form of the present technology, power supply 4210 is external of the external housing 4010 of the PAP device 4000.

[0082] In one form of the present technology power supply 4210 provides electrical power to the PAP device 4000 only. In another form of the present technology, power supply 4210 provides electrical power to both PAP device 4000 and humidifier 5000. In one form of the present technology power supply 4210 provides electrical power to

the electrical control components of the PAP device 4000 only.

1.4.2.2 Input devices 4220

[0083] In one form of the present technology, a PAP device 4000 includes one or more input devices 4220 in the form of buttons, switches or dials to allow a person to interact with the device. The buttons, switches or dials may be physical devices, or software devices accessible via a touch screen. The buttons, switches or dials may, in one form, be physically connected to the external housing 4010, or may, in another form, be in wireless communication with a receiver that is in electrical connection to the central controller 4230.

[0084] In one form the input device 4220 may be constructed and arranged to allow a person to select a value and/or a menu option.

1.4.2.3 Central controller 4230

[0085] In some cases, versions of the technology may employ a controller such as a central controller 4230. A suitable central controller 4230 may be a processor adapted to control the PAP device 4000 such as an x86 INTEL processor.

[0086] A processor suitable to control a PAP device 4000 in accordance with another form of the present technology includes a processor based on ARM Cortex-M processor from ARM Holdings. For example, an STM32 series microcontroller from ST MICROELECTRONICS may be used.

[0087] Another processor suitable to control a PAP device 4000 in accordance with a further alternative form of the present technology includes a member selected from the family ARM9-based 32-bit RISC CPUs. For example, an STR9 series microcontroller from ST MICROELECTRONICS may be used. In certain alternative forms of the present

technology, a 16-bit RISC CPU may be used as the processor for the PAP device 4000. For example a processor from the MSP430 family of microcontrollers, manufactured by TEXAS INSTRUMENTS, may be used.

[0088] The processor may be configured to receive input signal(s) from one or more transducers 4270, and one or more input devices 4220.

[0089] The processor may be configured to provide output signal(s) to one or more of an output device 4290, a therapy device controller 4240, a data communication interface 4280 and humidifier controller 5250.

[0090] The processor, or multiple such processors, may be configured to implement one or more methodologies described herein such as one or more algorithms expressed as computer programs stored in memory 4260. In some cases, as previously discussed, such processor(s) may be integrated with a PAP device 4000. However, in some devices the processor(s) may be implemented discretely from the flow generation components of the PAP device, such as for purpose of performing any of the methodologies described herein without directly controlling delivery of a respiratory treatment. For example, such a processor may perform any of the methodologies described herein for purposes of determining control settings for a ventilator or other respiratory related events by analysis of stored data such as from any of the sensors described herein.

1.4.2.4 Clock 4232

[0091] Preferably PAP device 4000 includes a clock 4232 that is connected to the controller or processor.

1.4.2.5 Therapy device controller 4240

[0092] In one form of the present technology, therapy device controller 4240 is a pressure control module that forms part of the algorithms executed by the processor.

[0093] In one form of the present technology, therapy device controller 4240 may include a dedicated motor control integrated circuit. For example, in one form a MC33035 brushless DC motor controller, manufactured by ONSEMI is used. In some embodiments, the therapy device controller 4240 may include one or more of the components for controlling the temperature of the steam cell.

1.4.2.6 Protection circuits 4250

[0094] Optionally a PAP device 4000 in accordance with the present technology includes one or more protection circuits 4250.

[0095] One form of protection circuit 4250 in accordance with the present technology is an electrical protection circuit.

[0096] One form of protection circuit 4250 in accordance with the present technology is a temperature or pressure safety circuit.

1.4.2.7 Memory 4260

[0097] In accordance with one form of the present technology the PAP device 4000 includes memory 4260, preferably non-volatile memory. In some forms, memory 4260 may include battery powered static RAM. In some forms, memory 4260 may include volatile RAM.

[0098] Preferably memory 4260 is located on PCBA 4202. Memory 4260 may be in the form of EEPROM, or NAND flash.

[0099] Additionally or alternatively, PAP device 4000 includes removable form of memory 4260, for example a

memory card made in accordance with the Secure Digital (SD) standard.

1.4.2.8 Transducers 4270

[00100] Optional transducers may be internal of the device, or external of the PAP device. External transducers may be located for example on or form part of the air delivery circuit, e.g. the patient interface. External transducers may be in the form of non-contact sensors such as a Doppler radar movement sensor that transmit or transfer data to the PAP device.

1.4.2.8.1 Flow

[0100] An optional flow transducer 4274 in accordance with the present technology may be based on a differential pressure transducer, for example, an SDP600 Series differential pressure transducer from SENSIRION. The differential pressure transducer is in fluid communication with the pneumatic circuit, with one of each of the pressure transducers connected to respective first and second points in a flow restricting element.

[0101] In use, a signal or total flow Q_t signal, from the flow transducer 4274, is received by the processor. However, other sensors for producing such a flow signal or estimating flow may be implemented. For example, a mass flow sensor, such as a hot wire mass flow sensor, may be implemented to generate a flow signal in some embodiments. Optionally, flow may be estimated from one or more signals of other sensors described here, such as in accordance with any of the methodologies described in a U.S. Patent Application No. 12/192,247, the disclosure of which is incorporated herein by reference.

1.4.2.8.2 Pressure

[0102] One or more optional pressure transducers 4272 in accordance with the present technology may be located in fluid communication with the pneumatic circuit such as within chamber of the steam cell. An example of a suitable pressure transducer is a sensor from the HONEYWELL ASDX series. An alternative suitable pressure transducer is a sensor from the NPA Series from GENERAL ELECTRIC.

[0103] In use, a signal from the pressure transducer 4272, is received by the processor. In one form, the signal from the pressure transducer 4272 may be filtered prior to being received by the processor.

1.4.2.8.3 Motor speed

[0104] In one form of the present technology motor speed signal 4276 may be generated such as in the case of the implementation of a blower. A motor speed signal 4276 may be provided by therapy device controller 4240. Motor or blower impeller speed may, for example, be generated by an optional speed sensor, such as a Hall effect sensor.

1.4.2.8.4 Temperature

[0105] In some examples of the present technology such as that illustrated in Fig. 6, a temperature sensor 6145 may generate a temperature signal. The signal may be provided to the therapy device controller 4240 and/or the central controller. For example, the temperature sensor may provide a temperature signal for closed or open loop control of a heat source of the steam cell by the therapy device controller and/or central controller. Optionally, a temperature sensor may be employed for a protection circuit to provide a heat source shutdown signal to prevent an over temperature situation of the steam cell. Any suitable temperature sensor may be employed

including, for example, a thermocouple, resistive temperature detector and/or thermistor.

1.4.2.9 Data communication systems

[0106] In one form of the present technology, a data communication interface 4280 is provided, and is connected to the processor or central controller 4230. Data communication interface 4280 is preferably connectable to remote external communication network 4282. Data communication interface 4280 is preferably connectable to local external communication network 4284. Preferably remote external communication network 4282 is connectable to remote external device 4286. Preferably local external communication network 4284 is connectable to local external device 4288.

[0107] In one form, data communication interface 4280 is part of processor or central controller 4230. In another form, data communication interface 4280 is an integrated circuit that is separate from processor or central controller 4230.

[0108] In one form, remote external communication network 4282 is the Internet. The data communication interface 4280 may use wired communication (e.g. via Ethernet, or optical fibre) or a wireless protocol to connect to the Internet.

[0109] In one form, local external communication network 4284 utilises one or more communication standards, such as Bluetooth, or a consumer infrared protocol.

[0110] In one form, remote external device 4286 is one or more computers, for example a cluster of networked computers. In one form, remote external device 4286 may be virtual computers, rather than physical computers. In either case, such remote external device 4286 may be

accessible to an appropriately authorised person such as a clinician.

[0111] Preferably local external device 4288 is a personal computer, mobile phone, tablet or remote control.

1.4.2.10 Output devices 4290 including optional display, alarms, etc.

[0112] An output device 4290 in accordance with the present technology may take the form of one or more of a visual, audio and haptic unit. A visual display may be a Liquid Crystal Display (LCD) or Light Emitting Diode (LED) display.

1.4.2.10.1 Display driver 4292

[0113] A display driver 4292 receives as an input the characters, symbols, or images intended for display on the display 4294, and converts them to commands that cause the display 4294 to display those characters, symbols, or images.

1.4.2.10.2 Display 4294

[0114] A display 4294 is configured to visually display characters, symbols, or images in response to commands received from the display driver 4292. For example, the display 4294 may be an eight-segment display, in which case the display driver 4292 converts each character or symbol, such as the figure "0", to eight logical signals indicating whether the eight respective segments are to be activated to display a particular character or symbol.

1.4.2.11 Therapy device 4245

[0115] In a preferred form of the present technology, the therapy device 4245 is under the control of a controller to deliver therapy to a patient 1000.

[0116] The therapy device 4245 may be a positive air pressure device 4140.

1.5 Humidifier 5000

[0117] In one form of the present technology there is provided a humidifier 5000, such as the example illustrated in Fig. 4. The humidifier may include a water reservoir and a heating plate 5240 as shown in Fig. 3c. The heating plate may be configured to warm the water of the reservoir to provide humidity to the gas/air passing through the water reservoir and to the air circuit 4170. However, in some cases, such as those that employ a steam cell, a humidifier may be unnecessary.

1.6 Further Example Steam Cell Systems

[0118] As previously described and illustrated in Fig. 5, in some cases, a flow generator of the PAP device 4000 may be implemented with one or more steam cells 5124. Each steam cell will typically include a fluid chamber 5124-C and a heat source 5124-HS. The fluid chamber is configured to contain a stored fluid (e.g., water) for heating. The heat source is configured for heating the fluid in the chamber to convert the fluid to its gaseous state (e.g., steam). For example, in the case of water, the heat source may be capable of raising the temperature of the fluid to its boiling point (e.g., boiling the water). Thus, in some cases, the heat source may generate temperatures in a range of about the boiling point of water (e.g., about 100°C or 212°F) or the boiling point of other suitable liquid. Such a heat source may be electric (e.g., one or more heating coils

and/or heat plates). Optionally, such a heat source may be a combustible fuel such as a flammable gas (e.g., propane or natural gas, etc.). The steam cell may be configured to generate a flow of steam at pressure(s) above atmospheric pressure.

[0119] The chamber will typically have gas release port 5125. The gas release port may lead (downstream) to a conduit pathway associated with the air circuit 4170. In some cases, the chamber and its release port may be configured to contain the hot gas of the steam cell for release above one or more desired pressures. As such, the steam cell may produce a controlled flow of steam at pressures above atmospheric pressure. In some cases, the gas release port may comprise an electro-mechanical valve that may be in communications with a controller such as a steam cell controller 6230.

[0120] Optionally, the conduit pathway leading from the gas release port may include a gas mixer 5127. Thus, the gas mixer may be in a steam flow path downstream of the chamber 5124-C of the steam cell. The gas mixer may be implemented to combine the hot gas generated by the steam cell with breathable gas (e.g., air or ambient air) drawn into the mixer such as from an ambient air intake 5129. The gas mixer 5127 may further be configured to increase pressures and/or velocities of the steam and/or air. In some cases, the mixer may serve to decrease the temperature of the hot gas (e.g., steam) from the steam cell by the addition of the relatively cooler ambient air. In some cases, the mixer may serve to entrain the ambient air into the pathway with the steam for delivery to a user of the patient interface 3000 via the air circuit 4170.

[0121] A further example steam cell respiratory treatment system is illustrated in Fig. 6. As

illustrated, the steam cell may be implemented with a steam cell controller 6230, such as a central controller 4230 and/or a therapy device controller 4240. The controller may be configured to control the operational parameters of the steam cell, and may do so in accordance with conditions detected by any sensors described herein. For example, in addition to any of the components of the PAP device previously mentioned, the steam cell controller 6230 may also be electrically coupled with any one or more of a steam cell pressure sensor 6272, a temperature sensor 6145, water level sensor 6147, water pump 6149, steam cell heat source 5124-HS and an electro-mechanical proportional valve 6151.

[0122] Thus, the steam cell controller may be configured to operate (change the settings) for the steam cell. For example, with the optional pressure sensor 6272, the controller 6230 may sense the steam pressure of the chamber 5124-C of the steam cell. With this measured pressure, the controller may regulate the pressure of the chamber. For example, the controller may set the heat source 5124-HS to raise or lower the pressure level of the chamber. By way of further example, with the optional temperature sensor 6145, the controller 6230 may sense the temperature of the chamber 5124-C (e.g., the fluid therein) of the steam cell. With this measured temperature, the controller may regulate the temperature of the chamber. For example, the controller may set the heat source 5124-HS to raise or lower the temperature level therein.

[0123] Optionally, the chamber of the steam cell may include a safety release valve 6153. The safety release valve may be configured to release steam to reduce the pressure of the chamber of the steam cell in the event of

a dangerous over pressure condition within the steam cell.

[0124] In some cases, the release port 5125 of the steam cell may lead to an optional proportional valve 6151. The proportional valve may be manually adjustable to set the pressure level of the steam entering a steam conduit 6155 downstream of the valve. However, in some cases it may be an electro-mechanical proportional valve that may be adjusted or controlled by the steam cell controller 6230. Thus, the controller may adjust the valve to set the pressure level of the steam entering the steam conduit 6155 downstream of the valve. In some such cases, a further pressure sensor may be suitably located proximate to the proportional valve or proximate to a patient interface. Such adjustments may then serve to control the pressure of the breathable gas supplied to the user/patient and may be so controlled so as to provide any of the various therapies previously discussed (e.g., CPAP, bi-level CPAP etc.). Thus, in some case, the level of steam pressure may be varied or adjusted in response to detected events such as for example, sleep disordered breathing (e.g., apnea, hypopnea, partial obstruction, snoring, etc.), a respiratory cycle, etc., that may be detected by a controller from analysis of signal(s) from one or more sensors. For example, in some cases, a higher steam pressure level may be triggered in response to a detected inspiration and/or this higher steam pressure level may be reduced in response to detected expiration (e.g., by analysis a flow signal to detect portions of the respiratory cycle).

[0125] In the example of Fig. 6, the steam conduit 6155 or other steam flow pathway leads to the mixer 5127. In this example, the steam cell mixer may optionally be implemented with at least an injector 5127-I and an

ejector 5127-E. These may be formed in a venturi jet configuration. Thus, steam may be injected by an injector 5127-I into a mixing chamber 5127-MC of the mixer 5127. Supplemental air from the ambient air intake 5129 may therein be mixed with the steam and the steam/air mixture may be ejected from the mixing chamber by the ejector 5127-E. In this regard, the velocity of the flow of steam which may be increased due to the structure of the injector (e.g., a reducing cross sectional area of the pathway of the injector). The velocity of the steam in conjunction with an inner surface (e.g., curved) of the mixing chamber may then entrain air from the intake 5129 (e.g., by a Coandă effect flow). The mixed air (or other breathable gas) and steam then flows to the air circuit 4170. Alternatively, in some cases, the device may be configured such that the air may be injected from an injector 5127-I to entrain the steam being mixed in via the intake 5129.

[0126] Optionally, a hydro-filter 6157 may be implemented in the air circuit 4170 downstream of the mixer 5127. The hydro-filter may be a membrane configured to impede transfer of water through the air circuit to the patient/user while permitting humid breathable gas to transfer to the patient user. Such a membrane may be formed with, for example, a Gore-tex(TM) membrane. Other suitable materials may also be implemented.

[0127] In some cases, the steam/air pathway of the air circuit 4170, downstream of the mixer 5127, may optionally include a heat exchanger 6161 (e.g., condenser). The heat exchanger may serve to promote a transfer of the steam to its liquid state (e.g., water). For example, the heat exchange may be part of a conduit

or water flow path to a recycled water reservoir 6163. The recycled water reservoir 6163 may collect the water condensed by the heat exchanger 6161. In order to minimize any pressure loss in the air delivery circuit associated with the water pathway 6163-P of the exchanger 6161, the exchanger, or a pathway associated with the exchanger, may include airflow impedance element 6167. For example, a metal honeycomb structure within the pathway may be implemented to impede airflow (e.g., provide a high airflow impedance) but permit water flow there through.

[0128] Optionally, the recycled water reservoir 6163 may be coupled to or include a water return conduit 6165. The water return conduit 6165 may be further coupled to the steam cell chamber 5124-C to permit a return of cooled water to the steam cell chamber. In some such cases, a pump, that may be controlled by the controller 6230 may serve to move water from the recycled water reservoir 6163 to the steam cell chamber 5124-C where it may be heated again to be converted again to steam. For example, in some cases, the controller may be configured, in response to a signal from the water level sensor 6147, to detect the presence of water in the recycled water reservoir 6163. The controller may then selectively activate the pump 6149 to transfer detected fluid from the recycled water reservoir 6163 to the steam cell chamber 5124-C via the water return conduit 6165. In some such cases, the water return conduit 6165, steam cell chamber and/or recycled water reservoir may include a one-way valve 6129 to permit the flow of water into the steam cell chamber 5124-C from the water return conduit 6165 but not permit a flow of water from the steam cell chamber 5124-C despite the pressure of the steam cell chamber 5124-C.

[0129] Optionally, in some cases, the steam cell system may employ a back flow conduit 6171. The back flow conduit may be implemented to conduct the humid air produced by the system back toward the ambient air intake 5129. Such a back flow loop may optionally include an electro-mechanical valve 6173 under control of the controller 6230. It may further include a temperature sensor 6145-2 to permit the controller 6230 to sense a temperature of the humid air. In some such cases, the controller may regulate the back flow by activation/adjusting the valve 6173 to assist in regulation of the temperature of the flow of humid air produced by the mixer 5127 to meet a temperature set point or target temperature. For example, the valve may be opened (e.g., to a greater or lesser degree) by the controller to permit a back flow to increase the temperature of the humid air generated by the mixer. Similarly, the valve may be closed by the controller to decrease or prevent the back flow so as to decrease the temperature of the humid air generated by the mixer. In such a case, more cool ambient air may then enter the mixer at the ambient air intake 5129.

[0130] An example mixer 5127 is illustrated in Fig. 7. In this example, the mixer employs a set of venturi jets in a series arrangement. Each jet 5127-J may include an injector, ejector and mixing chamber (not shown in Fig. 7) as previously described with reference to Fig. 6. In this example, each jet 5127-J may add to the velocity and/or pressure of the flow of air, so that they have a cumulative effect. Another advantage of such a system may be that more jets 5127-J may be added as required to achieve a higher velocity and/or pressure.

[0131] In the example of Fig. 8, the gas mixer 8127 is formed in a radial configuration and it may be an

integral component of the integrated steam cell 8124. In the gas mixer 8127, steam and air in alternating chambers arranged circumferentially around a central air intake channel CAIC of the radial mixer will mix in and be ejected radially from the ejectors 5127-E of the mixer. The circumferential mixing is shown in more detail in the illustration of Fig. 9. As illustrated, the alternating steam and air compartments lead to and are divided by successive venturi jets to permit the mixture of steam and air.

1.6 Steam Cell Systems Employing Other Steam Driven Components

[0132] In some cases, any of the previously described steam cell systems may also optionally employ a steam driven component such as a blower and/or pump. For example, the steam generated may be implemented to drive a mechanical blower, such as one with a fan or impeller, so as to increase a flow of air or other breathable gas to the patient. In some cases, the steam generated may be implemented to drive a liquid or water pump such as, for example, a liquid impeller to supply water to the boiler.

[0133] One example may be the steam turbine 9002 component illustrated in Figs. 11a-11b. The steam turbine 9002 may serve as a blower. Such a device may typically include an air inlet 9004, an air outlet 9006, a steam inlet 9008, a steam outlet 9010 and an impeller assembly. In some cases, the impeller assembly may include a drive shaft 9012 or other rotatable coupling for the impellers, an air impeller 9014 and a steam impeller 9016. The air impeller may optionally be positioned within an air chamber such as an air volute 9018 and the steam impeller may be positioned within a steam chamber such as a steam volute 9020. In some such

cases, the steam will not mix with the air when these volutes present discrete flow paths for the air and steam. A stator 9022 and bearings 9024 may be implemented for rotation of the impellers and/or drive shaft 9012.

[0134] Generally, a flow of steam through the steam volute will drive (e.g., rotate) the impeller assembly. In this regard, the steam acts upon the steam impeller. Generally, a coupling of the steam impeller with one or more subordinate impeller(s) (e.g., a fan or air impeller 9014 or other fluid impeller), such as by a driveshaft, permits the subordinate impeller(s) to move in association with the movement of the steam impeller. As a result, the air impeller or fluid impeller will generate a flow of air and/or fluid within the volute of the subordinate impeller such that air and/or fluid will be drawn into a respective volute from an inlet to the volute (e.g., air inlet or fluid inlet) and be forced out through an outlet (e.g., air outlet and/or fluid outlet). Different rotational ratio's between the steam impeller on the one hand and the different subordinate impellers on the other hand (e.g., the water impeller or air impeller) can permit a common flow of steam to drive the fluid and air at different fluid and air flow rates. Such rotational differences may be implemented by differences in the size, efficiency or other properties of the impellers and/or by employing gears, for example.

[0135] Thus, the flow of steam through the steam volute 9020 drives a flow of air such that the steam turbine may serve as a blower. Such a flow of steam is illustrated in in Fig. 11c with a resultant flow of air illustrated in Fig. 11d. However, the steam turbine 9002 may also be configured to serve as a water pump, for example, when the shaft is coupled with a water impeller.

As such, the flow of steam through the steam volute may drive a flow of water. Thus, the steam turbine may be configured as an air blower as well as a water pump. In some cases, the steam turbine 9002 may be configured so that the amount of water pumped into the boiler may be a function of the air flow rate and/or pressure generated by the blower.

[0136] Figs. 12a-12e show various example system diagrams of the current technology that may employ any of the steam turbine 9002 components discussed herein. In the example of Fig. 12a, a steam turbine 9002 is configured as a blower 4142 which is driven by the flow of steam through the steam turbine 9002 when it enters a steam chamber (e.g., steam volute 9020) of the steam turbine. The steam is generated by a steam cell 5124. In some cases, air from the blower may be applied to a temperature and humidity adjustment system 5128, such as any of the gas mixers previously described. Optionally, such a temperature and humidity adjustment system may employ any of heating coils, steam based heat/humidity exchangers, as an alternative or in addition to a mixer. Still further, such a system may optionally employ one or more electro-mechanical valves, a humidity sensor, flow sensor and/or temperature sensor such that the controller may control settings of the temperature, flow rate and/or humidity. In some such cases, for example, a flow of steam, such as steam directly from the steam cell (not shown) or steam expelled from the turbine (as illustrated), may be mixed with the flow of pressurised air in a mixer 5127, such as under the control of one or more electro-mechanical valves to achieve a desired temperature, flow and/or humidity setting. Thus, the mixer may adjust properties of the controlled flow of air such as temperature, humidity, and/or flow rate.

[0137] In some cases, the centrifugal force and loss of energy through the steam turbine, and/or the temperature and humidity adjustment system may produce condensation droplets. Thus, in some cases, optional drains that may be coupled by water return conduits 9165-A, 9165-B may be implemented to direct recycled water back into the recycled water reservoir 6163. As a result, such condensed droplets may be reused as previously described.

[0138] In the example system of Fig. 12b, the steam turbine 9002 is implemented with an integrated temperature and humidity adjustment system 5128, such as one of the mixer previously described. In such an example, the resultant flow from the steam path of the steam turbine 9002 may optionally be a mixture of steam and air or just steam. Thereafter, that resultant flow may be mixed, such as in a Y-connector of a conduit, with the pressurized air from the blower portion of the steam turbine.

[0139] In the system example of Fig. 12c, the steam turbine 9002 is implemented as a water pump 6149 that includes a liquid impeller 6149-LI coupled with the steam impeller 9016. In this example, the water pump drives a return of water to the steam cell 5124. Additionally, the system may employ a venturi jet type mixer 5127 in addition to a temperature and humidity adjustment system 5128, such as the back flow conduit 6171, valve and sensor previously described. Additional components may include any of those illustrated in Fig. 6.

[0140] In Fig. 12d, the steam turbine 9002 is implemented as a water pump 6149 and a blower. Flow of pressurized air from the blower may be mixed with steam expelled from the steam turbine, such as in the

temperature and humidity adjustment system 5128, which may optionally be implemented as or with a mixer 5127.

[0141] Another example of the current technology is shown in Fig. 12e. Here, the steam turbine 9002 is configured to drive some components, e.g., the blower, of the system. However, the steam is not directly mixed with any breathable gas supplied to the user/patient. Rather, the steam is employed indirectly for a transfer of some characteristics of the steam to the breathable gas. For example, steam may be applied to warm the breathable gas and/or fluid of a humidifier. Thus, a steam may be applied to a conduit with a material suitable for heat transfer. Such a conduit may serve as a heat exchanger or a steam heater. Thus, the heat exchanger conduit 7156 may optionally be a heating element for an air supply conduit 7157. Similarly, such a heat exchanger conduit, may serve as a heating element 7159 for a humidifier reservoir 5000 as shown in Fig. 12e. Still further, as with additional embodiments, the steam may be employed to drive the blower for pressurizing breathable gas.

[0142] In the illustrated example of Fig. 12e, a flow sensor 4274 may be employed such as previously described. In some cases, for example, the flow rate of the breathable gas may be measured and controlled by a control loop such as of a processor of the steam cell controller 6230. For example, the rate may be set to meet a target rate by selectively controlling release of steam by an electromechanical valve of the proportional valve 6151.

[0143] In some cases, the systems described herein may implement alternative components for water movement rather than, or in addition to, a pump. For example, as illustrated in 12e, one or more Giffard injector(s) 6149-

G may be employed. In this example, the Giffard injector with a venturi jet directs steam to entrain water into the steam cell. Thus, the steam may drive water from the water reservoir to the boiler. In the example of Fig. 12e, a pump 6149-1 may optionally be implemented to periodically supply recycled water to a water container of the humidifier 5000 via an optional humidifier re-supply conduit 5111. However, in some cases, such a pump may alternatively be implemented with a Giffard injector to periodically do so. For example, such a pump or Giffard injector may be controlled by the controller with a timer to operate once in a certain period of time (e.g., every eight hours) or with an optional water sensor of the humidifier when it detects a low water situation. In such events, the steam cell controller 6230 may selectively operate the pump or one or more electro-mechanical valves for selectively permitting flow through the Giffard injector. As a result of such automatic refilling of the humidifier 5000, its water container may be configured without any opening for user/patient refilling. For example, it may include a permanent, nonremovable tank. In some such cases, the water reservoir 6163 may have removable tank so that it may be refilled with water by a user/patient for system operation. Optionally, the Giffard injector to the steam cell may be similarly controlled to selectively supply water to the steam cell under control of the steam cell controller 6230.

[0144] In some examples such as that based on the system of Fig. 12e, the liquid of the boiler, as well as the steam, may be implemented as a closed system such that it is kept separate from the flow of breathable gas. For example, pump 6149-1 and the humidifier re-supply conduit 5111 may be omitted. Thus, other liquids may be

utilized in the steam cell. For example, a liquid with a lower boiling point than water may permit the use of steam with lower power requirements for the steam cell. In such a case, a separate water supply may be implemented for the humidifier 5000.

[0145] In any of the above examples, the system may include any of a number of components to regulate the flow of steam, air and/or water independently of each other throughout the system. For example, flow adjustments may be made by inclusion of additional electro-mechanical valves at various points of the system, such as in the air, steam and/or water circuits, or at any junction therebetween.

Example Controller Architecture

[0146] An example controller architecture of a controller suitable for the present steam generating control technology is illustrated in the block diagram of FIG. 10. In the illustration, the controller with the processes described herein for a respiratory treatment apparatus may include one or more processors 408. The system may also include a display interface 410 to output event reports (e.g., steam cell temperature, back flow temperature, pressure, flow, etc.) as described herein such as on a monitor or LCD panel. A user control/input interface 412, for example, for a keyboard, touch panel, control buttons, mouse etc. may also be provided to activate or modify the control methodologies described herein such as setting desired pressures, temperatures and/or flow rates, etc.. The system may also include a sensor or data interface 414, such as a bus, for receiving/transmitting data such as programming instructions, sensor signals, component control signals, pump control signals, heat source control signals, proportional valve control signals, back flow valve

control signals, etc. The device may also typically include memory/data storage components 420 containing control instructions of the aforementioned methodologies. These may include processor control instructions for pressure, temperature, water and/or flow signal processing (e.g., pre-processing methods, filters etc.) at 422. These may also include processor control instructions for steam treatment control based on the signal processing (e.g., treatment changes, temperature changes, pressure changes, water pump control, valve control, etc.) at 424 as discussed in more detail herein. Finally, they may also include stored data 426 for these methodologies such treatment settings, pressure settings data, valve settings, temperature data, steam use data, pump activation data, water level sensing data, etc.). In some embodiments, these processor control instructions and data for controlling the above described methodologies may be contained in a computer readable recording medium as software for use by a general purpose computer so that the general purpose computer may serve as a specific purpose computer according to any of the methodologies discussed herein upon loading the software into the general purpose computer.

* * *

[0147] Although the technology herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the technology. It is therefore to be understood that numerous modifications may be made to the illustrative embodiments and that other arrangements may be devised without departing from the spirit and scope of the technology.

CLAIMS

1. A respiratory treatment apparatus to generate a flow of breathable gas comprising:

a steam cell configured to generate a flow of steam;
and

a mixer coupled with the steam cell, the mixer configured to combine the flow of steam with a breathable gas; and

a delivery circuit adapted to couple with the mixer, the delivery circuit configured to couple with a patient interface to provide steam heated breathable gas to the patient interface, wherein the flow of steam pressurizes the flow of breathable gas.

2. The apparatus of claim 1 wherein the mixer comprises an injector and an ejector.

3. The apparatus of claim 2 wherein the mixer comprises a mixing chamber between the injector and the ejector.

4. The apparatus of any one of claims 1 to 3 wherein the mixer comprises a venturi jet.

5. The apparatus of any one of claims 1 to 4, wherein the mixer comprises a series of venturi jets.

6. The apparatus of any one of claims 1 to 5 wherein the mixer comprises a circumferential series of venturi jets.

7. The apparatus of any one of claims 1 to 6 wherein the mixer is integrated with the steam cell.

8. The apparatus of any one of claims 1 to 7 wherein the steam cell comprises a heating coil heat source.

9. The apparatus of any one of claims 1 to 8 wherein the steam cell comprises a combustible fuel heating source.

10. The apparatus of any one of claims 1 to 9 further comprising a pressure sensor to detect a pressure level of a steam chamber of the steam cell.

11. The apparatus of any one of claims 1 to 10 further comprising a temperature sensor to detect a temperature level of the steam cell.

12. The apparatus of any one of claims 1 to 11 wherein a steam chamber of the steam cell is coupled with a safety release valve.

13. The apparatus of any one of claims 1 to 12 wherein a steam release port of the steam cell is coupled with a proportional valve.

14. The apparatus of any one of claims 1 to 13 further comprising a hydro-filter, the hydro-filter configured to remove water from the steam heated breathable gas and permit transfer of the steam heated breathable gas.

15. The apparatus of any one of claims 1 to 14 further comprising a heat exchanger, the heat exchanger configured to condense water from the steam heated breathable gas.

16. The apparatus of any one of claims 1 to 15 further comprising a liquid reservoir configured to collect water condensed from the steam heated breathable

gas, the reservoir coupled with the steam cell to return the collected water to the steam cell.

17. The apparatus of any one of claims 1 to 16 further comprising a pump configured to pump water condensed from the steam heated breathable gas to the steam cell.

18. The apparatus of any one of claims 1 to 18 further comprising a pump configured to pump water condensed from the steam heated breathable gas to the steam cell upon detection of a presence of water with a water sensor.

19. The apparatus of any one of claims 1 to 18 further comprising a back flow conduit, the back flow conduit configured to return steam heated breathable gas to the mixer.

20. The apparatus of any one of claims 1 to 19 further comprising a back flow conduit, the back flow conduit configured with a valve to selectively return steam heated breathable gas to the mixer in accordance with a detection of temperature with a temperature sensor.

21. The apparatus of any of claims 1 to 20 further comprising a controller, the controller configured to control an operational parameter of the steam cell.

22. The apparatus of any of claims 1 to 21 wherein a controller controls a heat source of the steam cell in accordance with a detected pressure of the steam cell.

23. The apparatus of any of claims 1 to 22 wherein a controller controls a heat source of the steam cell in accordance with a detected temperature of the steam cell.

24. The apparatus of any of claims 1 to 23 wherein a controller controls a proportional valve to set a pressure level released from the steam cell.

25. The apparatus of any of claims 1 to 24 wherein a controller controls a change to a pressure level released from the steam cell in accordance with detection of a physiological parameter of a patient.

26. The apparatus of any of claims 1 to 25 wherein a controller controls a change to a pressure level released from the steam cell in accordance with detection of a respiratory cycle.

27. The apparatus of any of claims 1 to 27 wherein a controller controls a change to a pressure level released from the steam cell in accordance with detection of a sleep disordered breathing event.

28. The apparatus of any of claims 1 to 27 further comprising a steam turbine.

29. The apparatus of claim 28 wherein the steam turbine further comprises a blower impeller.

30. The apparatus of any one of claim 28 or claim 29 wherein the steam turbine further comprises a liquid impeller.

31. The apparatus of any one of claims 1 to 30 further comprising a venturi jet configured to direct a supply of steam from the steam cell to entrain a supply of water to the steam cell.

32. The apparatus of any one of claims 1 to 31 further comprising a steam conduit configured with an exchanger material to exchange heat via the material.

33. The apparatus of claim 32 wherein the steam conduit is proximate to a humidifier tank to warm a fluid of the tank.

34. The apparatus of any one of claim 32 or claim 33 wherein the steam conduit is proximate to a breathable gas supply conduit to warm the breathable gas of the breathable gas supply conduit.

35. A method for controlling a respiratory treatment apparatus:

generating a flow of steam from a steam cell; and

combining the flow of steam with a breathable gas in a mixer coupled with the steam cell to form steam heated breathable gas,

wherein a delivery circuit is adapted to couple with the mixer, the delivery circuit being configured to couple with a patient interface to conduct the steam heated breathable gas to the patient interface, wherein the steam pressurizes the breathable gas.

36. The method of claim 35 wherein the mixing comprises injecting the steam into a chamber and entraining the breathable gas with the steam through an ejector.

37. The method of claim 36 wherein the mixer comprises a mixing chamber between an injector and the ejector.

38. The method of any one of claims 35 to 37 wherein the mixer comprises a venturi jet.

39. The method of any one of claims 35 to 38, wherein the mixer comprises a series of venturi jets.

40. The method of any one of claims 35 to 39 wherein the mixer comprises a circumferential series of venturi jets.

41. The method of any one of claims 35 to 40 wherein the mixer is integrated with the steam cell.

42. The method of any one of claims 35 to 41 further comprising heating water in the steam cell with a heating coil heat source.

43. The method of any one of claims 35 to 42 further comprising heating water in the steam cell with a combustibile fuel heating source.

44. The method of any one of claims 35 to 43 further comprising detecting a pressure level of a steam chamber of the steam cell with a pressure sensor.

45. The method of any one of claims 35 to 44 further comprising detecting a temperature level of the steam cell with a temperature sensor.

46. The method of any one of claims 35 to 45 wherein a steam chamber of the steam cell is coupled with a safety release valve.

47. The method of any one of claims 35 to 46 wherein a steam release port of the steam cell is coupled with a proportional valve.

48. The method of any one of claims 35 to 47 further comprising filtering the steam heated breathable gas with a hydro-filter, the hydro-filter removing water from the steam heated breathable gas and permitting transfer of the steam heated breathable gas.

49. The method of any one of claims 35 to 48 further comprising condensing water from the steam heated breathable gas with a heat exchanger.

50. The method of any one of claims 35 to 49 further comprising collecting water condensed from the steam heated breathable gas in a water reservoir coupled with the steam cell and returning the collected water to the steam cell.

51. The method of any one of claims 35 to 50 further comprising pumping water condensed from the steam heated breathable gas to the steam cell.

52. The method of any one of claims 35 to 51 further comprising pumping, with a pump, water condensed from the steam heated breathable gas to the steam cell upon detection of a presence of water with a water sensor.

53. The method of any one of claims 35 to 52 further comprising returning with a back flow conduit, steam heated breathable gas to the mixer.

54. The method of any one of claims 35 to 53 further comprising selectively returning with a back flow conduit and a valve the steam heated breathable gas to the mixer in accordance with a detection of temperature with a temperature sensor.

55. The method of any of claims 35 to 54 further comprising controlling with a processor an operational parameter of the steam cell.

56. The method of any of claims 35 to 55 further comprising controlling with a processor a heat source of the steam cell in accordance with a detected pressure of the steam cell.

57. The method of any of claims 35 to 56 further comprising controlling with a processor a heat source of the steam cell in accordance with a detected temperature of the steam cell.

58. The method of any of claims 35 to 57 further comprising controlling with a processor a proportional valve to set a pressure level released from the steam cell.

59. The method of any of claims 35 to 58 further comprising controlling with a processor a change to a pressure level released from the steam cell in accordance with detection of a physiological parameter of a patient with a sensor.

60. The method of any of claims 35 to 59 further comprising controlling with a processor a change to a pressure level released from the steam cell in accordance with detection of a respiratory cycle with a sensor.

61. The method of any of claims 35 to 60 further comprising controlling with a processor a change to a pressure level released from the steam cell in accordance with detection of a sleep disordered breathing event.

62. The method of any one of claims 35 to 61 further comprising directing steam from the steam cell at a steam turbine.

63. The method of claim 62 wherein the steam turbine further comprises a blower impeller.

64. The method of any one of claim 62 or claim 63 wherein the steam turbine further comprises a liquid impeller.

65. The method of any one of claims 35 to 64 further comprising entraining a supply of water to the steam cell with a venturi jet configured to direct a supply of steam from the steam cell.

66. The method of any one of claims 35 to claim 65 further comprising exchanging heat from a steam conduit configured with an exchanger material to exchange heat via the material.

67. The method of claim 66 wherein the steam conduit is proximate to a humidifier tank to warm a fluid of the tank.

68. The method of any one of claim 66 or claim 67 wherein the steam conduit is proximate to a breathable gas supply conduit to warm the breathable gas of the breathable gas supply conduit.

69. A respiratory treatment apparatus to generate a flow of breathable gas comprising:

a steam cell configured to generate a flow of steam;
and

a turbine coupled with the steam cell, the turbine configured for operation in response to the flow of steam; and

a delivery circuit configured to couple with a patient interface to provide pressurized breathable gas to the patient interface, the breathable gas pressurized by operation of the turbine.

70. The apparatus of claim 69 wherein the turbine comprises an impeller assembly.

71. The apparatus of claim 70 wherein the impeller assembly includes a blower impeller and a steam impeller.

72. The apparatus of any one of claims 69 to 71 further comprising a mixer to combine the flow of steam with a flow of air.

73. The apparatus of any one of claims 69 to 71 further comprising a mixer to combine the flow of steam with a flow of air from a blower impeller.

74. The apparatus of any one of claims 69 to 73 further comprising a liquid pump, the liquid pump moving a liquid by operation of the turbine.

75. The apparatus of claim 74 wherein an impeller assembly of the turbine comprises a liquid impeller and a steam impeller.

76. The apparatus of any one of claims 74 and 75 wherein the liquid pump supplies the liquid to the steam cell.

77. The apparatus of any one of claims 74 to 76 wherein the liquid pump supplies the liquid to a humidifier tank coupled with the delivery circuit, the humidifier configured to humidify the breathable gas.

78. The apparatus of any one of claims 69 to 77 further comprising controller and a sensor to sense a characteristic of the apparatus, wherein the controller sets operation of the turbine in response to a signal from the sensor.

79. The apparatus of claim 78 wherein the characteristic is any one or more of turbine speed, breathable gas pressure, steam pressure, breathable gas temperature, steam temperature, breathable gas humidity, steam flow rate, breathable gas flow rate, liquid flow rate and fluid level.

80. The apparatus of any one of claims 69 to 79 wherein a controller of the apparatus detects a flow rate of a supplied breathable gas with a flow sensor and regulates the flow of steam to the turbine to control the supplied breathable gas.

81. A method for controlling a respiratory treatment apparatus comprising:

generating a flow of steam in a steam cell of the apparatus; and

directing the flow of steam at a turbine coupled with the steam cell, the turbine configured for operation in response to the flow of steam; and

generating a pressurized breathable gas into a delivery circuit configured to couple with a patient interface, the breathable gas pressurized by operation of the turbine.

82. The method of claim 81 wherein the turbine comprises an impeller assembly.

83. The method of claim 82 wherein the impeller assembly includes a blower impeller and a steam impeller.

84. The method of any one of claims 81 to 83 further comprising combining in a mixer the flow of steam with a flow of air.

85. The method of any one of claims 81 to 84 further comprising combining in a mixer the flow of steam with a flow of air from a blower impeller coupled with the turbine.

86. The method of any one of claims 81 to 85 further comprising moving a liquid with a liquid pump by operation of the turbine.

87. The method of claim 86 wherein an impeller assembly of the turbine comprises a liquid impeller and a steam impeller.

88. The method of any one of claims 86 and 87 further comprising supplying the liquid to the steam cell with the liquid pump.

89. The method of any one of claims 86 to 88 further comprising, with the liquid pump, supplying the liquid to a humidifier tank coupled with the delivery circuit, the humidifier configured to humidify the breathable gas.

90. The method of any one of claims 81 to 89 further comprising, with a controller, setting an operation of the turbine in response to a signal from a sensor that senses a characteristic of the apparatus.

91. The method of claim 90 where the characteristic is any one or more of turbine speed, breathable gas pressure, steam pressure, breathable gas temperature, steam temperature, breathable gas humidity, steam flow rate, breathable gas flow rate, liquid flow rate and fluid level.

92. The method of any one of claims 81 to 91 further comprising, with a controller, detecting a flow rate of a supplied breathable gas with a flow sensor and regulating the flow of steam to the turbine to control the supplied breathable gas.

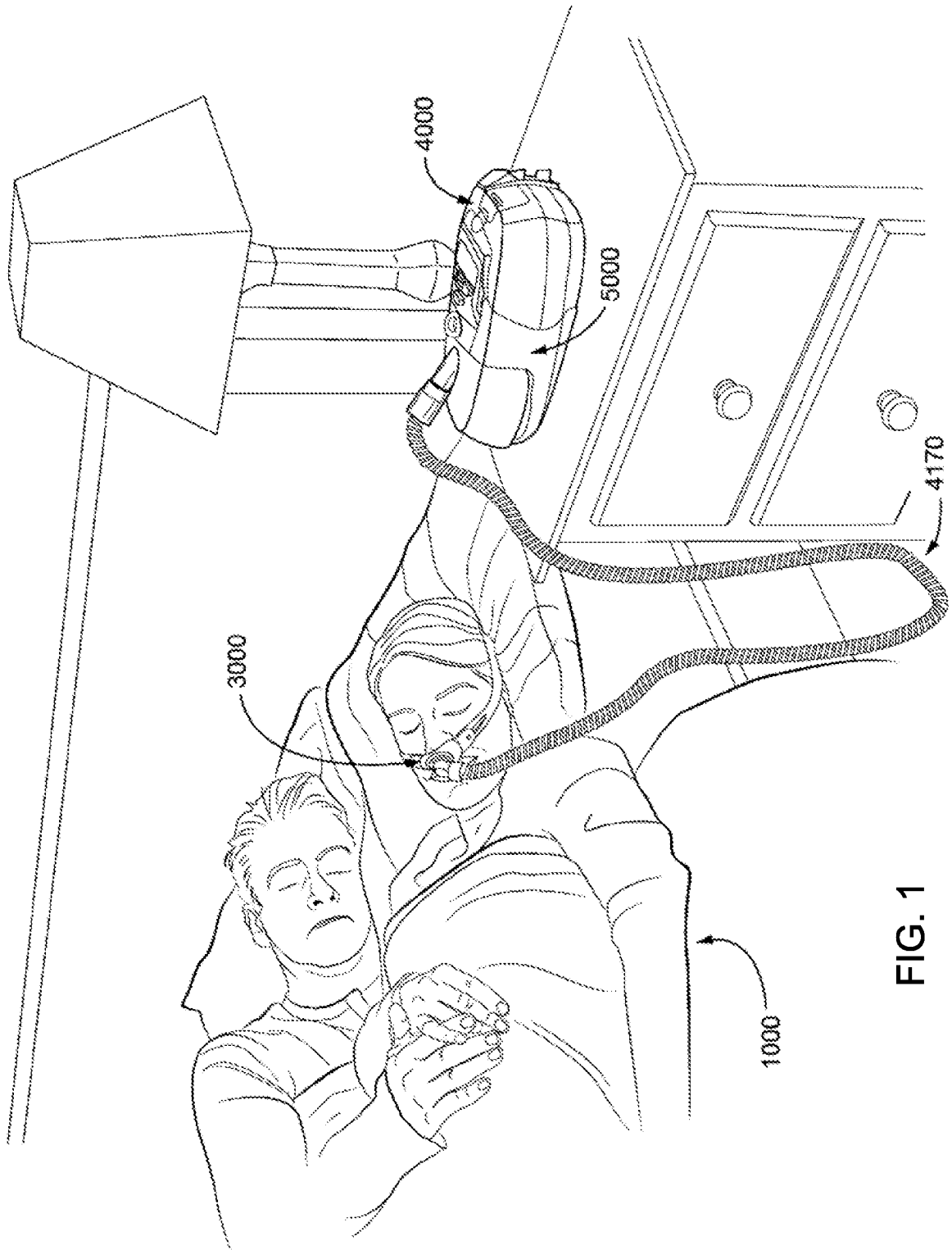


FIG. 1

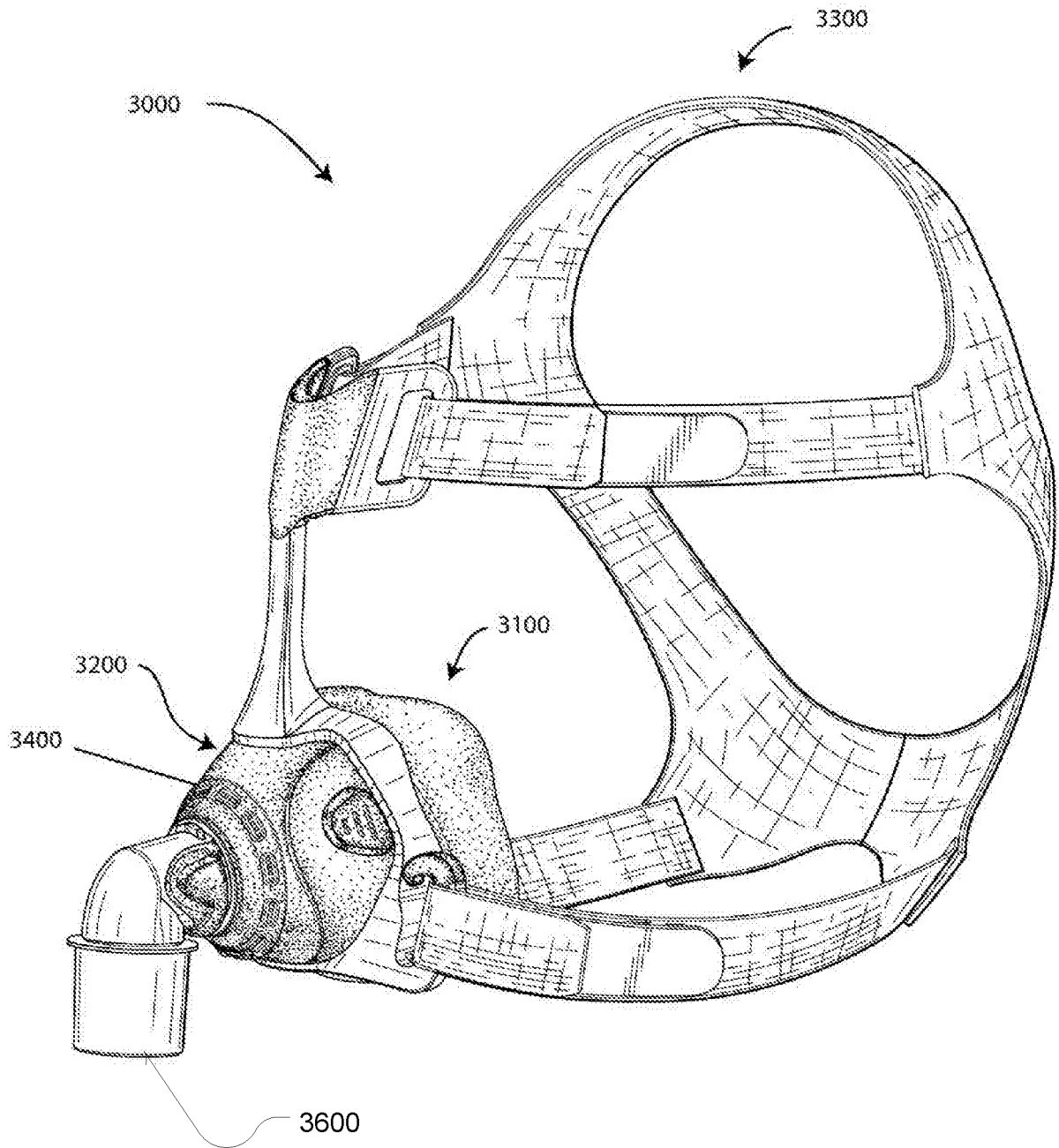


FIG. 2

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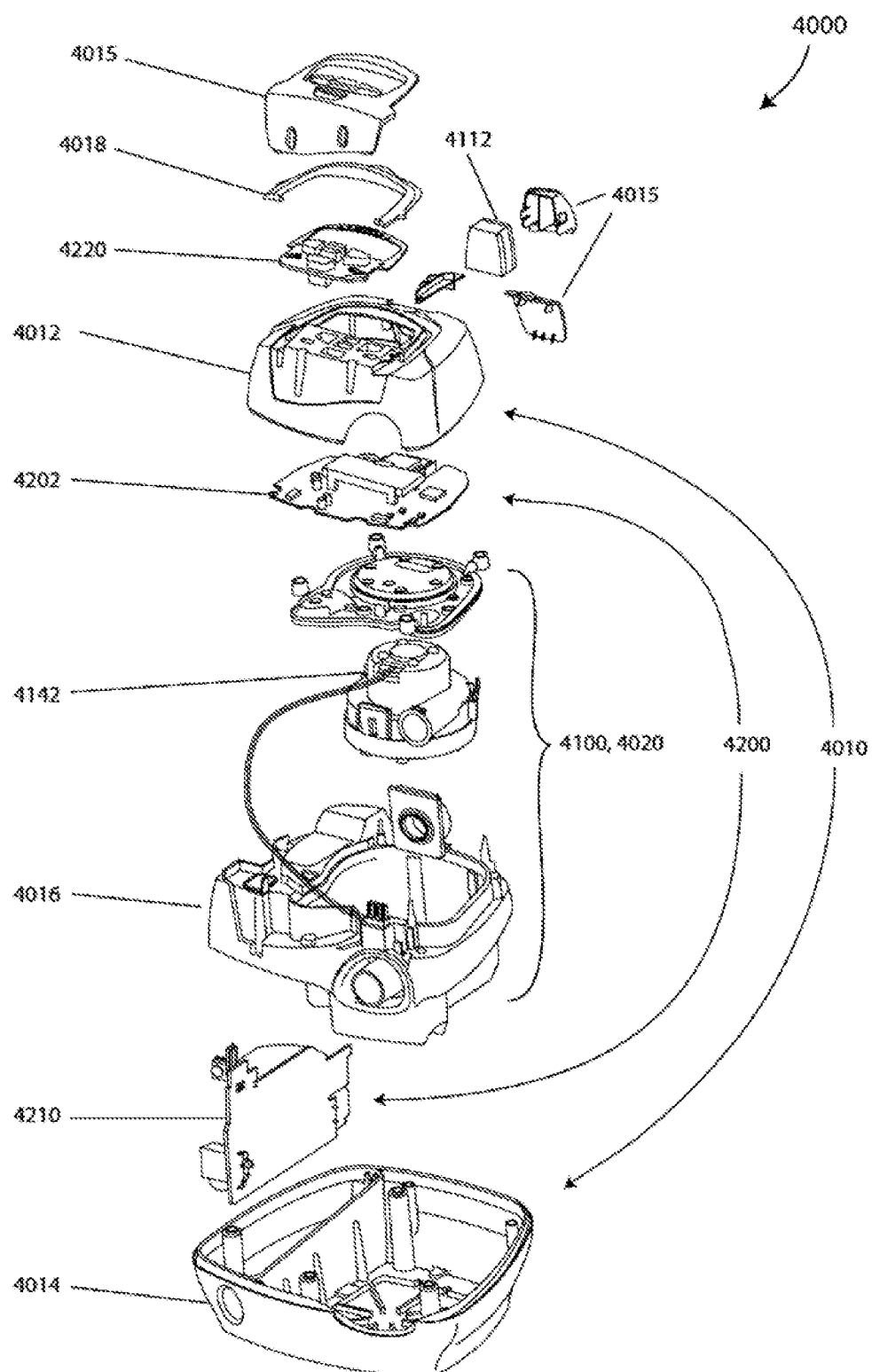
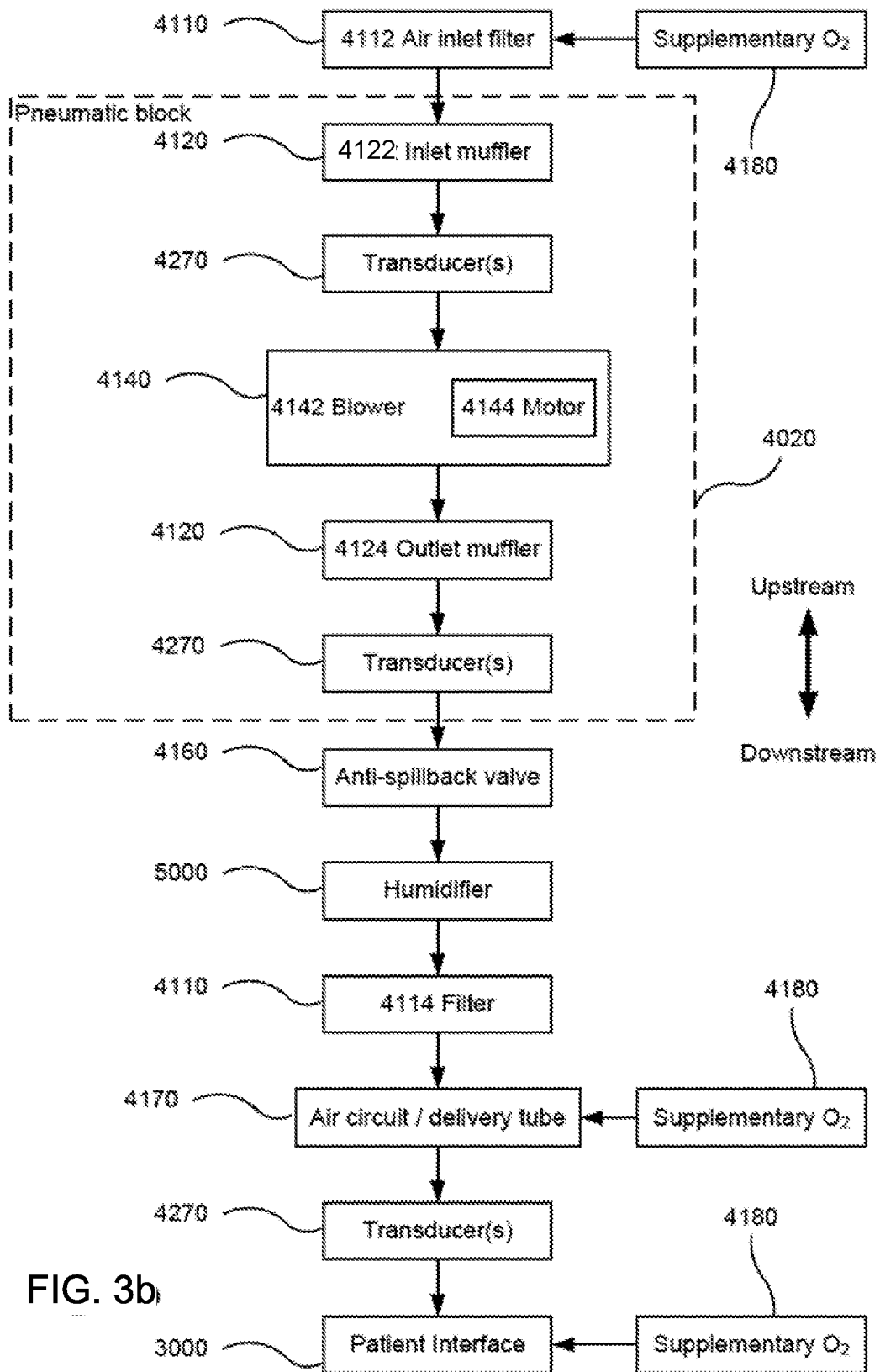


FIG. 3a

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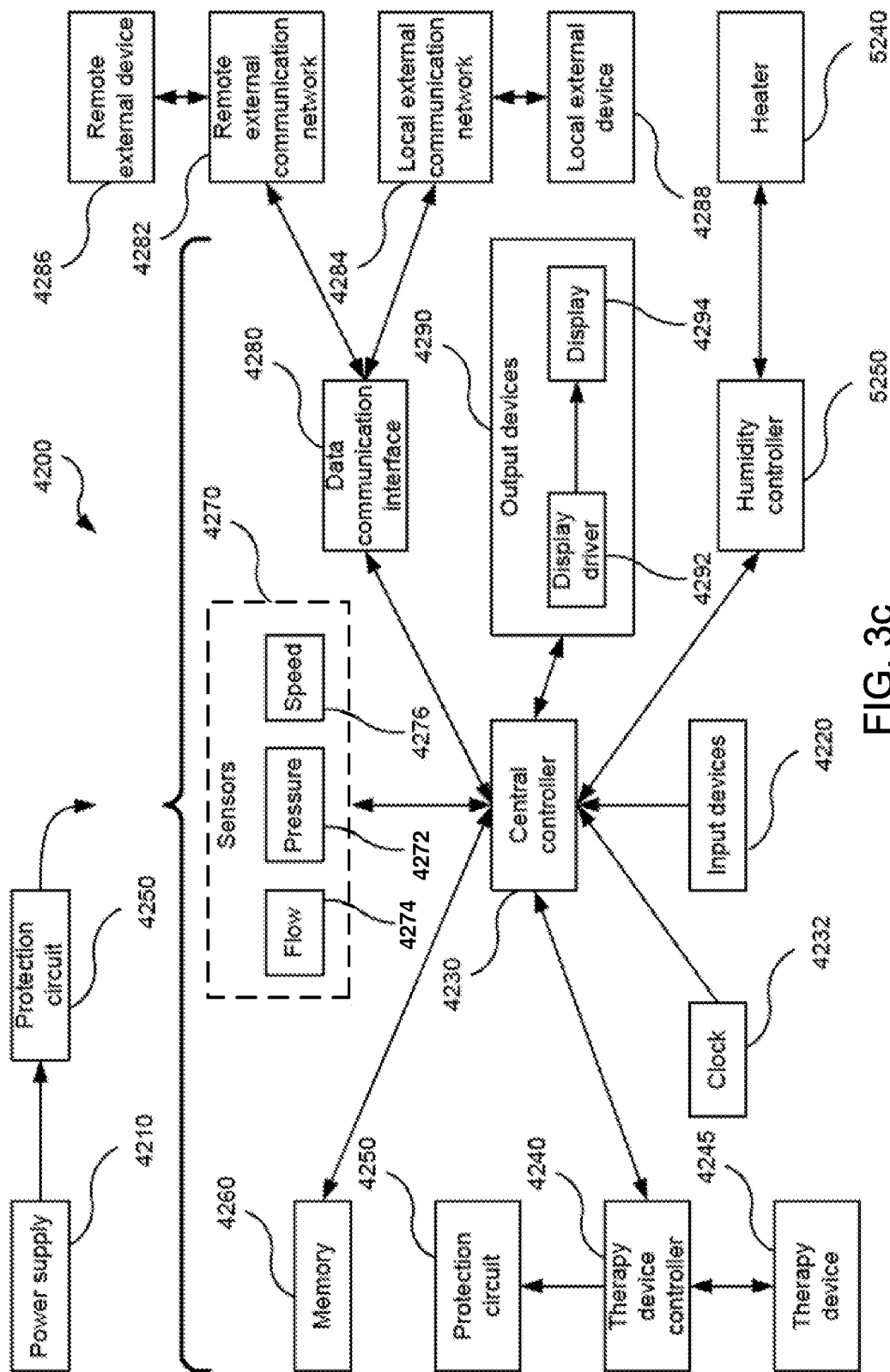


FIG. 3c

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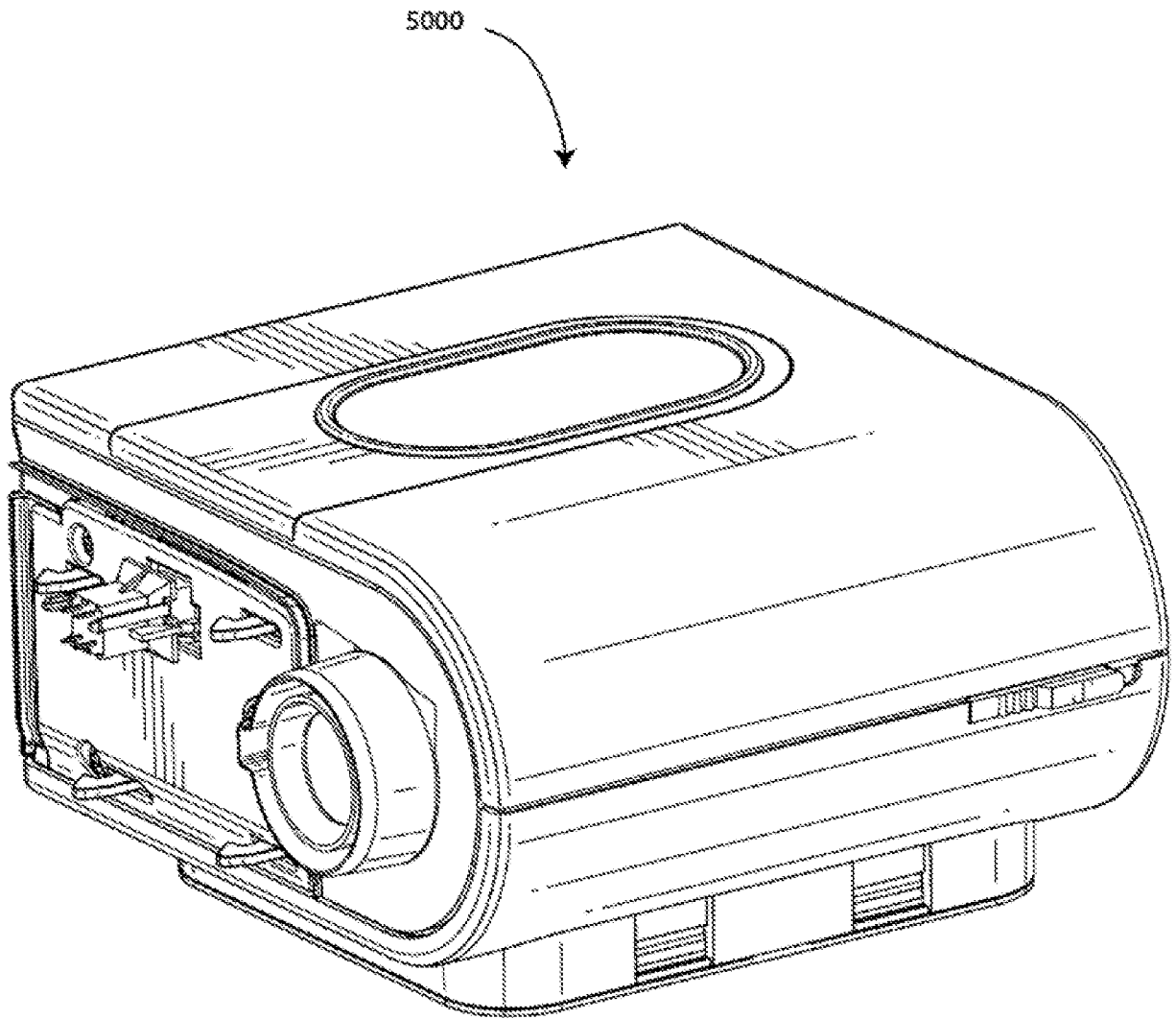


FIG. 4

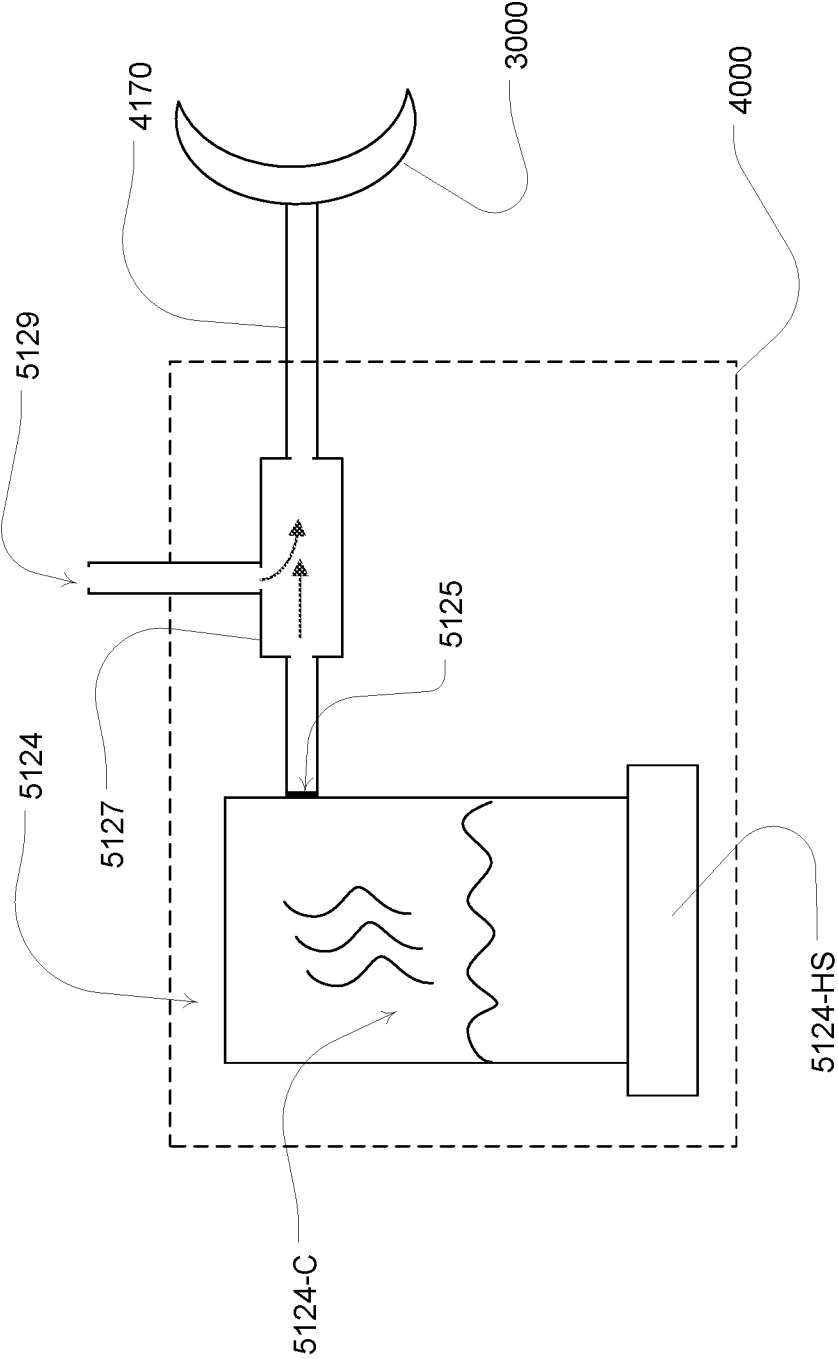


FIG. 5

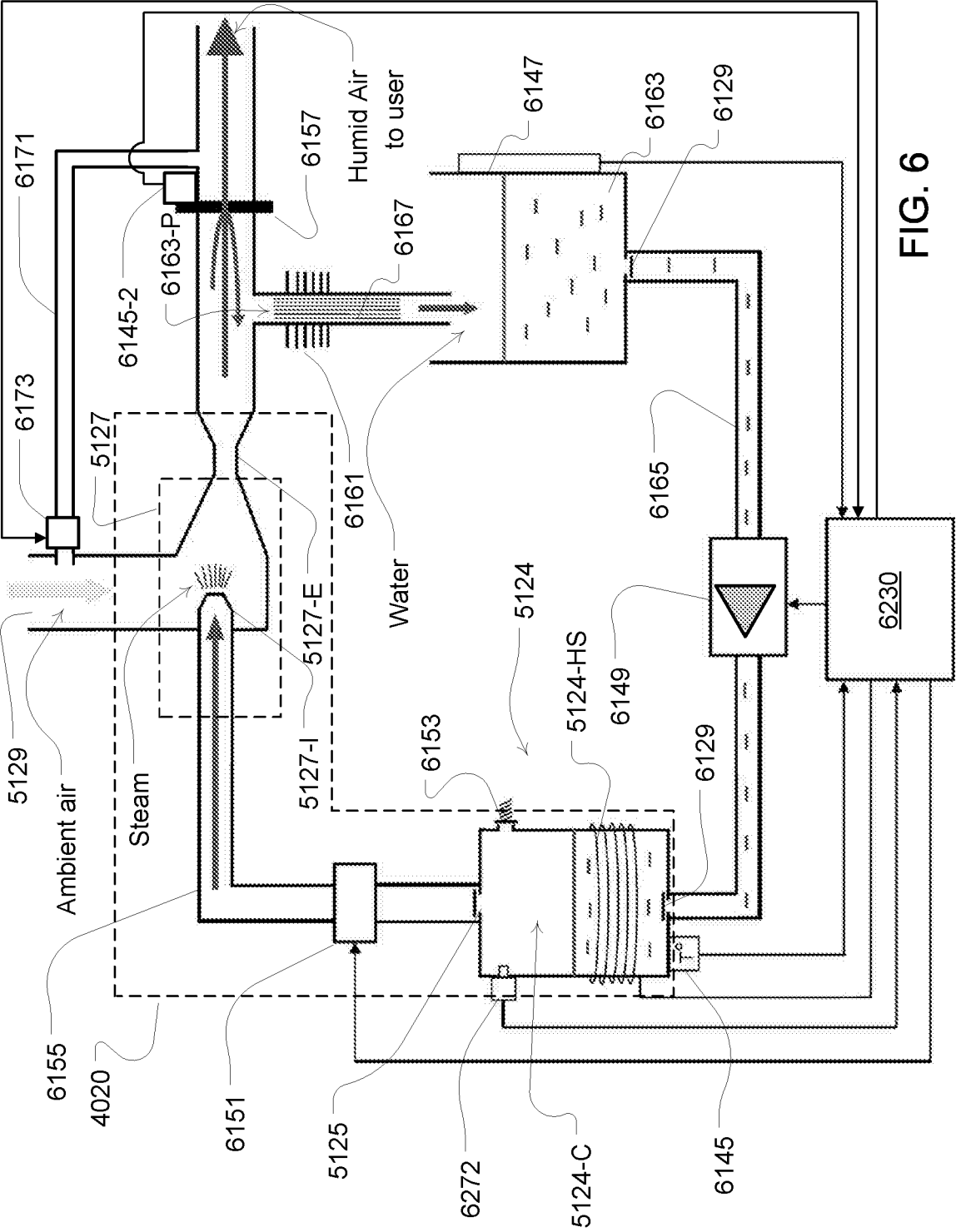


FIG. 6

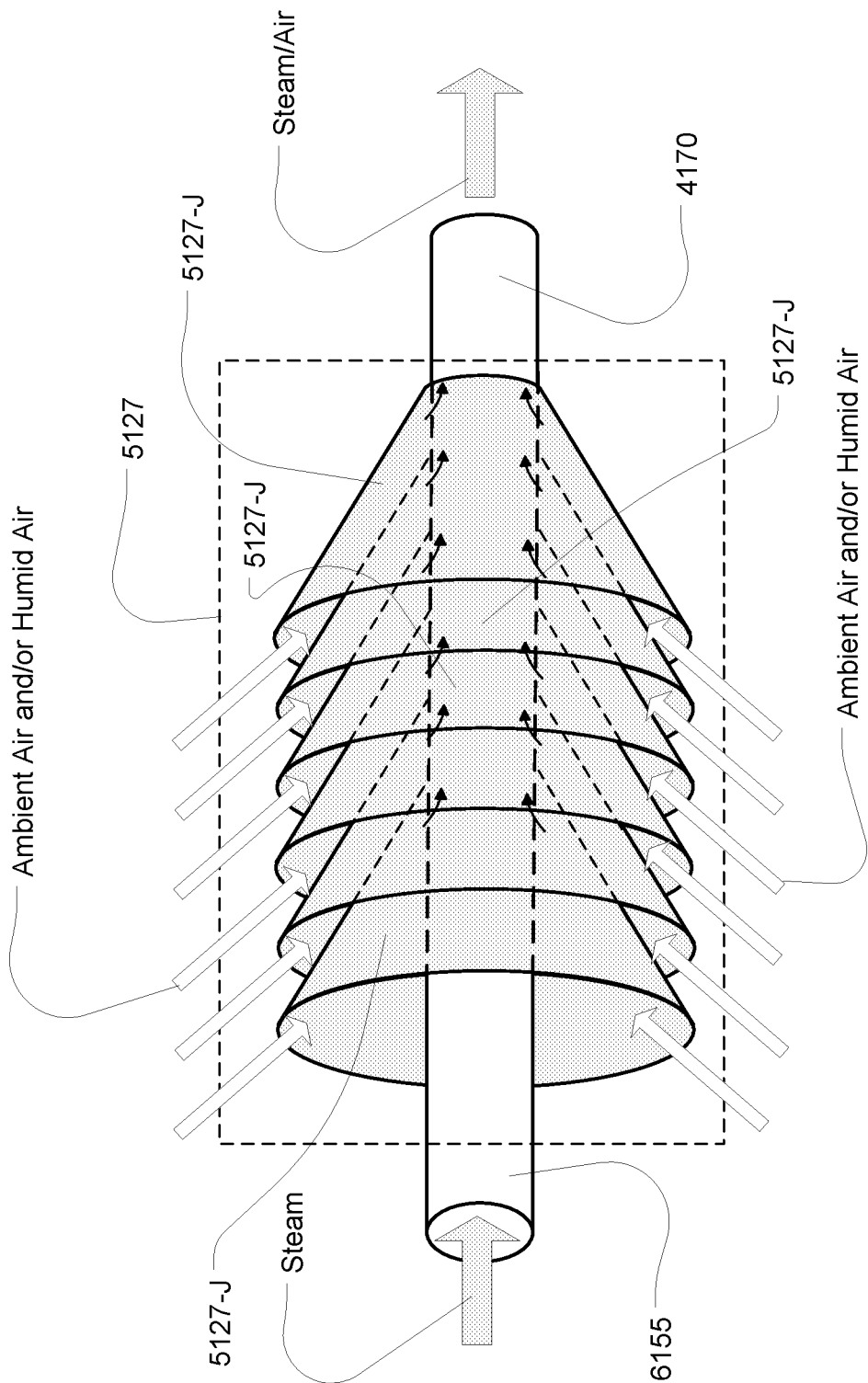
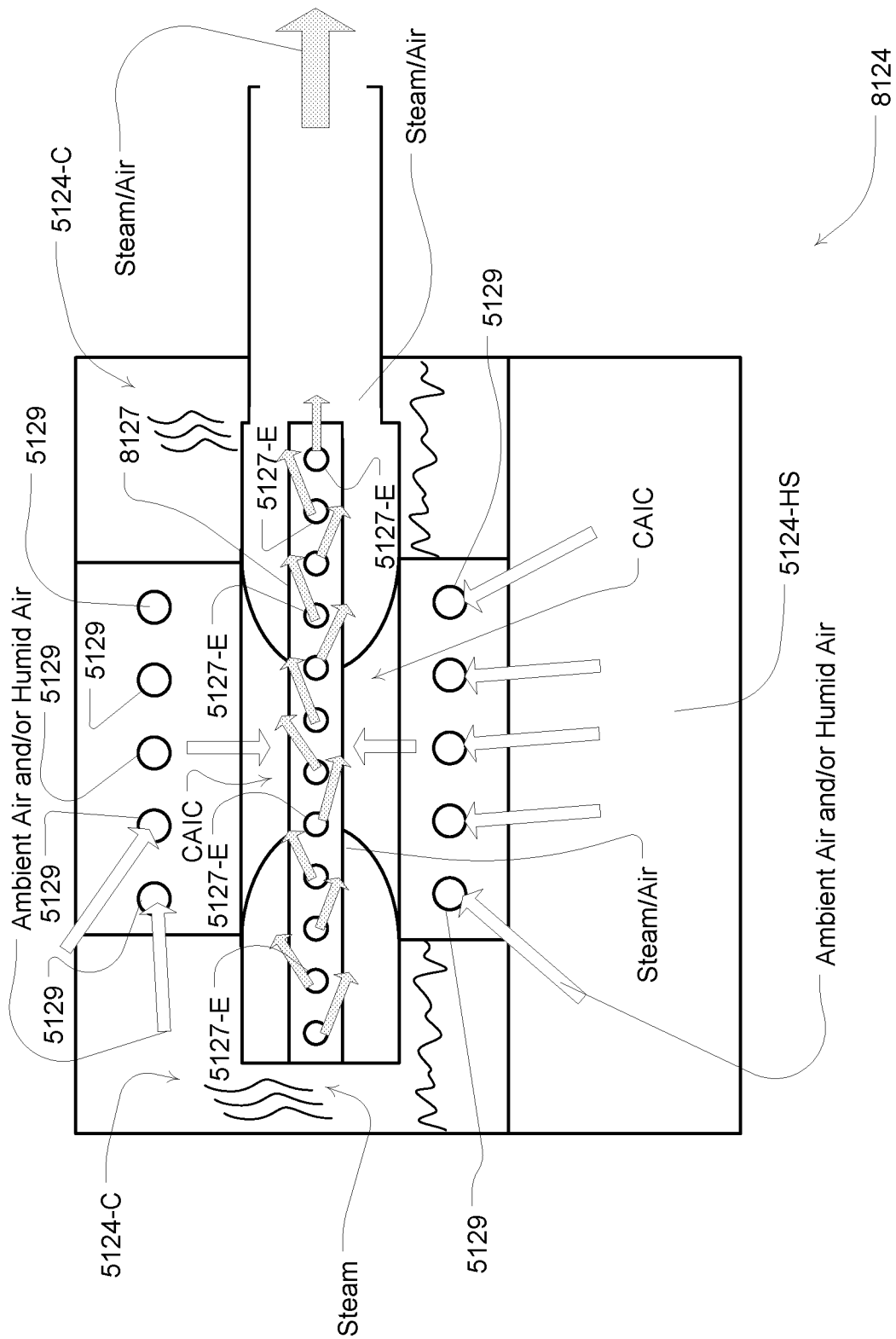


FIG. 7

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F/G. 8

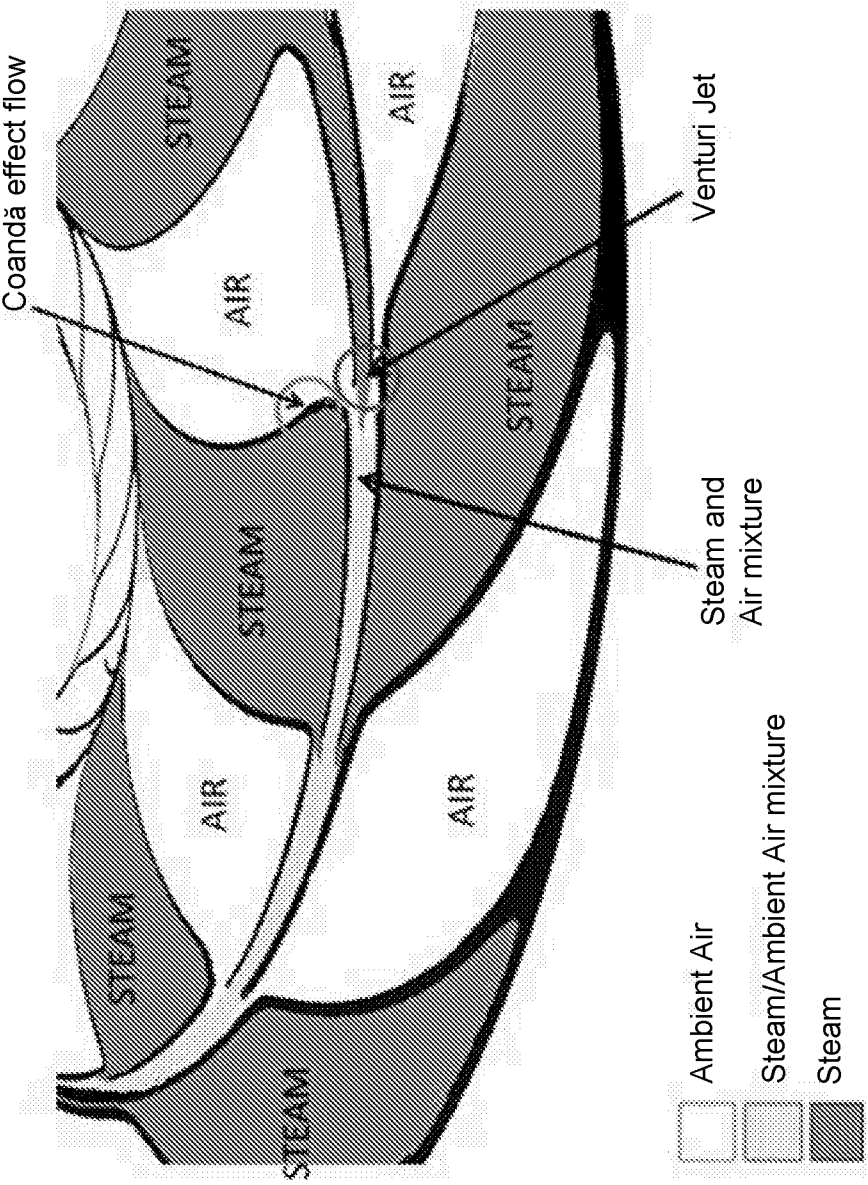


FIG. 9

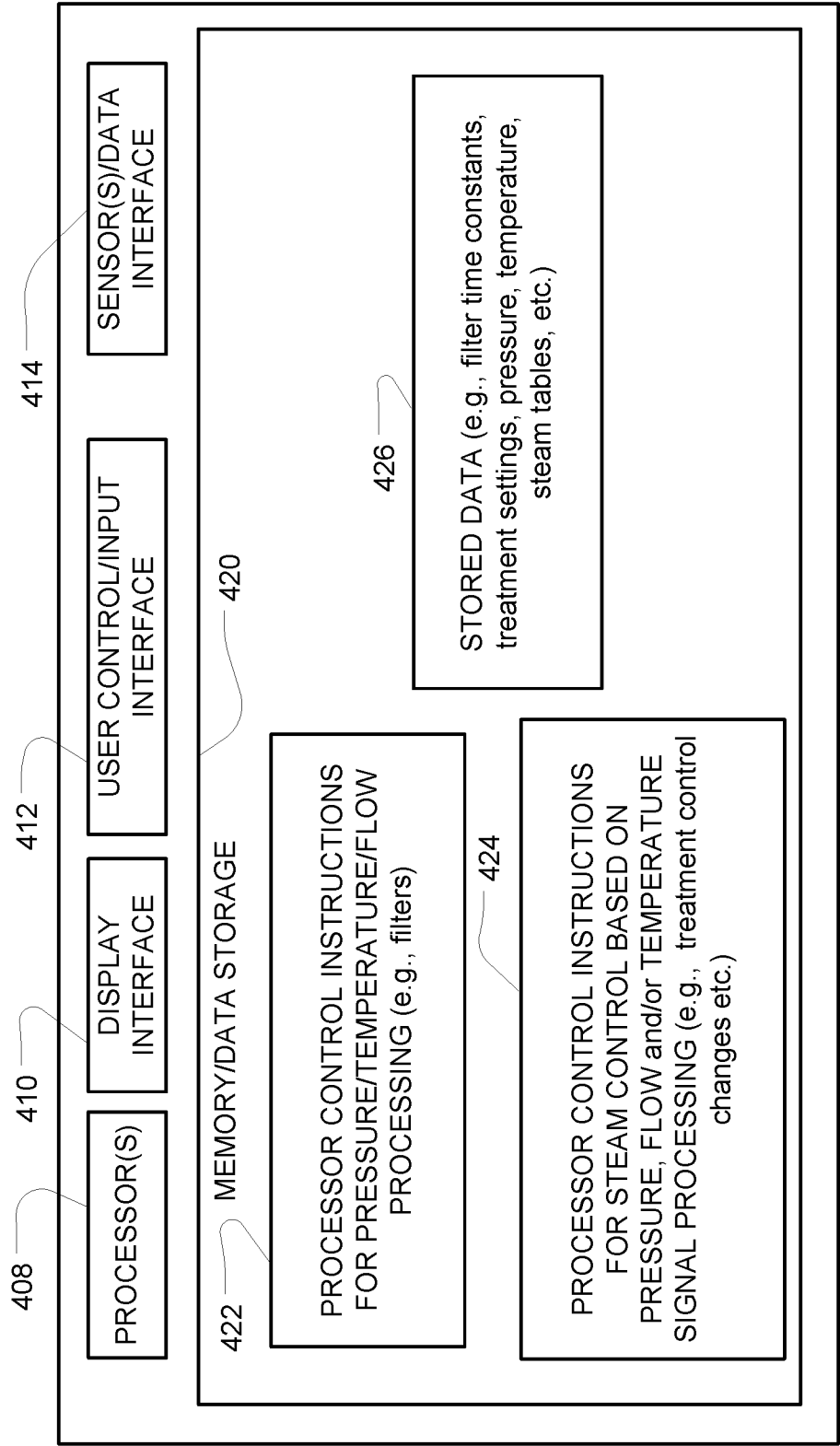


FIG. 10

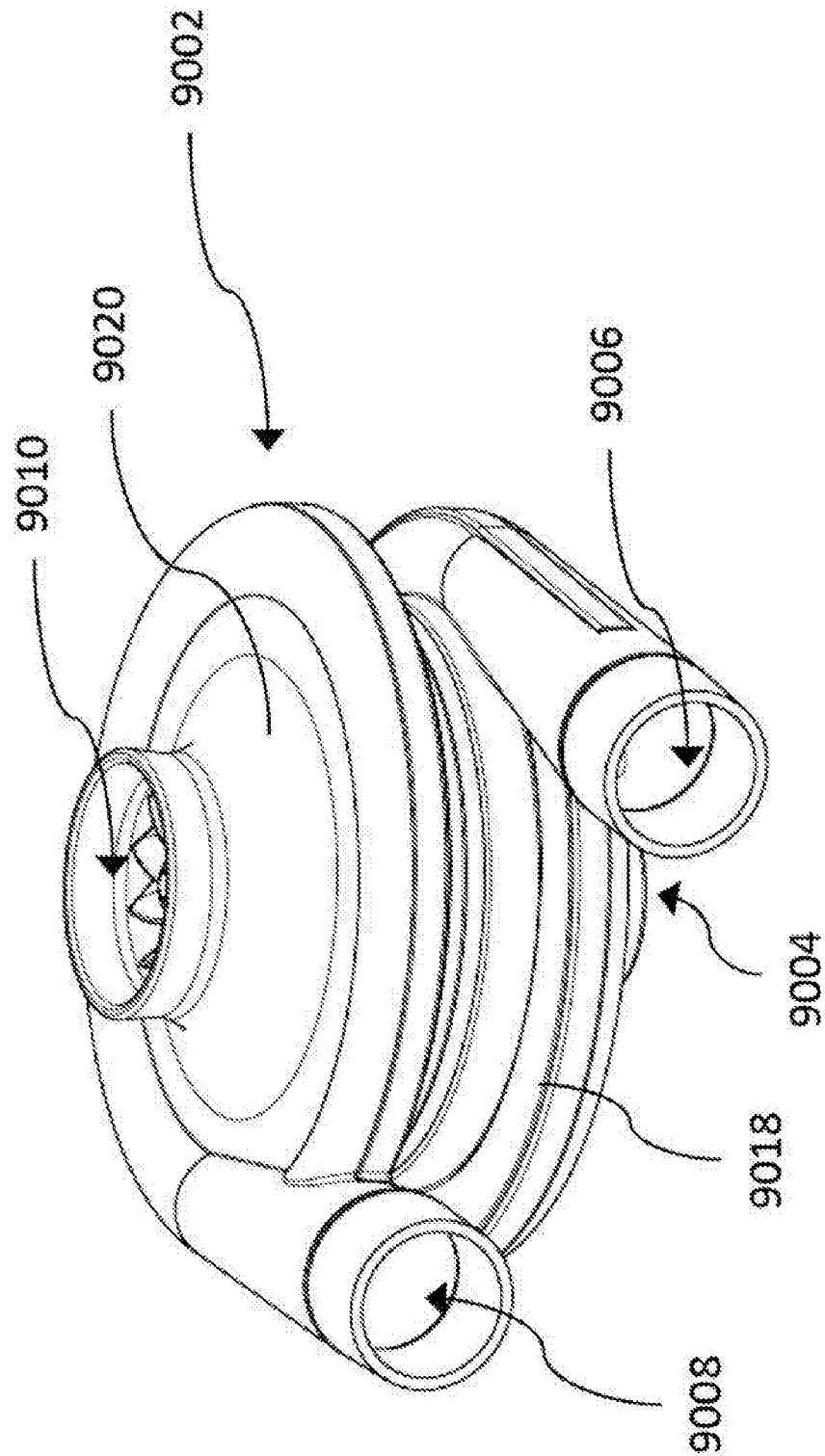


FIG. 11a

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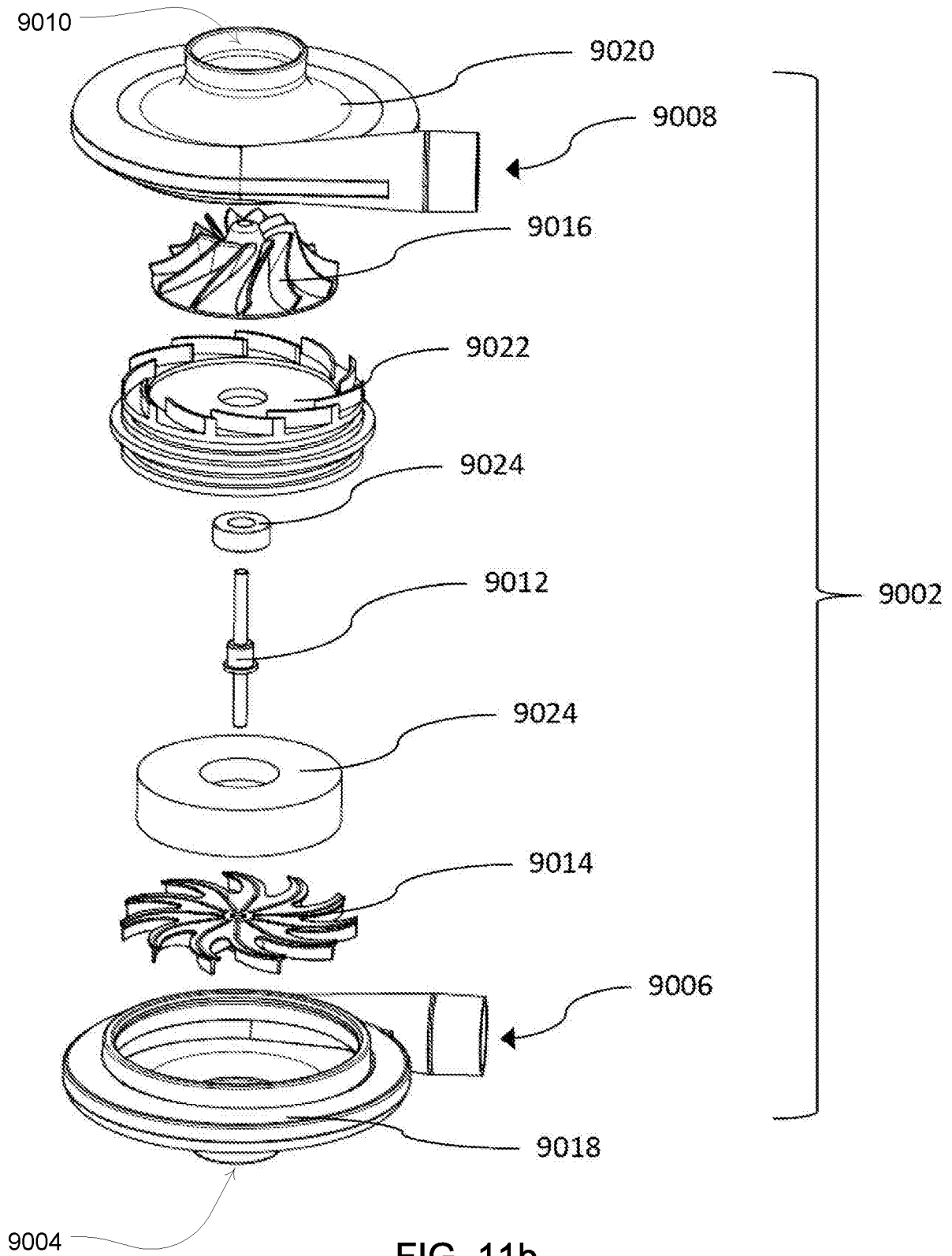


FIG. 11b

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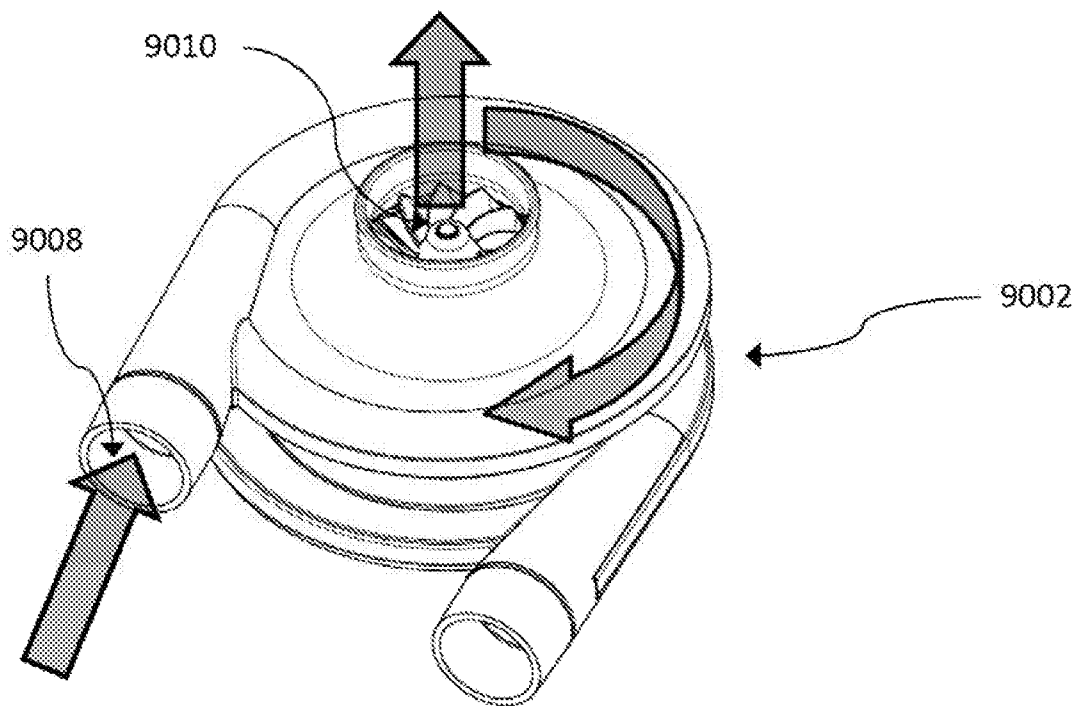


FIG. 11c

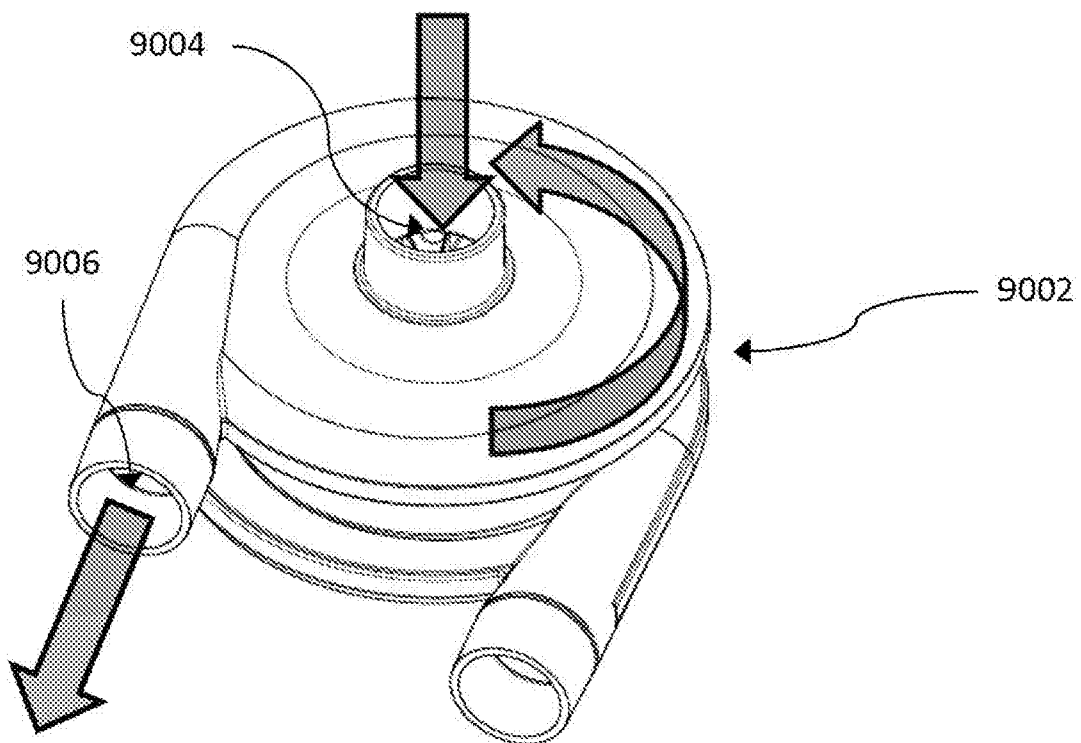


FIG. 11d

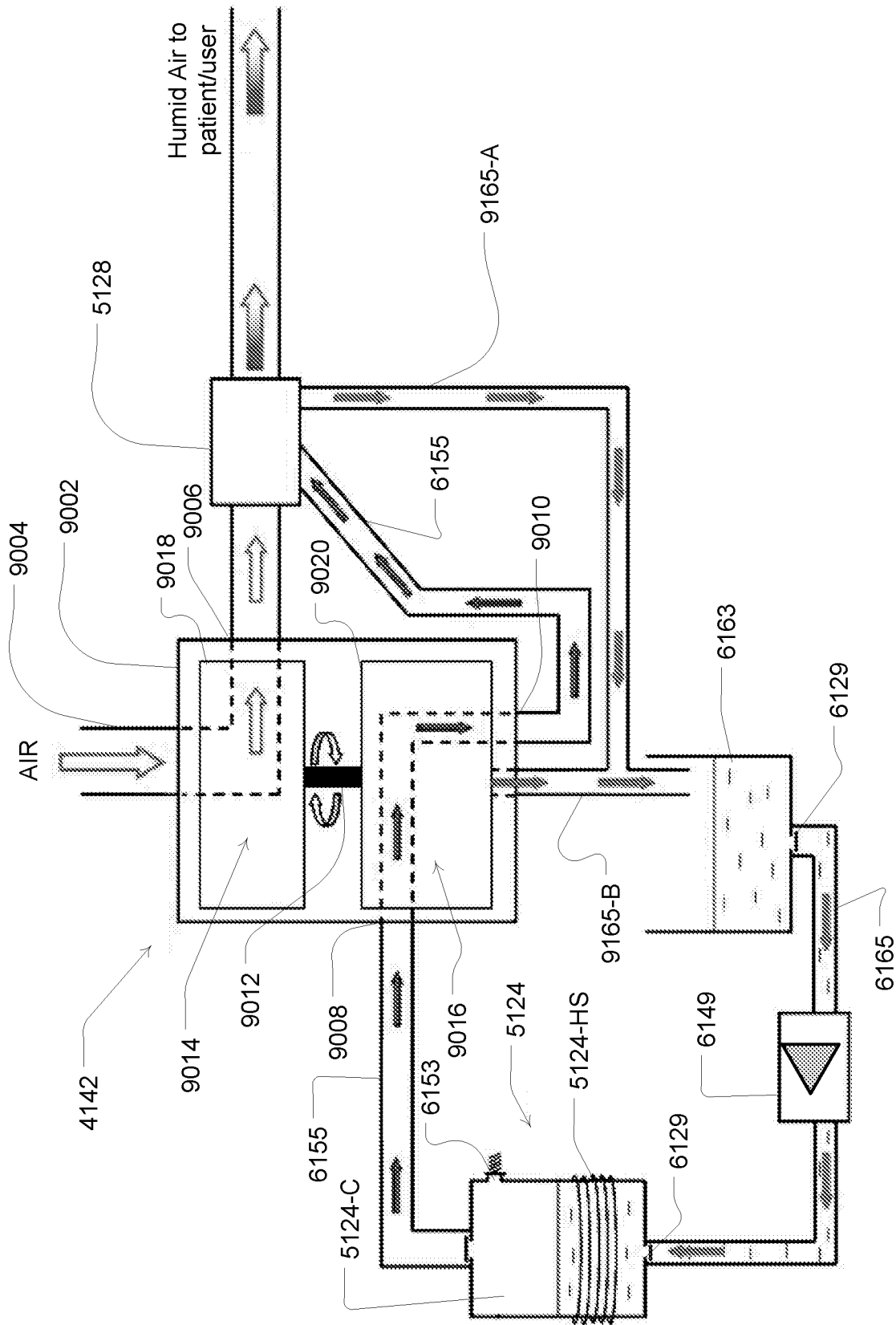


FIG. 12a

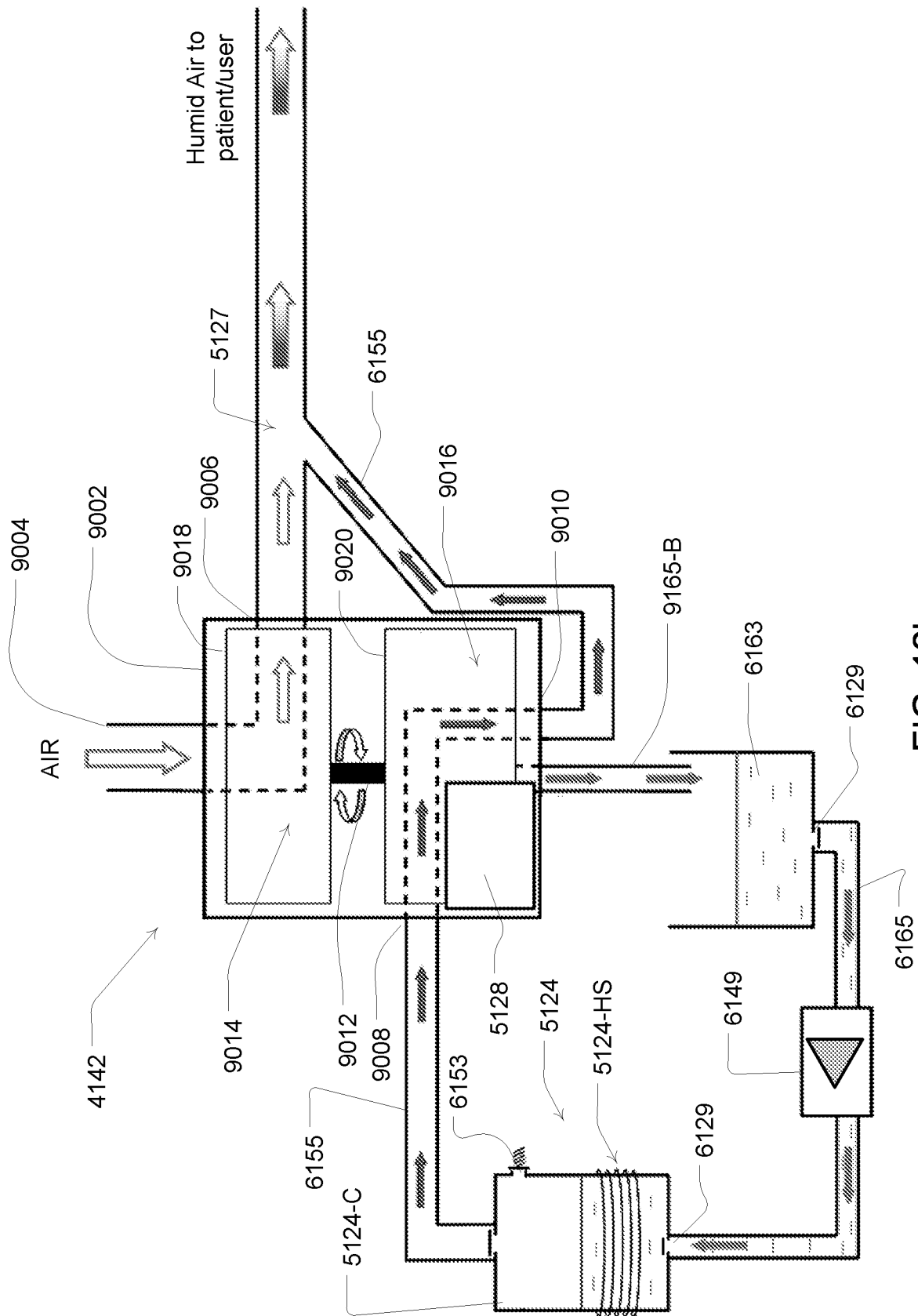
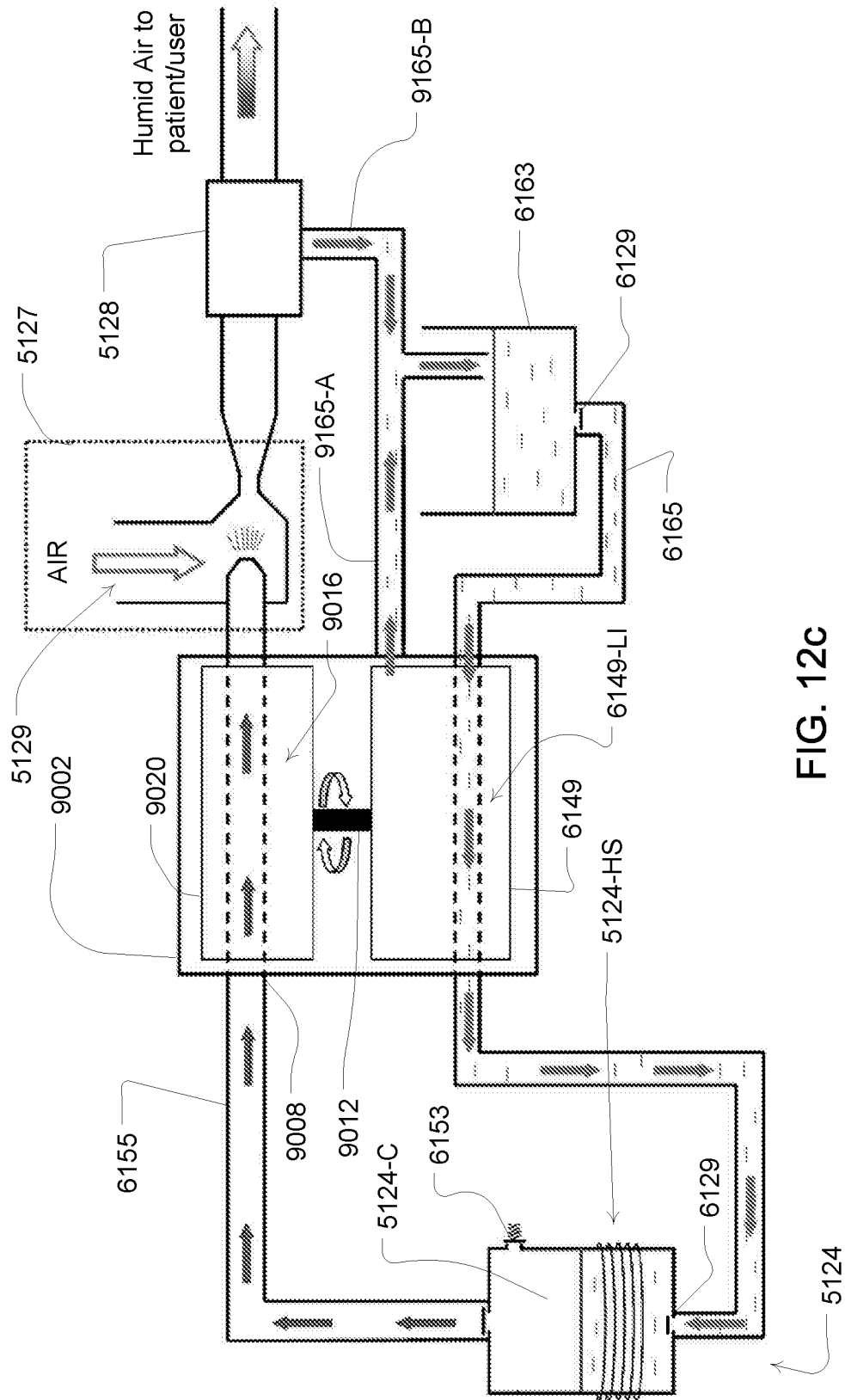


FIG. 12b



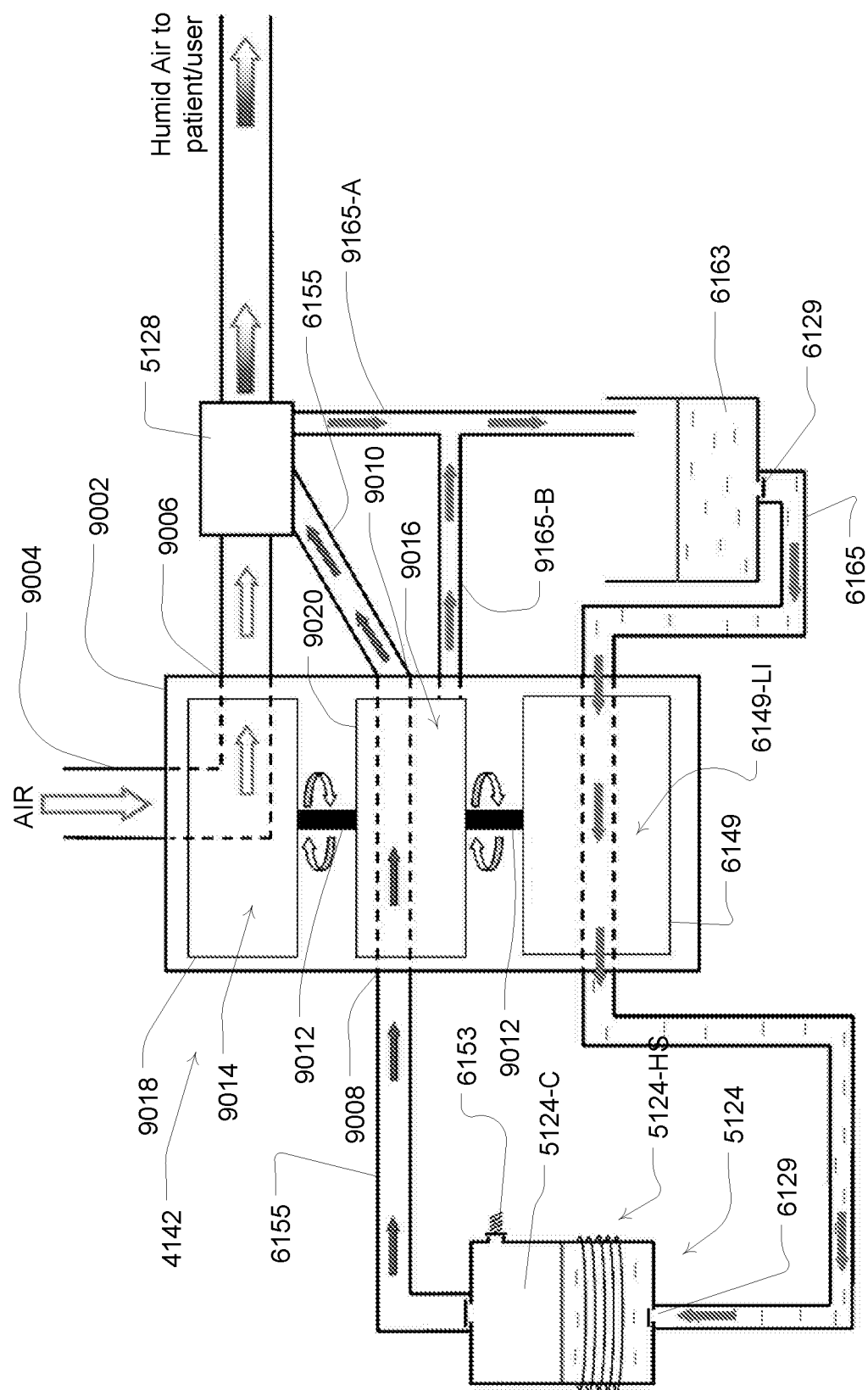


FIG. 12d

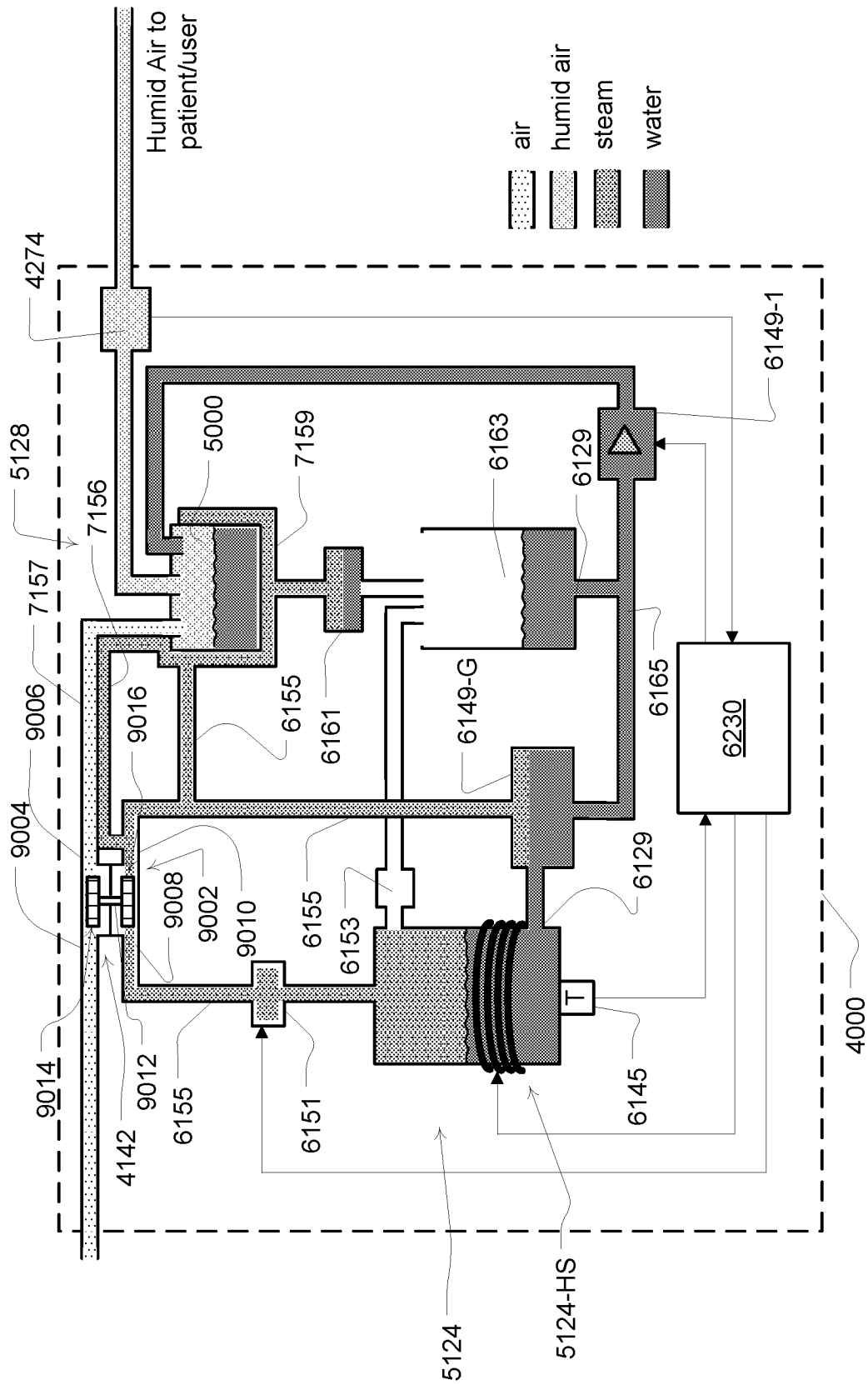


FIG. 12e

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2014/050071

A. CLASSIFICATION OF SUBJECT MATTER

A61M 16/00 (2006.01)

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)

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)

WPI, EPODOC, TXTE: A61M16/00 and keywords (Respiration, Breath, System, Water, Steam, Mixer and like terms).

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

☒ Further documents are listed in the continuation of Box C☒ See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"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
"E"	earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 9 October 2014		Date of mailing of the international search report 09 October 2014	
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustalia.gov.au		Authorised officer Timothy Williams AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262832067	

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2014/050071
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4200093 A (CAMP) 29 April 1980 Abstract, Figure 1, Column 2 Line 41-68, Column 3 Line 31-44, Column 3 Line 16-20, Column 4 Line 41- Column 5 Line 13	1-92
X	US 6997183 B2 (KOCH et al) 14 February 2006 Abstract, Figure 1, Column 3 Line 39-Column 4 Line 8, Column 3 Line 18-20, Column 3 Line 15-18	1-92
X	US 5063921 A (HOWE) 12 November 1991 Abstract, Figure 1, Column 2 Line 63-Column 3 Line 11, Column 9 Line 52-55, Column 9 Line 35-68, Column 15 Line 9-45	1-92
X	WO 2001/002043 A1 (J & M DISTRIBUTORS LTD.) 11 January 2001 Abstract, Figures 1-9, Page 11 Line 1-10, Page 8 Line 18-24, Page 12 Line 4-12, Page 6 Line 1-20	1-92

Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2014/050071	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
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US 6997183 B2	14 February 2006	US 6997183 B2	14 Feb 2006
		AU 2003227324 A1	19 Feb 2004
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WO 2001/002043 A1	11 January 2001	AU 5383400 A	22 Jan 2001
		US 6435180 B1	20 Aug 2002
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			