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(54) **SYSTEM AND METHOD FOR MONITORING COMPOSITION IN A SIDESTREAM SYSTEM USING A PUMP AND DETECTOR WITH CONTROL ELECTRONICS THAT ARE TIGHTLY INTEGRATED**

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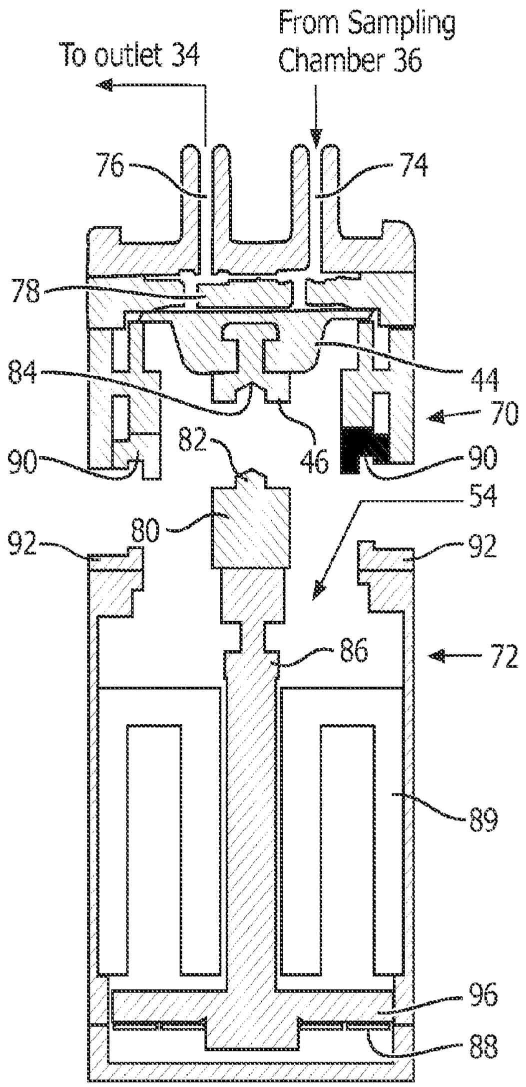
USPC **600/407**

(57) **ABSTRACT**

A system and method are configured to monitor composition of a flow of breathable gas being provided to a subject. The monitoring is accomplished in a sidestream configuration in which control of a pump and a detector are implemented in a tightly integrated controller.



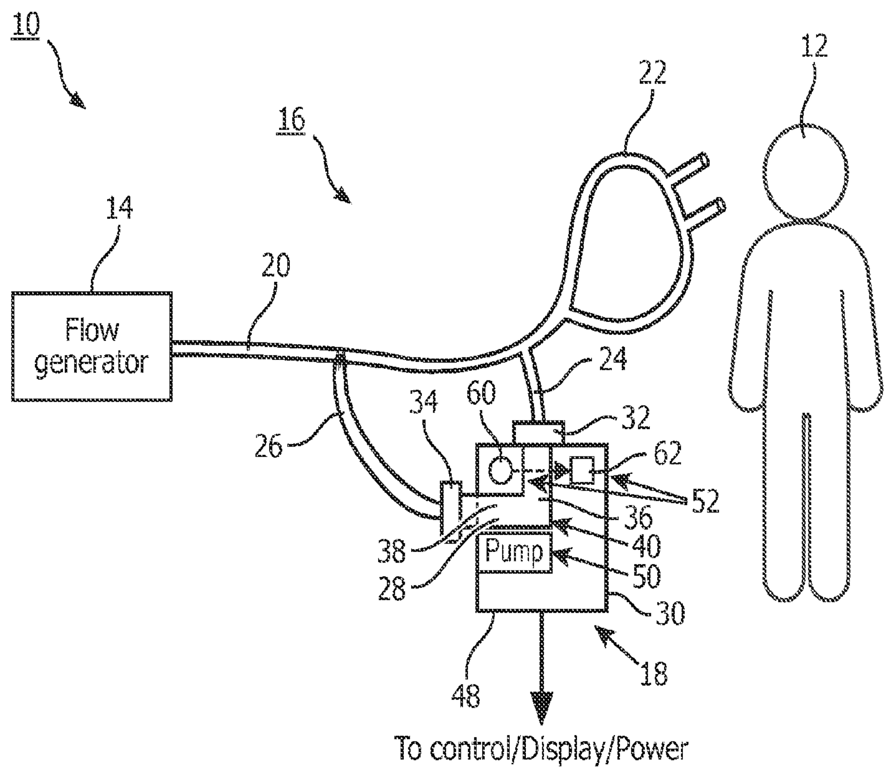

10
16
22
12
14
20
Flow generator
24
34
60
32
26
62
52
36
40
38
Pump
50
28
30
18
48
To control/Display/Power

FIG. 1

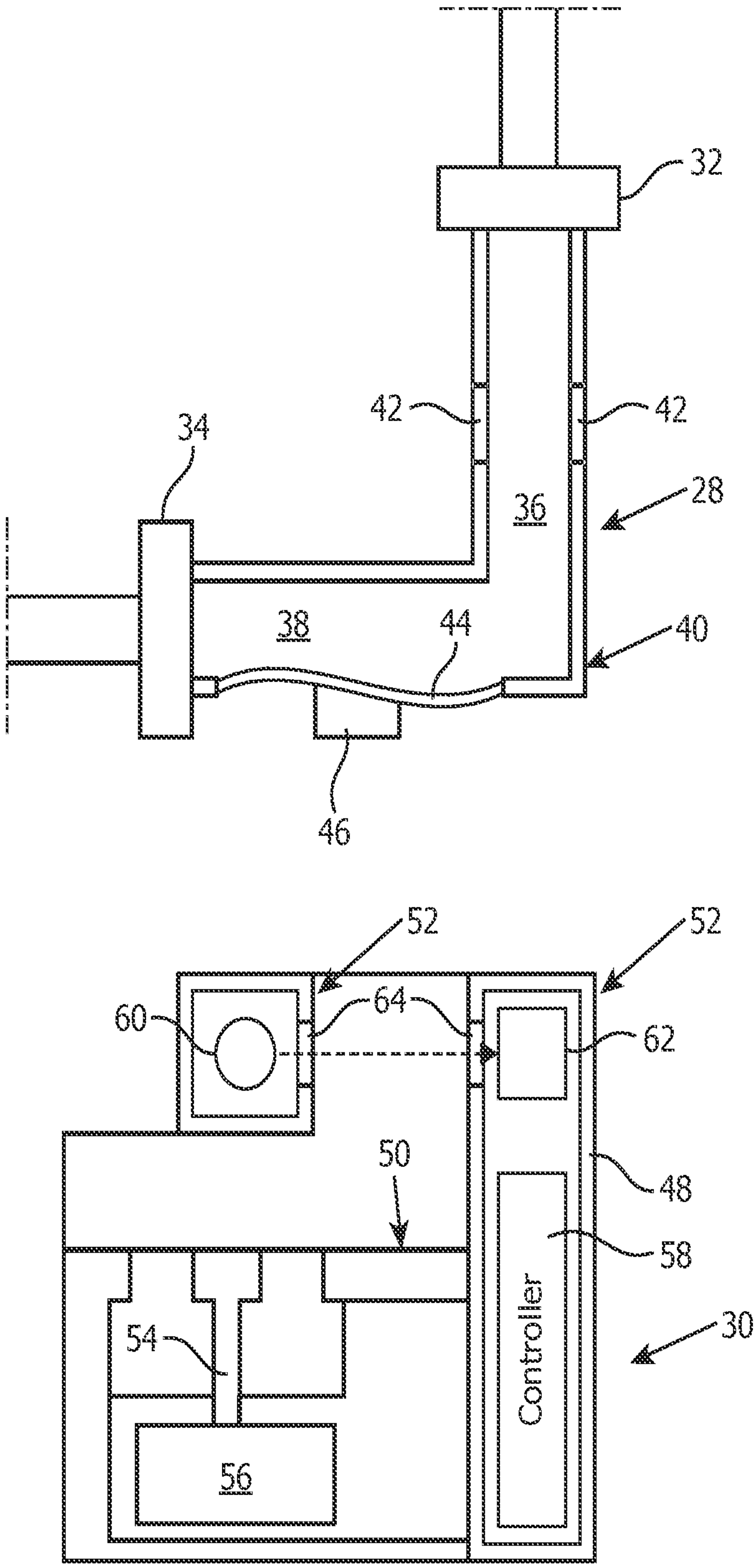
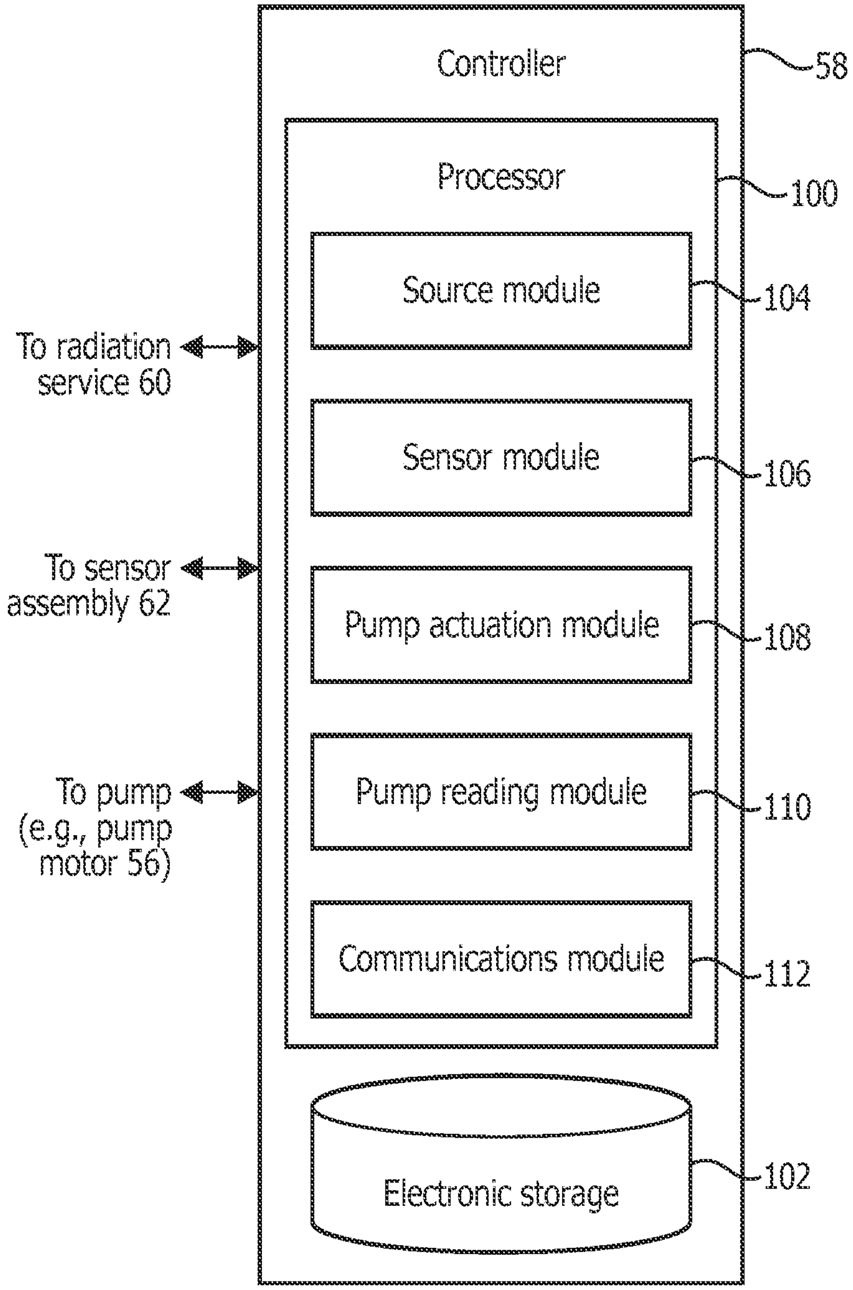

32
42
42
34
36
28
38
44
40
46
52
52
60
64
62
50
48
58
Controller
30
54
56

FIG. 2



Controller
58
Processor
100
Source module
104
To radiation service 60
Sensor module
106
To sensor assembly 62
Pump actuation module
108
To pump (e.g., pump motor 56)
Pump reading module
110
Communications module
112
Electronic storage
102

FIG. 3

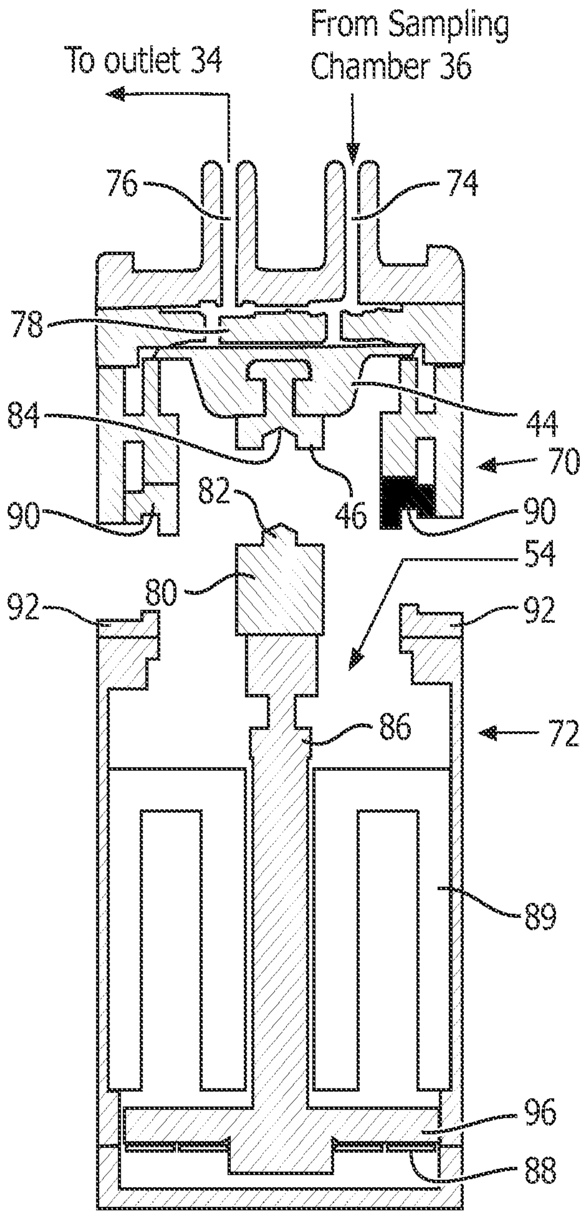
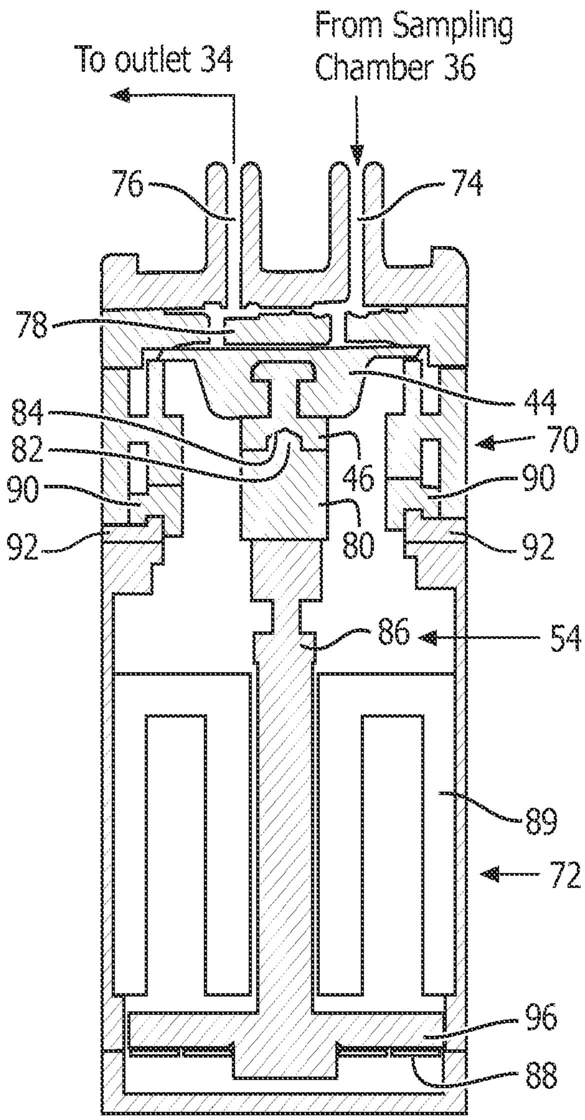

From Sampling
Chamber 36
To outlet 34
76
74
78
84
44
70
46
82
90
90
54
80
92
92
86
72
89
96
88

FIG. 4


From Sampling
Chamber 36
To outlet 34
76
74
78
44
84
82
70
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90
92
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92
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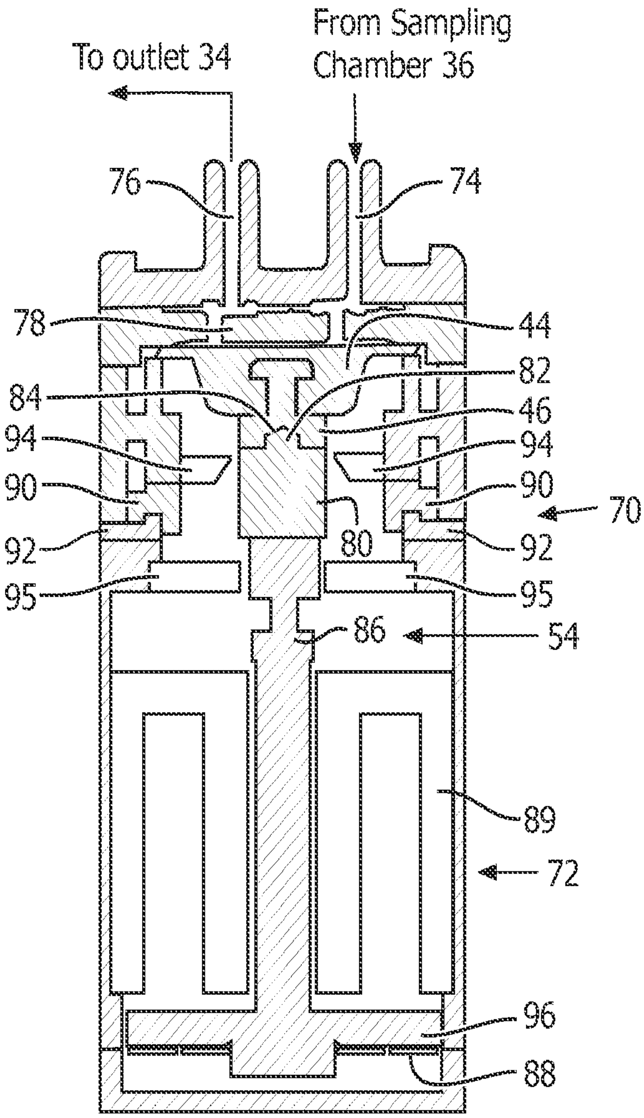
54
89
72
96
88

FIG. 5



To outlet 34
From Sampling
Chamber 36
76
74
78
44
82
84
46
94
94
90
90
70
92
80
92
95
95
86
54
89
72
96
88

FIG. 6

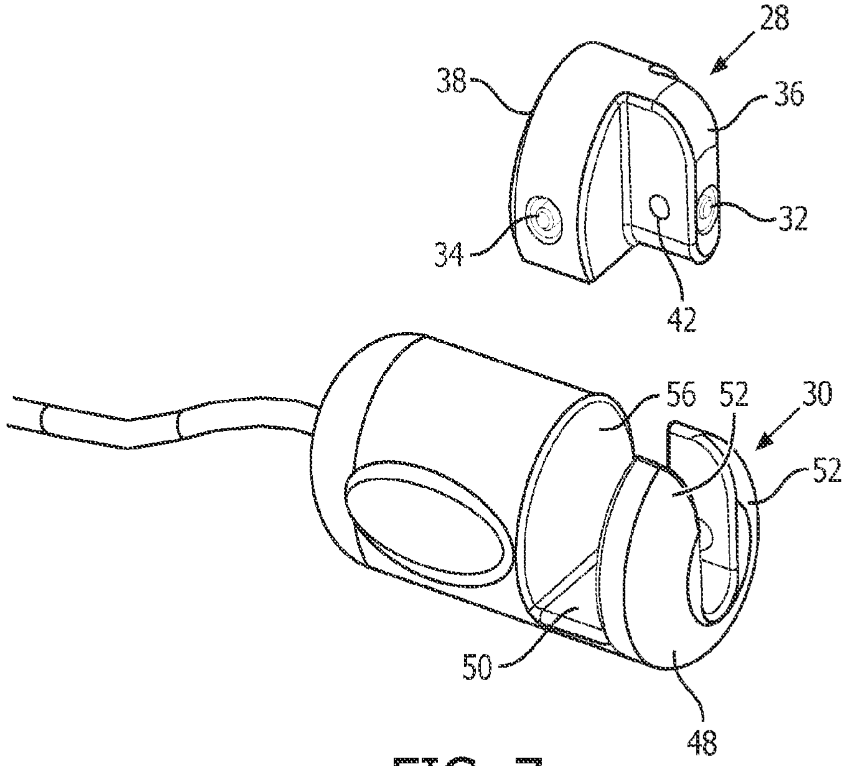


FIG. 7

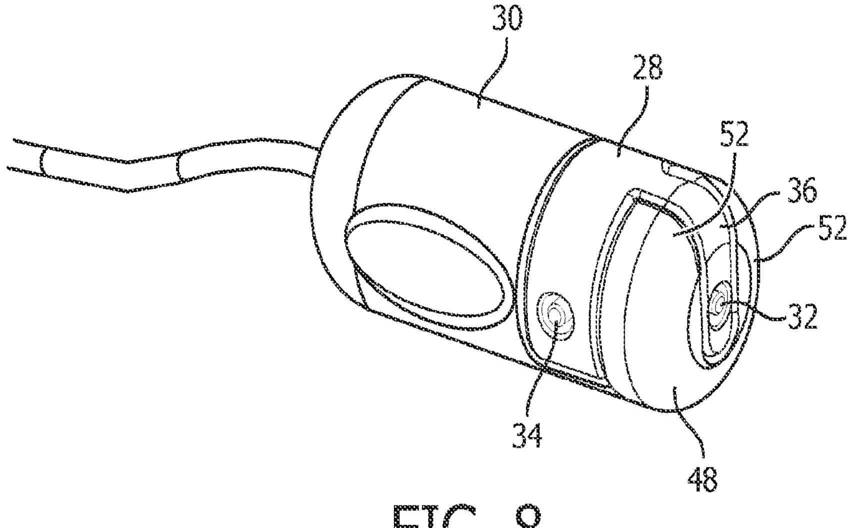


FIG. 8

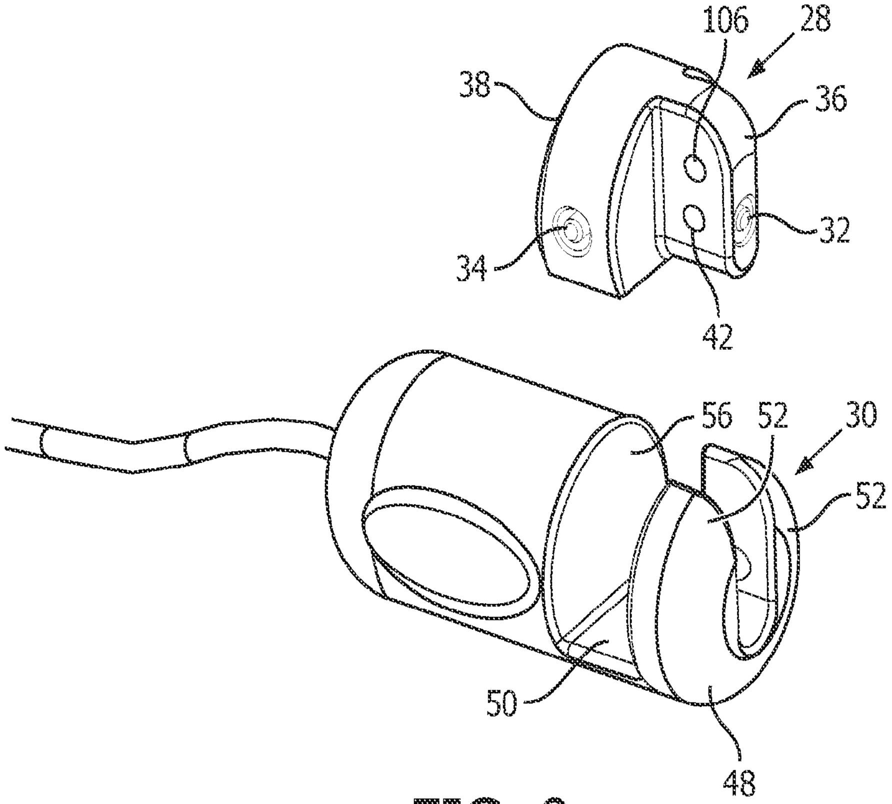


FIG. 9

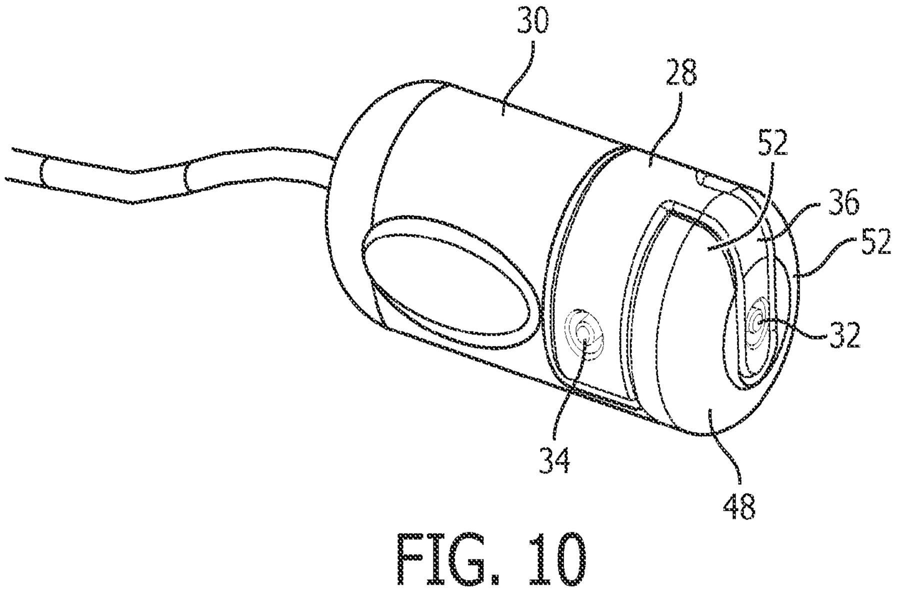
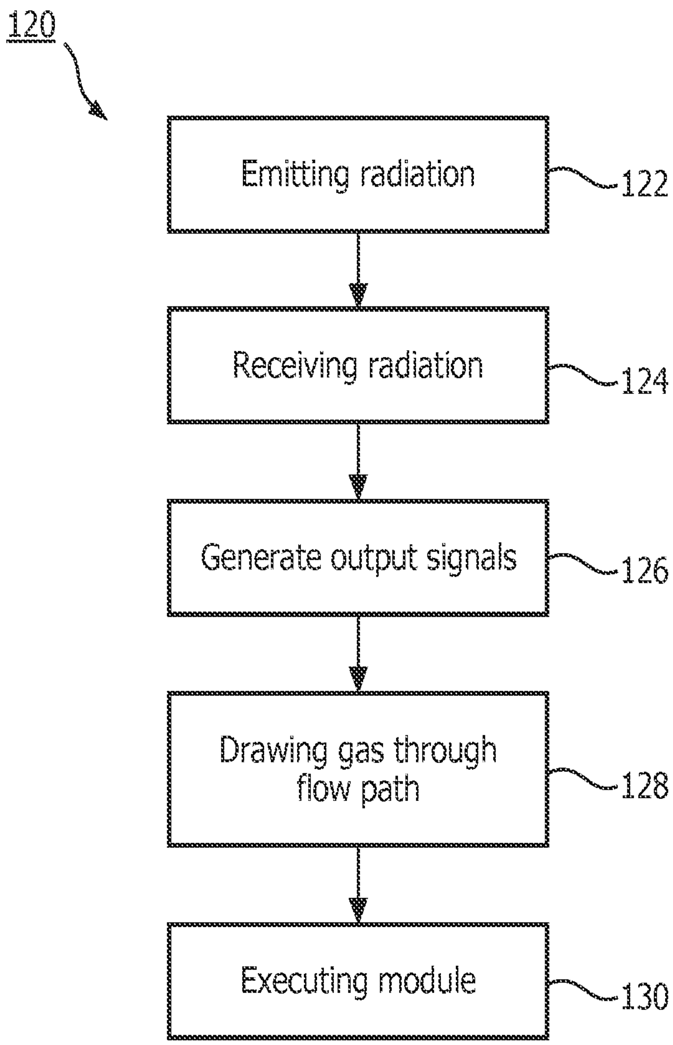


FIG. 10



120
Emitting radiation
122
Receiving radiation
124
Generate output signals
126
Drawing gas through flow path
128
Executing module
130

FIG. 11

SYSTEM AND METHOD FOR MONITORING COMPOSITION IN A SIDESTREAM SYSTEM USING A PUMP AND DETECTOR WITH CONTROL ELECTRONICS THAT ARE TIGHTLY INTEGRATED

BACKGROUND

[0001] 1. Field

[0002] The present disclosure pertains to a method and apparatus for monitoring the composition of a measurement flow of breathable gas received in a sidestream manner with a pump and detector assembly that are controlled by control electronics that are tightly integrated.

[0003] 2. Description of the Related Art

[0004] Systems that monitor composition of gas by obtaining a measurement flow of breathable gas from a therapeutic flow of breathable gas in a sidestream manner are known. Generally, these systems require a pump to draw the measurement flow of breathable gas through a sampling chamber where measurements are taken, and a detector assembly to measure composition of the gas. In conventional systems, the pump and the detector assembly are separate and discrete systems each with their own control system. As a result, control over these components is accomplished via two separate and discrete sets of control electronics.

SUMMARY

[0005] Accordingly, one or more aspects of the present disclosure relate to a detector device configured to measure composition of a flow of breathable gas received from a respiratory circuit. In some embodiments, the detector device comprises a housing, a flow path, a radiation source, a sensor assembly, a pump, and one or more processors. The flow path is for the flow of breathable gas, and has an inlet and an outlet. The radiation source is housed within the housing and is configured to emit electromagnetic radiation into the flow path. The sensor assembly is housed within the housing and is configured to receive electromagnetic radiation that has been emitted by the radiation source and has passed through the flow path. The sensor assembly is further configured to generate output signals conveying information related to one or more parameters of the received electromagnetic radiation. The pump comprises a pump motor and a pump actuator. The pump motor is carried by the housing. The pump actuator is carried by the housing, and is configured to be driven by the pump motor to draw the flow of breathable gas through the flow path. The one or more processors are housed within an individual housing compartment formed within the housing, and are configured to execute modules. The module comprises a source module, a sensor module, a pump actuation module, and a pump reading module. The source module is configured to drive the radiation source. The sensor module is configured to read the output signals generated by the sensor assembly. The pump actuation module is configured to drive the pump motor. The pump reading module is configured to obtain information related to one or more operating parameters of the pump.

[0006] Yet another aspect of the present disclosure relates to a method of measuring composition of a flow of breathable gas received from a respiratory circuit. In some embodiments, the method comprises emitting electromagnetic radiation from a radiation source into a flow path for the flow of breathable gas; receiving the emitted electromagnetic radiation after it has passed through the flow path; generating output signals from a sensor assembly that convey information related to one or more parameters of the received electromagnetic radiation; drawing the flow of breathable gas through the flow path with a pump that includes a pump motor and a pump actuator, wherein the radiation source, the sensor assembly, and the pump are housed in and/or carried by a single housing; and executing modules on one or more processors that are contained within a single compartment of the housing. The modules comprise a source module, a sensor module, a pump actuation module, and a pump reading module. The source module is configured to drive the radiation source. The sensor module is configured to read the output signals generated by the sensor assembly. The pump actuation module is configured to drive the pump motor. The pump reading module is configured to obtain information related to one or more operating parameters of the pump.

[0007] Still another aspect of present disclosure relates to a detector device for measuring composition of a flow of breathable gas received from a respiratory circuit. In some embodiments, the detector device comprises means for emitting electromagnetic radiation into a flow path for the flow of breathable gas; means for receiving the emitted electromagnetic radiation after it has passed through the flow path; means for generating output signals that convey information related to one or more parameters of the received electromagnetic radiation; means for drawing the flow of breathable gas through the flow path, the means for drawing comprising a pump motor and a pump actuator, wherein the means for emitting, the means for generating, the pump motor, and the pump actuator are housed in and/or carried by a single housing; and means for executing modules, the means for executing being contained within a single compartment of the housing. The modules comprise a source module, a sensor module, a pump actuation module, and a pump reading module. The source module is configured to drive the radiation source. The sensor module is configured to read the output signals generated by the sensor assembly. The pump actuation module is configured to drive the pump motor. The pump reading module is configured to obtain information related to one or more operating parameters of the pump.

[0008] These and other objects, features, and characteristics of the present displosure, as well as the methods of operation and functions of the related elements of structure and the combination of parts and economies of manufacture, will become more apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of this specification, wherein like reference numerals designate corresponding parts in the various figures. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a system configured to monitor a composition of a flow of breathable gas;

[0010] FIG. **2** is a detector assembly and flow path element configured to monitor a composition of a flow of breathable gas;

[0011] FIG. **3** is a controller configured to control a detector assembly;

[0012] FIG. **4** is a pump configured to draw a flow of breathable gas through a sampling chamber;

[0013] FIG. **5** is a pump configured to draw a flow of breathable gas through a sampling chamber;

[0014] FIG. **6** is a pump configured to draw a flow of breathable gas through a sampling chamber;

[0015] FIG. **7** is a detector assembly and flow path element configured to monitor a composition of a flow of breathable gas;

[0016] FIG. **8** is a detector assembly and flow path element configured to monitor a composition of a flow of breathable gas;

[0017] FIG. **9** is a detector assembly and flow path element configured to monitor a composition of a flow of breathable gas;

[0018] FIG. **10** is a detector assembly and flow path element configured to monitor a composition of a flow of breathable gas; and

[0019] FIG. **11** is a method of monitoring a flow of breathable gas.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0020] As used herein, the singular form of "a", "an", and "the" include plural references unless the context clearly dictates otherwise. As used herein, the statement that two or more parts or components are "coupled" shall mean that the parts are joined or operate together either directly or indirectly, i.e., through one or more intermediate parts or components, so long as a link occurs. As used herein, "directly coupled" means that two elements are directly in contact with each other. As used herein, "fixedly coupled" or "fixed" means that two components are coupled so as to move as one while maintaining a constant orientation relative to each other.

[0021] As used herein, the word "unitary" means a component is created as a single piece or unit. That is, a component that includes pieces that are created separately and then coupled together as a unit is not a "unitary" component or body. As employed herein, the statement that two or more parts or components "engage" one another shall mean that the parts exert a force against one another either directly or through one or more intermediate parts or components. As employed herein, the term "number" shall mean one or an integer greater than one (i.e., a plurality).

[0022] Directional phrases used herein, such as, for example and without limitation, top, bottom, left, right, upper, lower, front, back, and derivatives thereof, relate to the orientation of the elements shown in the drawings and are not limiting upon the claims unless expressly recited therein.

[0023] FIG. **1** illustrates a system **10** configured to monitor composition of a flow of breathable gas being provided to a subject **12**. System **10** may be configured such that a measurement flow of breathable gas is diverted in order to monitor composition of the flow of breathable gas, and then the measurement flow of breathable gas is returned to the flow of breathable gas. This will tend to conserve the constituent gases within the flow of breathable gas, which may be significant in instances where the flow of breathable gas is being used to deliver medicaments or drugs (e.g., relatively expensive anesthetic, and/or other medicaments or drugs). Since the measurement flow of breathable gas will tend to have contaminants (e.g., mucus blood, medications, condensate or other materials), routing the measurement flow of breathable gas back into the flow of breathable gas constitutes a placement solution for the contaminants. This, however, is not intended to be limiting, as the measurement flow of breathable gas may not be returned to the flow of breathable gas in some embodiments. Instead, the measurement flow of breathable gas may be exhausted (e.g., through a filter or other exhaust). In some embodiments, system **10** may include one or more of a flow generator **14**, a respiratory circuit **16**, a measurement circuit **18**, and/or other components.

[0024] Flow generator **14** is configured to generate the flow of breathable gas for delivery to the airway of subject **12**. Flow generator **14** is configured to control one or more parameters of the flow of breathable gas. The parameter(s) controlled may include one or more of pressure, temperature, flow rate, humidity, velocity, acoustics, and/or other parameters. In some embodiments, flow generator **14** is configured to control the composition of the flow of breathable gas by blending gases from a two or more gas sources (e.g., to control oxygen content), by adding a drug or medicament (e.g., in nebulized and/or aerosolized form), and/or by other techniques. To pressurize the flow of breathable gas, flow generator **14** may include one or more of a blower, a bellows, a pressurized canister or Dewar, a wall gas source, and/or other sources of pressure.

[0025] Respiratory circuit **16** is configured to deliver the flow of breathable gas from flow generator **14** to the airway of subject **12**. Respiratory circuit **16** may include one or more of a conduit **20**, a subject interface **22**, and/or other components. Conduit **20** is configured to convey the flow of breathable gas from flow generator **14** to subject interface **22**. Conduit **20** interfaces with flow generator **14** to receive the flow of breathable gas therefrom, and provides a flow path from flow generator **14** to subject interface **22**. Conduit **20** may be resiliently flexible. Subject interface **22** may engage one or more orifices of the airway of subject **12** in a sealed or unsealed manner. Some examples of subject interface **22** may include, for example, an endotracheal tube, a nasal cannula, a tracheotomy tube, a nasal mask, a nasal/oral mask, a full face mask, a total face mask, a partial rebreathing mask, or other interface appliances that communicate a flow of gas with an airway of a subject. The present invention is not limited to these examples, and contemplates implementation of any subject interface. For example, sidestream gas sampling (e.g., as shown and described with respect to system **10**) may be used in conjunction with an airway adapter which is in-line with both expiratory and inspiratory gases, a facemask from which a tap is often made and a nasal cannula as shown in FIG. **1** which may be used to sample a respiratory gas (e.g. $CO2$) and/or to deliver a therapeutic gas (e.g., oxygen).

[0026] Measurement circuit **18** is configured to draw a measurement flow of breathable gas off from the flow of breathable gas in respiratory circuit **16** to monitor the compositions of the flow of breathable gas. The measurement flow of breathable gas may be between about 30 ml/min and about 250 ml/min. In some embodiments, the measurement flow of breathable gas is about 50 ml/min. Measurement circuit **18** may return some or all of the gas in the measurement flow of breathable gas back to the flow of breathable gas within respiratory circuit **16**. Measurement circuit **18** may include one or more of a circuit inlet **24**, a circuit outlet **26**, a flow path element **28**, a detector device **30**, and/or other components.

[0027] Circuit inlet **24** is configured to receive a portion of the gas in the flow of breathable gas within respiratory circuit **16** as a measurement flow of breathable gas, and to guide the measurement flow of breathable gas to flow path element **28**. Circuit outlet **26** is configured to receive the measurement flow of breathable gas after it has passed through flow path element **28**. Circuit outlet **26** may be configured to provide the measurement flow of breathable gas back into respiratory circuit **16**. Circuit inlet **24** and circuit outlet **26** may be conduits similar in structure (or the same as) conduit **20**. Circuit outlet **26** may be a connector or not even exist if the flow is to pass into the atmosphere. The interface(s) between one or both of circuit inlet **24** and conduit **20**, and circuit outlet **26** and conduit **20** may be releasable.

[0028] FIG. **2** provides a more detailed schematic of flow path element **28** and detector device **30**. In the view shown in FIG. **2**, flow path element **28** has been disengaged from detector device **30** (FIG. **1** depicts flow path element **28** releasably engaged with detector device **30**). As can be seen in FIG. **2**, flow path element **28** includes an inlet **32**, an outlet **34**, and provides an enclosed flow path between inlet **32** and outlet **34**. Inlet **32** is configured to interface with circuit inlet **24**, and outlet **34** is configured to interface with circuit outlet **26** such that the enclosed flow path formed by flow path element **28** carries the measurement flow of breathable gas through flow path element **28** from inlet **32** to outlet **34**. The walls of flow path element **28** between inlet **32** and outlet **34** may be formed of substantially rigid plastic and/or polymer materials. Flow path element **28** further comprises one or more of a sampling chamber **36**, a pump section **38**, a device interface **40**, and/or other components.

[0029] Although detector device **30** and flow path element **28** are shown exploded from each other in FIG. **2**, this is not intended to be limiting. In some embodiments, detector device **30** and flow path element **28** are not removably coupled, but instead are formed either integrally or with a permanent (or substantially permanent) attachment therebetween. In some embodiments in which detector device **30** and flow path element **28** are not removably coupled, these components (and/or their parts) may be cleaned or sterilized via suitable cleaning and sterilization methods.

[0030] Sampling chamber **36** is configured to facilitate measurements of the composition of the measurement flow of breathable gas to be taken. As such, sampling chamber **36** includes windows **42**. Windows **42** are optically transparent to electromagnetic radiation at one or more wavelengths used to measure the composition of gas within sampling chamber **36**. By way of non-limiting example, windows **42** may be formed from sapphire, IR transmissive plastics, and/or other materials.

[0031] Pump section **38** is configured to generate flow through flow path element **28** from inlet **32** to outlet **34**. In some embodiments, pump section **38** operates as the head of a membrane pump system to generate flow through flow path element **28**. Pump section **38** may include one or more of a membrane **44**, an actuator interface **46**, and/or other components. Membrane **44** is configured to be movable to generate flow through pump section **38**. Actuator interface **46** is configured to releasably engage a pump actuator **54** associated with detector device **30** to actuate membrane **44** in a manner that causes movement by membrane **44** resulting in flow through flow path element **28**.

[0032] For embodiments in which flow path element **28** is detachable/replaceable, the enclosed flow path formed by flow path element **28** enables flow path element **28** to be used for a subject individually. This means that for another subject, and/or for another usage session, flow path element **28** can be swapped for another (e.g., new) flow path element. It will be appreciated that in such embodiments, the components of flow path element **28** may be relatively inexpensive from a materials and/or manufacturing perspective. For example, flow path element **28** may not include any sensor or radiation emitter elements, and may not include any parts of a motor that operates to drive the pump formed by pump section **38**. In some embodiments, flow path element **28** does not include any processing and/or storage components, to maintain a relatively low cost. As such, flow path element **28** may be replaced without impacting operation of the active components of detector device **30** (e.g., a composition sensor and a pump motor, as described herein). This may enhance the usability of detector device **30** in a setting in which detector device **30** is implemented in respiratory circuits for a plurality of subjects. However, flow path element **28** may include a memory element (e.g., read only or read/write) for storage of calibration information relating to the windows (e.g., absorption characteristics for use in infrared measurements; calibration factors for signal correction for use in luminescence quenching measurements; and/or other calibration information) or other components of flow path element. Such a memory element could store usage information to help alert detector device **30**, a system including detector device **30**, and/or a user of reuse of a component intended to be single-use and/or for use by a single subject, such as flow path element **28**.

[0033] As can be seen in FIG. **2**, detector device **30** is configured to cause the measurement flow of breathable gas to be drawn through flow path element **28**, monitor the composition of the gas within sampling chamber **36**, and/or to perform other functions. Detector device **30** may include one or more of a housing **48**, element dock **50**, a detector assembly **52**, a pump actuator **54**, pump motor **56**, a controller **58**, and/or other components.

[0034] Housing **48** is configured to house some or all of the components of detector device **30**. Housing **48** is formed of a rigid material, such as a metallic, plastic or polymer. Housing **48** may provide mechanical protection, fluid protection, and/or other types of protection for the components of detector device **30**.

[0035] In embodiments in which flow path element **28** is removably engaged with detector device **30**, element dock **50** is configured to removably engage flow path element **28**. Element dock **50** may be formed by housing **48**. For example, housing **48** may have a shape at element dock **50** that accommodates the external shape of flow path element **28**. Element dock **50** secures flow path element **28** to detector device **30**, and places the various components of flow path element **28** and detector device **30** in the proper relative positions for use. In securing flow path element **28** to detector device **30**, element dock **50** may engage flow path element **28** with one or more of a threaded engagement, an interlocking engagement, a friction fit, a snap fit, a latch, and/or other mechanisms for releasable engagement.

[0036] Detector assembly **52** is configured to monitor the composition of gas in sampling chamber **36**. For example, detector assembly **52** may be configured to detect a relative level of carbon dioxide, a relative level of oxygen, anesthetic agents (e.g., nitrous oxide, halothane, desflurane, etc.), trace gases (e.g., PPM or PPB concentrations), and/or relative levels of other gas constituents within sampling chamber **36**. Detector assembly may include one or more of a radiation source **60**, a sensor assembly **62**, windows **64**, and/or other components.

[0037] Radiation source **60** is configured to emit electromagnetic radiation through sampling chamber **36** (e.g., through windows **64**). The electromagnetic radiation emitted travels through the gas within sampling chamber **36**, and out of sampling chamber **36** on the other side of sampling chamber **36**. The electromagnetic radiation generated by radiation source **60** may have a specified set of one or more wavelengths used to detect one or more gases. By way of non-limiting example, infrared electromagnetic radiation from radiation source **60** may be implemented to monitor the relative level of carbon dioxide within sampling chamber **36**. Although not shown in FIG. **2**, radiation source **60** may include one or more optical elements configured to guide the emitted electromagnetic radiation into sampling chamber **36**. Such elements may include one or more of a mirror, a lens, and/or other optical elements.

[0038] Sensor assembly **62** is configured to receive electromagnetic radiation emitted by radiation source **60** that has passed through sampling chamber **36**, and the gas contained therein, and to generate output signals conveying information related to one or more parameters of the received electromagnetic radiation. The one or more parameters may include one or more of intensity, flux, luminescence, phase, and/or other parameters. Sensor assembly **62** includes one or more photosensitive sensors configured to generate output signals related to the intensity of received electromagnetic radiation. Sensor assembly **62** may include one or more optical elements to filter, shape, and/or guide the electromagnetic radiation to the one or more photosensitive sensors. Such optical elements may include one or more of a mirror, a half-mirror, a wavelength filter, a polarizer, a lens, and/or other optical elements. For example, the output signals may convey information related to intensity of the electromagnetic radiation in a wavelength range that is absorbed by a gaseous constituent of interest (e.g., carbon dioxide), and the intensity of electromagnetic radiation in a reference wavelength range expected to be substantially unabsorbed. As another example, the output signals may convey information related to a difference between intensity in the absorbed wavelength range and the references wavelength range.

[0039] In some embodiments, radiation source **60** and sensor assembly **62** may operate to monitor the composition of the measurement flow of the gas drawn through flow path element **28** in the manner described in U.S. Pat. No. 7,748,280, which is hereby incorporated by reference in its entirety.

[0040] This description of detector assembly **52** is not intended to be limiting. It will be appreciated that the assembly described and shown may be replaced and/or augmented with other assemblies for detecting relative levels of gaseous constituents. For example, a relative level of oxygen may be monitored with a luminescence quenching assembly that provides electromagnetic radiation into sampling chamber **36**, receives electromagnetic radiation emitted by a luminescent material within sampling chamber, and generates output signals providing information related to the received electromagnetic radiation and/or the electromagnetic radiation emitted by detector assembly **52**. This type of monitoring is described, for example, in U.S. Pat. Nos. 6,325,978, and 6,632,402, both of which are hereby incorporated by reference into the present application in their entirety.

[0041] Pump actuator **54** is configured to releasably engage actuator interface **46** of flow path element **28**, and to actuate membrane **44** to create flow through flow path element **28**. In some embodiments, actuator interface pump actuator **54** is configured to magnetically couple with actuator interface **46** to secure the engagement therebetween. This is not intended to be limiting.

[0042] As is discussed further below with respect to FIGS. **4-6**, pump motor **56** is configured to drive pump actuator **54** such that pump actuator **54** actuates membrane **44** to create flow through flow path element **28**. The operation of pump motor **56** can be controlled to adjust one or both of pressure and/or flow rate through flow path element **28**. For example, one or more operating parameters of the pump motor **56** can be used to infer one or more parameters of the measurement flow of breathable gas through the flow path. Without limitation one or more of current drawn, load (e.g., actuator load, motor load, and/or other loads), position, and/or other operating parameters may be used in this manner. The one or more parameters of the measurement flow of breathable gas may include one or more of pressure, flow rate, volume, and/or other gas parameters. In some embodiments, the one or more parameters of the measurement flow of breathable gas can be directly measured by one or more sensors separate from the pump. Controller **58** is configured to provide processing and/or control functionality within detector device **30**. Controller **58** is configured to control operation and/or receive output from both the pump (which includes pump actuator **54** and pump motor **56**) and detector assembly **52**. By virtue of this integrated control over both subsystems of detector device **30**, the footprint, cost, form factor, weight, manufacturability, and/or other features may be enhanced over systems in which the pump and detector assembly **52** are controlled by separate control systems.

[0043] FIG. **3** illustrates controller **58**, in accordance with some embodiments of this disclosure. As shown, in some embodiments, controller **58** includes one or more of one or more processors **100**, electronic storage **102**, and/or other components.

[0044] Processor **100** is configured to provide processing functionality in controller **58**. Processor **100** may include, without limitation, a digital processor, an analog processor, a digital circuit designed to process information, an analog circuit designed to process information, a state machine, and/or other mechanisms for electronically processing information. Processor **100** is configured to execute one or more modules. Processor **100** is configured to execute one or more modules via hardware, software, firmware, some combination of hardware, software and/or firmware, and/or through other mechanisms for configuring processing functionality. The modules may include one or more of a source module **104**, a sensor module **106**, a pump actuation module **108**, a pump reading module **110**, a communications module **112**, and/or other modules.

[0045] Source module **104** is configured to drive radiation source **60**. This includes controlling distribution of power to radiation source **60** that will cause radiation source **60** to emit electromagnetic radiation suitable for the detection that will take place within the flow path. For example, source module **104** may control one or more of a level, a current, an amplitude, a frequency of modulation, a voltage, duty cycle, and/or other parameters of power provided to radiation source **60** in order to cause radiation source **60** to emit electromagnetic radiation. The driving of radiation source **60** may be accomplished in a feedback manner based on output signals from sensor assembly **62** and/or a temperature sensor (not shown) disposed at or near radiation source **60** and/or sensor assembly **62**.

[0046] Sensor module **106** is configured to read the output signals generated by sensor assembly **62**. This may include receiving the output signals generated by sensor assembly **62** and processing the output signals prior to transmission of the output signals from controller **58** to some other system (e.g., a monitor unit that presents results to a user). Such processing may include one or more of a signal processing operation (e.g., amplification, digitization, multiplexing, differencing, filtering, and/or other operations), obtaining some measurement or value from the output signals (e.g., to use in feedback operation of radiation source **60**, and/or other measurements or values), and/or other processing.

[0047] Pump actuation module **108** is configured to drive pump motor **56**. This includes controlling distribution of power to pump motor **56**. For example, pump actuation module **108** may control one or more of a level, a current, an amplitude, a frequency of modulation, and/or other parameters of power provided to pump motor **56** in order to cause the pump to draw the flow of breathable gas through the flow path. The driving of the pump actuation module may be accomplished in a feedback module to maintain one or more parameters of the flow of breathable gas at a specific level or range of levels. The one or more parameters may include pressure, flow rate, and/or other parameters.

[0048] Pump reading module **110** is configured to obtain information related to one or more operating parameters of the pump. Such parameters may include, for example, a rate of operation (e.g., cycles or revolutions per unit time, and/or other rates), an electrical current level driving pump motor **56**, and/or other parameters. These parameters may be obtained from a power circuit supplying power to the pump (e.g., under control of pump actuation module **108**), from one or more sensors that generate output signals conveying information related to one or more operating parameters of the pump (e.g., an ammeter, a voltmeter, a cycle or revolution sensor, and/or other sensors), and/or from other sources. From the obtained operating parameters, pump reading module **110** may determine one or more of the parameters of the flow of breathable gas through the flow path. For example, pump reading module **110** may determine one or more of a pressure, a flow rate, and/or other parameters of the flow of breathable gas. In some embodiments, a flow and/or pressure sensor (not shown) may be included in the detector device **30** (e.g., as shown in FIGS. **1** and **2**), and may provide output signals to pump reading module **110**. Pump reading module **110** may use the output signals from this sensor(s) instead and/or in conjunction with the operating parameters of the pump.

[0049] Communications module **112** is configured to manage communications between controller **58** and some external monitor device. The external monitor device may include a user interface that enables a user to provide information to and/or receive information from a system that includes detector device **30** (e.g., as shown in FIGS. **1** and **2**). The user interface may be used to display, for example, results from the monitoring being performed. The user interface may be used to control operation of detector device **30**. For example, detector device **30** may be turned off and/or on through the user interface, and/or controlled in other ways. Communications module **112** may be common for communication of control and/or results directed to and/or generated from output signals of radiation source **60**, sensor assembly **62**, and the pump. This is a consolidation over embodiments in which the pump and the detector assembly including radiation source **60** and sensor assembly **62** are managed by separate control systems. Typically in such systems communication with the pump and the detector assembly are managed by separate communication modules.

[0050] Although processor **100** is shown in FIG. **3** as a single entity, this is for illustrative purposes only. In some embodiments, processor **100** may include a plurality of processing units. However, to maintain the tight integration between the controls for the pump, sensor assembly **60**, and radiation source **62**, an individual one of the processors included in the processor **100** performs some or all of the functionality of each of source module **104**, sensor module **106**, pump actuation module **108**, and pump reading module **110**. The individual processor may further perform some or all of the functionality of communications module **112**.

[0051] In some embodiments, electronic storage **102** comprises electronic storage media that electronically stores information. The electronic storage media of electronic storage **102** includes system storage that is provided integrally (i.e., substantially non-removable) with controller **58**. Electronic storage **102** may include one or more of electrical charge-based storage media (e.g., EEPROM, RAM, etc.), solid-state storage media (e.g., flash drive, etc.), and/or other electronically readable storage media. Electronic storage **102** may store one or more of modules **104**, **106**, **108**, **110**, and/or **112**, information determined by processor **100**, information received from one or more of sensor assembly **62**, the pump, and/or other sensors, and/or other information that enables controller **58** to function properly. Electronic storage **102** may be a separate component within controller **58**, and/or electronic storage **102** may be provided integrally with one or more other components of controller **58** (e.g., processor **100**).

[0052] In some embodiments, to maintain the tight integration of control of the pump, radiation source **60**, and sensor assembly **62**, electronic storage **102** stores (i) at least a portion of one or both of source module **104** and/or sensor module **16**, and (ii) at least a portion of one or both of pump actuation module **108** and/or pump reading module **110**. In some embodiments, electronic storage **102** includes a single physical block of electronic storage that stores (i) at least a portion of one or both of source module **104** and/or sensor module **16**, and (ii) at least a portion of one or both of pump actuation module **108** and/or pump reading module **110**. And possibly information read from flow path element **28** including calibration and usage information. As used herein, the single physical block of electronic storage does not refer to a single memory address. Instead, the single physical block of memory refers to an individual memory component (e.g., chip, Flash memory component, and/or other components), or logically bound memory components (e.g., the memory components addressed as a single array of memory).

[0053] In some embodiments, controller **58** includes a circuit board (not shown). The circuit board is an integral structure that includes at least some of the components of controller **58**, and conductors that interconnect and/or couple the components to allow them to operate properly. Without limitation, the circuit board may include a printed circuit board. To maintain the tight integration of control of the pump, radiation source **60**, and sensor assembly **62**, the circuit board may be a single board that carries components of controller **58** associated with controlling all of these components. For example, the circuit board may carry all of processor **100** (e.g., all of the individual processors associated with processor **100**). As another example, the circuit board may carry an individual processor that performs at least some of all of the functionality of each of modules **104**, **106**, **108**, and **112**, and further carries a single physical block of electronic storage that stores (i) at least a portion of one or both of source module **104** and/or sensor module **16**, and (ii) at least a portion of one or both of pump actuation module **108** and/or pump reading module **110**. Including such electronics on a single circuit board may enhance the footprint, the efficiency, the cost, the manufacturability, and/or other aspects of controller **58**. For example, the circuit board carrying the components described in one or both of the foregoing examples may have dimensions that include a length of less than about 4.5 cm, and/or a width of less than about 2.5 cm.

[0054] Referring back to FIG. **2**, due to the tight integration of control of the pump, radiation source **60**, and sensor assembly **62**, controller **58** may be housed within a single compartment of housing **40**. As used herein, a single compartment does not necessarily refer to a compartment that is wholly sealed off from any other exterior compartment within housing **40**. Instead, the single compartment may refer to an individual cavity within housing **40**. This cavity may communicate with one or more other compartments within housing **40**, but is sufficiently segregated structurally from the other compartments as to form a separate structural compartment. In some embodiments, the volume of this compartment may be less than 12 ml. The dimensions may include one or more of a width of less than about 2.5 cm, a length of less than about 2.5 cm, and/or a depth of less than about 2.0 cm.

[0055] By virtue of the integration of control of the pump, radiation source **60**, and sensor assembly **62** within controller **58**, power to controller **58** for detector device **30** may be received through a single power connection (not shown). The single power connection may couple detector device **30** with a power source that drives radiation source **60**, sensor assembly **62**, and/or the pump. The power source may be external to detector device **30** and/or internal to detector device **30** (e.g., an internal battery). Distribution of power received through this single power connection may be distributed to radiation source **60**, sensor assembly **62**, and/or the pump by the controller (e.g., as described above).

[0056] FIGS. **4** and **5** illustrate the operation of the pump formed by flow path element **28** and detector device **30**, in some embodiments. The pump comprises a pump housing which comprises two parts **70**, **72**, a first part **70** (formed as a part of pump section **38** in flow path element **28** in FIGS. **1** and **2**) in which membrane **44**, an inlet **74** and an outlet **76** are arranged, and a second part **72** (formed as a part of detector device **30** in FIGS. **1** and **2**) in which pump actuator **54** is arranged. Membrane **44** is mounted to the first part **70** of the pump housing and delimits a pump chamber **78** inside said first part **70**. The inlet **74**, which has a first non-return valve (not shown) connected thereto, is arranged for feeding the measurement flow of breathable gas into the pump chamber **78**, and the outlet **76**, which has a second non-return valve (not shown) connected thereto, is arranged for discharging the measurement flow of breathable gas from the pump chamber **78**. The pump actuator **54** is configured for moving the membrane **44** back and forth between a first and a second position when the pump is in its assembled form and in use. The membrane **44** is configured to be detachably connected to the pump actuator **54** by means of a magnetic coupling, which comprises actuator interface **46** fixed to the membrane **44** and a corresponding magnetic coupling part **80** fixed to the pump actuator **54**. The magnetic coupling can be achieved by having one of the actuator interface **46** and the magnetic coupling part **80** comprising a permanent magnet and the other comprising a ferromagnetic material. The magnetic coupling can of course instead comprise two permanent magnets, one permanent magnet comprised in the actuator interface and one in the magnetic coupling part **80**. An electromagnetic coupling is of course also possible. Preferably, the actuator interface **46** comprises a ferromagnetic material and the magnetic coupling part **80** comprises a permanent magnet. The magnetic coupling part **80** also comprises a protrusion **82** configured for insertion into a corresponding recess **84** comprised in the actuator interface **46**. Of course a protrusion instead can be comprised in the actuator interface **46** for insertion into a corresponding recess comprised in the magnetic coupling part **80**. The pump actuator **54** comprises a shaft **86**, which at one end is provided with said magnetic coupling part **80**. To move the membrane **44** back and forth the shaft **86** of the pump actuator **54** is driven by a spring, preferably a flat spring **88**, longitudinally in one direction and an electromagnet **89** longitudinally in the opposite direction. The spring **88** can of course be replaced by a second electromagnet.

[0057] The first part **70** of the pump housing is detachably connected to the second part **72** of the pump housing by means of a coupling, which coupling comprises a first coupling part **90** fixed to the first part **70** of the pump housing and a second coupling part **92** fixed to the second part **72** of the pump housing. The coupling of the pump housing shown in FIGS. **4** and **5** is a magnetic coupling, wherein one of the first **90** and second **92** coupling parts comprises a permanent magnet and the other coupling part comprises a ferromagnetic material. The magnetic coupling can of course instead comprise two permanent magnets, one permanent magnet comprised in the first coupling part **90** and one in the second coupling part **92**. Preferably the first coupling part **90** comprises a ferromagnetic material and the second coupling part **92** comprises a permanent magnet. The coupling of the pump housing can also be a snap coupling or any other mechanical or electromechanical coupling suitable for the purpose of connecting the first **70** and the second **72** parts of the pump housing to each other.

[0058] The first part **70** of the pump housing is exchangeable (e.g., along with the rest of flow path element **28**) and in order to detach it from the second part **72** of the pump housing (and/or detector device **30**) said first part **70** is moved in the longitudinal direction of said shaft **86** away from the second part **72** of the pump housing, whereby the actuator interface **46** is detached from the magnetic coupling part **80** and the first coupling part **90** of the pump housing is detached from the second coupling part **92** of the pump housing. If the coupling of the pump housing is a snap coupling or any other coupling, other operations may be needed for detaching the first part **70** of the pump housing from the second part **72** of the pump housing. To attach the first part **70** of the pump housing to the second part **72** of the pump housing the two parts **70**, **72** of the pump housing are moved towards each other so as to allow the corresponding coupling parts to come into engagement with each other.

[0059] In the embodiments illustrated in FIG. **6**, the pump comprises guiding means **94** configured for radially guiding the shaft **86** of the pump actuator **54** so as to guide the protrusion **82** of the magnetic coupling part **80** into the recess **84** of the pump actuator **54** when the first part **70** of the pump housing is connected to the second part **72** of the pump housing. The guiding means **94** of the first part **70** of the pump housing has a central opening configured for receiving said shaft **86** and/or the magnetic coupling part **80**. The second part **70** of the pump housing comprises guiding means **95** configured for restricting radial movement of the shaft **86** in said second part **72** of the pump housing. The guiding means **95** of the second part **72** of the pump housing is especially important when the first part **70** of the pump housing is detached, due to the risk for damaging the shaft **86** by having it hit the electromagnet **89** if said guiding means **95** is absent. The guiding means **95** of the second part **72** of the pump housing has a central opening configured for receiving said shaft **86**.

[0060] During pumping using the pumps shown in FIGS. **4-6**, in a first phase the flat spring **88** affects the shaft **86**, and thereby the membrane **44**, with a force pulling the membrane **44** in a direction away from the pump chamber **78**, whereby the volume of the pump chamber **78** expands and the first non-return valve is opened so as to allow the measurement flow of breathable gas to flow into the pump chamber **78** through the inlet **74**. During this first phase, the membrane **44** is moved under the action of the spring **88** from a first end position to a second end position. In a second phase the electromagnet **89** is activated, whereby the electromagnet **89** attracts a protruding magnetic part **96** of the shaft **86** and the shaft **86** is pulled in a direction towards the pump chamber **78**, and the membrane **44** consequently also moves towards the pump chamber **78**. The pump chamber **78** is thereby contracted and the measurement flow of breathable gas flows out from the pump chamber **78** through the second non-return valve and the outlet **76**. During this second phase, the membrane **44** is moved under the action of the electromagnet **89** and against the action of the spring **88** from the second end position to the first end position. Of course another electromagnet can replace the spring **88** and provide the force for pulling the membrane **44** away from the pump chamber **78**. If the spring **88** is replaced by an electromagnet, the other electromagnet **89** can be replaced by another spring, which provides the force for pushing the membrane **44** towards the pump chamber **78**. By way of non-limiting example, the pump may operate as described in WIPO publication no. WO2010/128914, which is hereby incorporated by reference in its entirety.

[0061] In some embodiments, operation of the pumps shown in FIGS. **4-6** may be precise enough that one or more parameters of the measurement flow of breathable gas can be determined, inferred, and/or adequately estimated without further monitoring. Such parameters may include, for example, pressure, flow rate, and/or other parameters. In some embodiments, one or more detectors may be included with the pumps to directly measurement one or more parameters of the measurement flow of breathable gas. For example, a sensor may be held in second part **72** that contacts membrane **44**. The output signals generated by the sensor may indicate one or more of a pressure applied by membrane **44**, movement of membrane **44**, and/or other parameters. This output signal may facilitate determination of the pressure and/or flow rate of the measurement flow of breathable gas through pump chamber **78**. As another non-limiting example, a pressure and/or flow rate detector may be included within first part **70** to directly measure the pressure and/or flow rate of measurement flow of breathable gas. In such embodiments, electrical contacts may be included on first part **70** and/or second part **72** to facilitate communications of the output signals of such detectors to a controller (e.g., controller **58** in FIG. **2**).

[0062] FIGS. **7** and **8** illustrate flow path element **28** and detector device **30** having different form factors than illustrated in FIGS. **1** and **2**. In particular, in the embodiments illustrated in FIGS. **7** and **8**, flow path element **28** and detector device **30** have a generally cylindrical shape.

[0063] FIGS. **9** and **10** illustrate one or more embodiments in which detector assembly **52** create a plurality of optical paths through sampling chamber **36**. For example, a first optical path may be associated with a sensor assembly designed to determine a relative level of carbon dioxide within sampling chamber **36**, and a second optical path may be associated with a sensor assembly designed to determine a relative level of one or more other gaseous constituents using, without limitation, luminescence quenching. To facilitate the second optical path, flow path element **28** includes a window **106** in addition to window **42**, to enable electromagnetic radiation to be guided into sampling chamber **36** from two separate radiation sources within detector assembly **52**. In such embodiments, control of the further sources and/or sensors associated with determining the relative level of the one or more other gaseous constituents may be tightly integrated with controller **58** (shown in FIGS. **2** and **3** and described above). This may include executing modules associated with the further sources and/or sensors on one or more common processors within controller **58**, disposing control electronics for the further sources and/or sensors on a common circuit board of controller **58**, storing models associated with the further sources and/or sensors on a common physical block of electronic storage within controller **58**, and/or integrating control of the further sources and/or sensors in other ways.

[0064] FIG. **11** illustrates a method of measuring the composition of a flow of breathable gas received from a respiratory circuit. The operations of method **120** presented below are intended to be illustrative. In some embodiments, method **120** may be accomplished with one or more additional operations not described, and/or without one or more of the operations discussed. Additionally, the order in which the operations of method **120** are illustrated in FIG. **11** and described below is not intended to be limiting.

[0065] At an operation **122**, electromagnetic radiation is emitted from a radiation source into a flow path for the flow of breathable gas. In some embodiments, the radiation source is the same as or similar to radiation source **60** (shown in FIGS. **1** and **2**, and described herein).

[0066] At an operation **124**, the emitted electromagnetic radiation is received after it has passed through the flow path. In some embodiments, operation **124** is performed by a detector assembly the same as or similar to detector assembly **52** (shown in FIGS. **1** and **2** and described herein).

[0067] At an operation **126**, output signals are generated by a sensor assembly. The output signals convey information related to one or more parameters of the received electromagnetic radiation. In some embodiments, the sensor assembly is the same as or similar to sensor assembly **62** (shown in FIGS. **1** and **2** and described herein).

[0068] At an operation **128**, the flow of breathable gas is drawn through the flow path by a pump. In some embodiments, the pump includes a pump actuator and a pump motor that are the same as or similar to pump actuator **54** and pump motor **56** (shown in FIGS. **2** and **3-6** and described herein).

[0069] At an operation **130**, modules are executed on one or more processors. The modules may be the same as or similar to modules **104**, **106**, **108**, **110**, and/or **112** (shown in FIG. **3** and described herein). The processor may be associate with a controller the same as or similar to controller **58** (shown in FIGS. **2** and **3** and described herein).

[0070] In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" or "including" does not exclude the presence of elements or steps other than those listed in a claim. In a device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. In any device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain elements are recited in mutually different dependent claims does not indicate that these elements cannot be used in combination.

[0071] Although the description provided above provides detail for the purpose of illustration based on what is currently considered to be the most practical and preferred embodiments, it is to be understood that such detail is solely for that purpose and that the disclosure is not limited to the expressly disclosed embodiments, but, on the contrary, is intended to cover modifications and equivalent arrangements that are within the spirit and scope of the appended claims. For example, it is to be understood that the present disclosure contemplates that, to the extent possible, one or more features of any embodiment can be combined with one or more features of any other embodiment.

1. A detector device configured to measure composition of a flow of breathable gas received from a respiratory circuit, the detector device comprising:

a housing;

a flow path engaged with a portion of the housing for the flow of breathable gas having an inlet and an outlet;

a radiation source within the housing and configured to emit electromagnetic radiation into the flow path;

a sensor assembly within the housing and configured to receive electromagnetic radiation that has been emitted by the radiation source and has passed through the flow path, the sensor assembly being further configured to generate output signals conveying information related to one or more parameters of the received electromagnetic radiation;

a pump, at least a portion of which is within the housing, the pump comprising:

a pump motor; and

a pump actuator configured to be driven by the pump motor to draw the flow of breathable gas through the flow path; and

one or more processors housed within an individual compartment within the housing, the one or more processors being configured to execute modules, the modules comprising:

a source module configured to drive the radiation source;

a sensor module configured to read the output signals generated by the sensor assembly;

a pump actuation module configured to drive the pump motor; and

a pump reading module configured to obtain information related to one or more operating parameters of the pump.

2. The detector device of claim **1**, wherein the one or more processors comprise a single processor that performs at least some of the functionality of each of the source module, the sensor module, the pump actuation module, and the pump reading module.

3. The detector device of claim **1**, wherein the one or more processors are carried on a common circuit board.

4. The detector device of claim **4**, wherein the common circuit board has a length of less than about 4.5 cm, and a width of less than about 2.5 cm.

5. The detector device of claim **1**, further comprising a physical block of electronic storage that stores:

at least a portion of one or both of the source module and the sensor module; and

at least a portion of one or both of the pump actuation module and the pump reading module.

6. A method of measuring composition of a flow of breathable gas received from a respiratory circuit, the method comprising:

emitting electromagnetic radiation from a radiation source into a flow path for the flow of breathable gas;

receiving the emitted electromagnetic radiation after it has passed through the flow path;

generating output signals from a sensor assembly that convey information related to one or more parameters of the received electromagnetic radiation;

drawing the flow of breathable gas through the flow path with a pump that includes a pump motor and a pump actuator,

wherein the radiation source, the sensor assembly, and at least a portion of the pump are housed in a common housing; and

executing modules on one or more processors that are contained within a single compartment of the housing, the modules comprising:

a source module configured to drive the radiation source;

a sensor module configured to read the output signals generated by the sensor assembly;

a pump actuation module configured to drive the pump motor; and

a pump reading module configured to obtain information related to one or more operating parameters of the pump.

7. The method of claim **6**, wherein the one or more processors comprise a single processor that performs at least some of the functionality of each of the source module, the sensor module, the pump actuation module, and the pump reading module.

8. The method of claim **6**, wherein the one or more processors are carried on a common circuit board.

9. The method of claim **8**, wherein the common circuit board has a length of less than about 4.5 cm, and a width of less than about 2.5 cm.

10. The method of claim **6**, further comprising storing, to a physical block of electronic storage housed within the housing:

at least a portion of one or both of the source module and the sensor module; and

at least a portion of one or both of the pump actuation module and the pump reading module.

11. A detector device for measuring composition of a flow of breathable gas received from a respiratory circuit, the detector device comprising:

means for emitting electromagnetic radiation into a flow path (**28**) for the flow of breathable gas;

means for receiving the emitted electromagnetic radiation after it has passed through the flow path;

means for generating output signals that convey information related to one or more parameters of the received electromagnetic radiation;

means for drawing the flow of breathable gas through the flow path, the means for drawing comprising a pump motor and a pump actuator,

wherein the means for emitting, the means for generating, the pump motor, and the pump actuator are housed in and/or carried by a common housing; and

means for executing modules, the means for executing being contained within a single compartment of the housing, the modules comprising:

a source module configured to drive the radiation source;

a sensor module configured to read the output signals of the means for generating;

a pump actuation module configured to drive the pump motor; and

a pump reading module configured to obtain information related to one or more operating parameters of the pump.

12. The detector device of claim **11**, wherein the means for executing comprise a single processor that performs at least some of the functionality of each of the source module, the sensor module, the pump actuation module, and the pump reading module.

13. The detector device of claim **11**, wherein the means for executing are carried on a common circuit board.

14. The detector device of claim **13**, wherein the common circuit board has a length of less than about 4.5 cm, and a width of less than about 2.5 cm.

15. The detector device of claim **11**, further comprising means for storing:

at least a portion of one or both of the source module and the sensor module; and

at least a portion of one or both of the pump actuation module and the pump reading module,

wherein the means for storing consists of a physical block of electronic storage housed within the housing.

* * * * *

专利名称(译)	使用具有紧密集成的控制电子设备的泵和检测器来监测侧流系统中的成分的系统和方法		
公开(公告)号	US20140316241A1	公开(公告)日	2014-10-23
申请号	US14/361551	申请日	2012-11-27
[标]申请(专利权)人(译)	皇家飞利浦电子股份有限公司		
申请(专利权)人(译)	皇家飞利浦N.V.		
当前申请(专利权)人(译)	皇家飞利浦N.V.		
[标]发明人	JAFFE MICHAEL BRIAN		
发明人	JAFFE, MICHAEL, BRIAN		
IPC分类号	A61B5/08 A61B5/00		
CPC分类号	A61M16/1075 A61M16/0666 A61M2016/103 A61M16/0672 A61M2016/1025 A61M2205/502 A61M16/16 A61B5/082 A61M2205/3306 A61M16/0051 A61B5/0059 A61M2016/1035		
优先权	61/565549 2011-12-01 US		
其他公开文献	US10448863		
外部链接	Espacenet USPTO		

摘要(译)

一种系统和方法被配置为监测提供给受试者的可呼吸气体流的组成。监测在侧流配置中完成，其中泵和检测器的控制在紧密集成的控制器中实现。