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(54) **SAFETY MONITOR FOR GAS MIXTURES REQUIRING STORAGE IN SPECIFIC TEMPERATURE REGIMES**

(57) The present invention pertains to providing a monitoring of the status of a gaseous mixture within a gas cylinder, which may be subjected to various ambient temperatures that influence the state of the gaseous mixture. Accordingly, a gas monitoring device a gas monitoring device (10) for use with a gas cylinder (12) is suggested, comprising a first temperature sensor (16) for measuring an ambient temperature of the gas cylinder (12), an indicator (18) for indicating a status of a gaseous mixture comprised in the gas cylinder(12), and an evaluation unit(20) in communication with the first temperature sensor (16) and the indicator (18) and configured to determine a status of the gaseous mixture based on the received ambient temperature measurement. The evaluation unit (20) is furthermore configured to output a signal corresponding to said status to the indicator (18), when the gas monitoring device (10) is coupled to the gas cylinder (12).

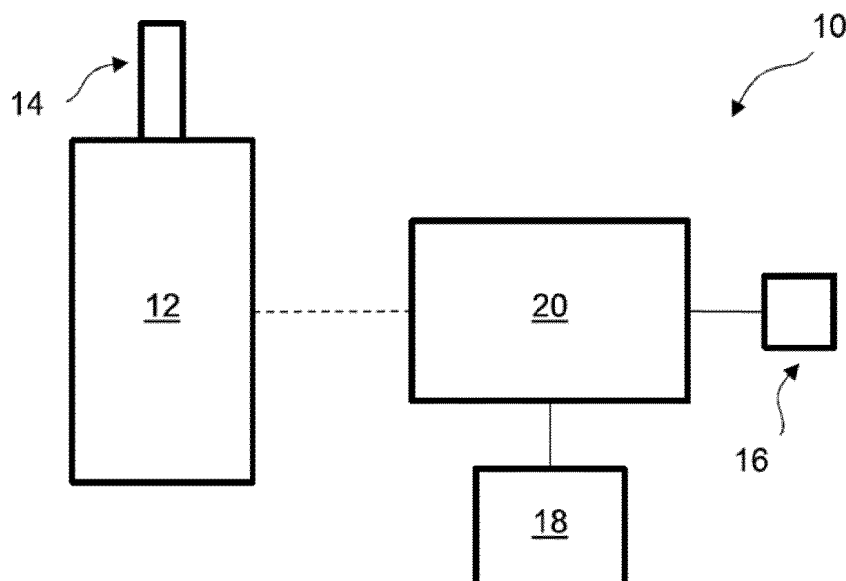


Fig. 2

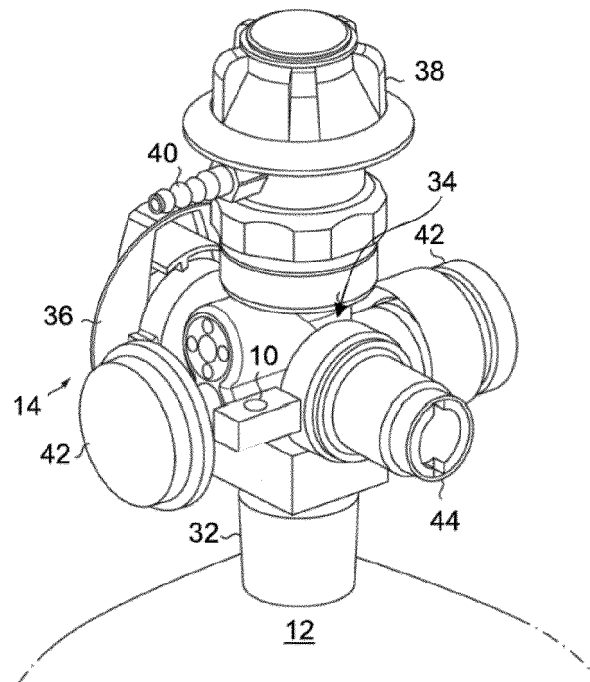


Fig. 6

Description

Technical Field

[0001] The invention relates to a gas monitoring device for use with the gas cylinder and a corresponding valve comprising such gas monitoring device, in particular for determining a liquid phase in a gaseous mixture.

Technological Background

[0002] Gaseous mixtures comprising one or more gaseous components are used in a variety of fields and are often applied at remote locations and/or in varying compositions and concentrations, such that the on-site production of such gaseous mixtures is limiting. In order to ensure that the required amount of the gaseous mixture is provided in a sufficient and well defined amount, such gaseous mixtures are hence commonly stored in gas cylinders having a predefined volume and permitting a compression of the gaseous mixture to provide the gaseous mixture in a compressed state.

[0003] Depending on the use and original fill level or filling pressure of a respective gas cylinder, pressures of the respective gaseous mixtures may however vary between gas cylinders. Furthermore, the gas cylinders may be stored at different locations having distinct ambient temperatures. Since the gaseous mixtures are generally stored in a strongly compressed state at high pressures, e.g. above 100 bar, the storage temperature may affect the physical state of the gases mixture comprised within the gas cylinder.

[0004] For example, a gaseous mixture may comprise two or more gaseous components having a distinct density, wherein both gaseous components are in the gas state at the respective pressure and within a predefined temperature range, while a reduction of the temperature below the lower limit of said temperature range, i.e. below a critical temperature, may result in a transition from the gas state into a liquid state for at least one of the gaseous components. In such situation, the mixture comprised within the gas cylinder is provided as a two-phase mixture comprising both a gas state and a liquid or condensed state, wherein the liquid state, may e.g. adhere to the inner wall of the gas cylinder in the form of droplets or is collected at a lower end of the respective gas cylinder. This poses the problem that the gaseous mixture is no longer homogeneous and is comprised at a different concentration in the gas state, such that during the application of the gaseous mixture, i.e. by opening a valve of the gas cylinder, the gaseous mixture comprises an incorrect concentration or even a lack of a particular component.

[0005] Such situation is of particular concern in medical applications, wherein the gaseous mixture is administered to a patient in the form of a breathable medicament or support gas. For example, a medical gas may be provided as a gaseous mixture comprised of two gaseous

components, such as nitrous oxide and oxygen, which may be administered to a patient e.g. using a demand valve downstream of a pressure regulator of the valve of the gas cylinder. The demand valve in such case administers the appropriate volume of gas to the patient, dependent on the patients inspiratory effort. Although these gases are highly stable at the pressures and temperatures specified for the product, an ambient temperature below the lower limit may result in a transition of the gaseous nitrous oxide into a condensed or liquid state, such that the administration of the breathing gas initially provides an oxygen-rich gaseous mixture with a low amount of nitrous oxide or no nitrous oxide at all. Thereby, the desired therapeutic effect may not be achieved and detrimental side effects may occur, potentially leading to critical conditions and harming the patient.

[0006] In order to avoid the phenomena where the nitrous oxide will condense out of the mixture, preventive techniques commonly include the provision of specific advice to the patient or user, e.g. by providing proper instructions prior to use, a patient information leaflet and/or by properly labeling the gas cylinder. Such preventive techniques in particular comprise the advice to a user that the respective gas cylinder should be stored at a temperature above 10°C for at least 24 hours before use. Where this is not possible, the optional instructions are given to invert the gas cylinder three times prior to use to mix the gas before administration.

[0007] However, in case of an urgent requirement of the gaseous mixture, it may not be possible to wait for the prescribed storage time to lapse. Furthermore, although depending on the particular circumstances a brief storage at lower temperatures may not immediately result in a condensation of at least one gaseous component, the user or patient may not be capable to assess the exact state of the gaseous mixture and the necessity of further preventive measures. In addition, even if such measures are performed, e.g. by multiple inversions of the gas cylinder, such inversions may have been performed incorrectly or may be insufficient to fully reduce the liquid state, even when performed correctly. Therefore, an increased risk of administering an incorrect gaseous mixture remains.

[0008] Accordingly, further improvements are required to e.g. determine that the gaseous mixture has been stored correctly and has been mixed properly to ensure the safe use of the gaseous mixture.

Summary of the invention

[0009] It is an object of the present invention to provide a device for use with a gas cylinder, which is adapted to monitor a state of a gaseous mixture within the gas cylinder to improve the safe use of the gaseous mixture.

[0010] Accordingly, in a first aspect, a gas monitoring device for use with a gas cylinder device is suggested, which comprises a first temperature sensor for measuring an ambient temperature of the gas cylinder, an indi-

cator for indicating a status of a gaseous mixture comprised in the gas cylinder, and an evaluation unit in communication with the first temperature sensor and the indicator and configured to determine a status of the gaseous mixture based on the received ambient temperature measurement and to output a signal corresponding to said status to the indicator, when the gas monitoring device is coupled to the gas cylinder.

[0011] By measuring an ambient temperature of the respective gas cylinder, the evaluation unit may hence determine whether the detected temperature corresponds to a predefined temperature or exceeds a particular threshold. For example, the evaluation unit may be configured for a particular type of gas and/or a particular mixing ratio of various gaseous components having a corresponding critical temperature at which a transition from the gas state into the liquid state may occur. Accordingly, the evaluation unit may determine the state of the gaseous mixture within the gas cylinder based on the detected ambient temperature and depending on whether said temperature is above or below such critical temperature, so as to indicate a probability of the presence of a liquid state within the gaseous mixture. The type of gas, the ratio of the gaseous components, and/or a preset critical temperature may be stored in the evaluation unit and/or may be adjusted and provided to the evaluation unit by means of an inputting device, such as a keyboard, touchscreen, or a selective mechanical switch or dial provided on the device.

[0012] When the ambient temperature sensor measures a temperature that is below the critical temperature, the evaluation unit may hence determine an increased probability of a liquid state being present in the gaseous mixture and accordingly outputs a signal to the indicator, such that the indicator may indicate the determined status. By the same token, if the measured ambient temperature is above the critical temperature, the evaluation unit may accordingly output a signal corresponding to a low probability of a liquid state being present, such that the indicator may provide a status indicating that the gaseous mixture may be safely used. A user, e.g. a patient or medical professional, is hence provided with an actual status of the gaseous mixture comprised within the gas cylinder and indicates to a user whether a use of the gas cylinder may impose a potential risk.

[0013] In order to provide a reliable measurement of the first temperature sensor, the temperature sensor is preferably arranged at a position, wherein the temperature sensor is not in direct contact with the components arranged at the gas cylinder outlet, e.g. the pressure regulator, a valve, or valve outlet, such that a temperature change during active use of the gas cylinder caused by the expansion of the gaseous mixture does not affect the ambient temperature measurement of the first temperature sensor. For example, the first temperature sensor may be arranged at an outer end or outer surface of the gas monitoring device and preferably points away from the valve components. Alternatively, the first temperature

sensor may be arranged so as to be in contact with or parallel to a wall of the gas cylinder in the coupled state. The temperature sensor may be formed as e.g. a thermistor, a thermocouple, or digital thermometer.

[0014] It is to be understood that the gas monitoring device may be provided as a separate electronic module, which may be coupled to a gas cylinder, in particular to a valve of a gas cylinder. Accordingly, the gas monitoring device is configured to be coupled with at least one component of the gas cylinder and/or valve thereof, for example, by the provision of attachment or fixation means, e.g. by the provision of an electromagnetic coupling, screwing attachment, clamp or strap. Thereby, the gas monitoring device may be coupled to any gas cylinder irrespective of the type of gas comprised within the respective gas cylinder and/or the type of valve used with the gas cylinder. Existing valves, pressure regulators, and/or gas cylinders may hence be retrofitted with the gas monitoring device without requiring any invasive modifications with pressure regulating elements being in fluid communication with the gaseous mixture and potentially being under high pressure. The coupling may also be indirectly provided, for example, by providing a coupling to a framework or rack of the gas cylinder. Such coupling may hence also be provided for a plurality of gas cylinders stored and transportable in a single rack.

[0015] The gas monitoring device may hence be coupled and securely fixed to the gas cylinder yet provides a releasable modular unit, which may be removed, adjusted, and/or replaced. Alternatively, the gas monitoring device may also be embedded in the valve of the gas cylinder to form an integral unit therewith. Due to the coupling with a respective gas cylinder, the ambient temperature measurement furthermore becomes more reliable and specific for the respective gas cylinder.

[0016] Preferably, the evaluation unit is further configured to determine the status of the gaseous mixture based on an evaluation of the ambient temperature measurement over a predefined time period and/or a comparison of the ambient temperature measurement with a predefined temperature range, wherein the outputted signal comprises an alarm, when the determined status deviates from a predefined status stored in the evaluation unit. In other words, the evaluation unit can record whether the gas cylinder has been stored at the correct temperature for the correct amount of time and so is safe for use, i.e. does not comprise a gaseous mixture with separated phases.

[0017] For example, the gas cylinder may be subjected to an ambient temperature below a critical temperature of the respective gaseous mixture for a brief period of time, e.g., during transportation between nearby facilities after being stored at room temperature. Although the temperature of the wall of the gas cylinder, which is generally made of metal, may be accordingly reduced, the gaseous mixture may not fall below the critical temperature during said period of time. Accordingly, the evaluation unit may determine the status of the gaseous mixture

based on the time in which the ambient temperature was measured below the critical temperature. By the same token, the probability of a transition from the gas state into the liquid state may be increased for a particular temperature range, such that even in a case where the ambient temperature measurement does not fall below the critical temperature or only for a brief period of time, the evaluation unit may determine an increased probability of the presence of a liquid state, if the ambient temperature measurement is within the predefined temperature range. Preferably, the evaluation unit determines the status based on an evaluation of the ambient temperature measurement over a predefined time period and a comparison with a predefined temperature range.

[0018] Based on the determined status of the gaseous mixture, the evaluation unit accordingly outputs a signal to the indicator so as to provide the user with information relating to the gaseous mixture, e.g. a level of safety for using the gaseous mixture. When the determined status deviates from a predefined status stored in or otherwise provided to the evaluation unit, the outputted signal may comprise an alarm to indicate an increased risk when using the gas cylinder. For example, the measured ambient temperature may exceed a lower threshold or critical temperature for the gaseous mixture and the evaluation unit may determine an increased probability of the presence of a liquid state of the gaseous mixture, such that the actual status of the gaseous mixture no longer corresponds to a safe status and instead corresponds to a risk status, which is provided to the user in the form of an alarm, e.g. a visual warning light or acoustic alarm, e.g. by means of a speaker or buzzer.

[0019] The determined status of the gaseous mixture and the corresponding outputted signal may indicate e.g. whether the gaseous mixture is at a temperature which is compatible with a medical gas application, i.e. is at a temperature suitable for being used as a breathable medical gas. Preferably, the determined status indicates the probability of the presence of a liquid phase within the gas cylinder, wherein the gaseous mixture preferably comprises nitrous oxide, oxygen, helium, nitrogen, nitric oxide, carbon monoxide, and/or carbon dioxide.

[0020] Accordingly, the gaseous mixture may be a medical gas or breathing gas for a patient, in particular for a patient suffering from a respiratory disorder, wherein the gaseous mixture is administered to the patient via inhalation or mechanical ventilation. The gaseous mixture may e.g. comprise a mixture of nitrous oxide and oxygen or may comprise a combination of helium and nitric oxide, depending on the required therapeutic effect.

[0021] For example, a combination of nitrous oxide, also known as laughing gas, and oxygen, e.g. at equal parts, may be provided as an anesthetic, due to its pain alleviating or analgesic effects while at the same time providing the patient with a sufficient level of oxygen. However, while the oxygen is maintained in the gas state, the nitrous oxide component of the gaseous mixture may at least partly transition into a liquid state, when a partic-

ular pressure is provided and the gaseous mixture is subjected to a temperature below the specific critical temperature, due to its larger density. Thereby, the gaseous mixture exiting the gas cylinder upon valve actuation is comprised of enriched oxygen, wherein the nitrous oxide is reduced or absent, thereby having a limited therapeutic effect. By providing the measurement of the ambient temperature of the gas cylinder, the evaluation unit may determine a probability of the presence of a liquid state and may accordingly alert the user via the outputted signal and the indicator.

[0022] The indicator may be provided as any means capable of visually, acoustically, and/or electromechanically representing the outputted signal. Preferably, the indicator is configured to present the status by activating one or more LEDs, by providing a graphical representation or text message on a display, and/or by outputting an acoustic signal. For example, the indicator may comprise one or more LEDs emitting light in different colors corresponding to a different status of the gaseous mixture, e.g. red and green, wherein red indicates an increased risk for the user and green indicates that the gaseous mixture is safe for use. Alternatively, or in addition, a display or screen may be provided, which may represent the status by means of a graphical icon or pictogram and/or by providing a text message corresponding to the status. Furthermore, an acoustic signal may be provided by means of e.g. a speaker or buzzer, or in the acoustic signal may be outputted as an alarm, e.g. when the determined status deviates from a predefined status or poses a potential risk to a user.

[0023] In other words, a real time indication may be provided whether the gas cylinder has been stored correctly and is ready for immediate use, which reduces the potential risk of a patient using the gaseous mixture where the gas has been stored incorrectly or not mixed properly.

[0024] Instead of continuously outputting the signal to the indicator, the indicator may be configured to present the status on-demand by means of an actuation of a touch-sensitive object of the indicator, preferably a button or mechanical switch, or upon actuation due to a coupling with a remote device via NFC, Bluetooth, Zigbee, RFID, or WiFi.

[0025] By providing a retrievable status rather than a continuous status the energy consumption of the gas monitoring device may be reduced. Furthermore, the status may be only retrievable, when an identifier is provided to the gas monitoring device. Such identifier may be provided by means of a touch-sensitive object or keypad, but may also be automatically retrieved upon a successful coupling with a compatible remote device, e.g. via NFC in case of a nearby remote device or control or via Wi-Fi, or WLAN in case of more remote devices. Thereby, a level of security may be provided to the determined status of the gaseous mixture in the gas monitoring device.

[0026] The gas monitoring device may furthermore

comprise a valve activation sensor for a valve of the gas cylinder, which is in communication with the evaluation unit and wherein the evaluation unit outputs the signal based on the determined status and the detected valve activity.

[0027] By means of the valve activation sensor an opening or closing of the valve may be detected. Should the evaluation unit determine a status of the gaseous mixture indicating an increased risk for a user when using the gaseous mixture and detect an activation of the valve by means of the valve activation sensor, e.g. an opening or flow rate setting of the valve, a signal may be outputted and be presented by the indicator to alert the user, e.g. by means of an alarm. Such detection mechanism hence facilitates that a further use of the gaseous mixture may be prevented. By the same token, if no increased risk is determined, the evaluation unit may either not output a signal or may output a signal indicating a safe use of the gaseous mixture. Accordingly, the valve activation sensor provides an additional confirmation and level of safety for a user or patient.

[0028] The valve activation sensor is preferably configured as a flow sensor for detecting a flow of a gas through the valve of the gas cylinder or the gas monitoring device comprises a second temperature sensor for measuring a temperature of a valve body of the gas cylinder and being in communication with the evaluation unit, wherein the evaluation unit determines an activation of the valve based on the first temperature sensor measurement and the second temperature sensor measurement.

[0029] For example, a flow sensor may be arranged at a valve outlet of the gas cylinder and may accordingly comprise a coupling device to provide a fluid coupling between the valve outlet and e.g. a gas application device, for example, by means of a bayonet or luer coupling. The use of such a flow sensor has the advantage that not only an activation of the valve may be detected, but also a current flow rate of the gas being applied is provided as additional information to the evaluation unit.

[0030] Alternatively, a second temperature sensor arranged at the valve body may provide a temperature measurement of the valve body to the evaluation unit, wherein the evaluation unit processes a compensated temperature calculated from the difference between the measured valve body temperature and the ambient temperature overtime to determine the flow-rate of the flow of gas from the cylinder and/or the pressure on the gas. Such compensated temperature may be based on the fact that when a gas experiences a rapid change in pressure, for example when it flows through a valve or regulator, the gas experiences an iso-enthalpic process leading to a temperature change, known as the Joule-Thomson effect. The valve body temperature can then be processed to distinguish between the change in temperature that is attributable to the flow-rate of the gas, and the change in temperature due to the pressure change in the cylinder. The flow-rate of the gas and the pressure

change in the cylinder can then both be determined from the temperature and time data.

[0031] From the flow-rate it is furthermore possible to calculate the change in volume in the gas cylinder over the time the valve was opened, and from the pressure change it is possible to calculate the volume change based on knowing the initial or last recorded and stored pressure and volume. Knowing the volume change hence enables the remaining volume of gas to be calculated.

[0032] The measured compensated temperature and time information can be processed to calculate the rate of change of temperature with time (the first temperature derivative), and the rate of change of the first derivative with time (the second temperature derivative) at any given time. Advantageously, information about the gas cylinder contents can be obtained from measuring the temperature alone rather than having to rely on flow-rate or pressure data which requires more sophisticated and invasive monitoring equipment.

[0033] Furthermore, the activation state of the valve may be factored into the temperature measurement of the first temperature sensor. This is particularly advantageous when the spatial arrangement between the first and second temperature sensor may not exclude that both sensor measurements influence each other. In addition, activation of the valve may incur a temperature change of the valve body, which may extend towards the wall of the gas cylinder and hence to the first temperature sensor. Accordingly, the measurement of the temperature of the valve body may be used to correct an ambient temperature measurement. Since the activation of the valve may furthermore cause a pressure difference within the gas cylinder, the activation state may furthermore be used to determine the status of the gaseous mixture, such that, for example, a low probability of the presence of a liquid state may be neglected, when a high flow rate is indicated by the valve activation sensor.

[0034] Preferably, the indicator is configured to prompt a user to maintain the gas cylinder within a predefined temperature range for a predefined time period and/or to invert the gas cylinder for a predefined number of times based on the determined status. Said time period and/or number of inversions may e.g. correspond to a probability level of the presence of a liquid state within the gaseous mixture or generally to an absolute ambient temperature measurement or sequence of ambient temperature measurements. For example, a prolonged storage of a respective gas cylinder below a critical temperature may require that the gas cylinder is maintained at e.g. room temperature for a prolonged period of time, while a brief ambient temperature measurement just below the critical temperature may be remedied by e.g. one to three inversions of the gas cylinder.

[0035] In order to ensure whether an inversion of the gas cylinder has taken place, the gas monitoring device preferably comprises an accelerometer or motion sensor in communication with the evaluation unit, wherein the

evaluation unit is configured to update the determined status based on a received measurement of said accelerometer or motion sensor. A brief storage of a respective gas cylinder and below the critical temperature of the gaseous mixture may e.g. be followed by one or more inversions of the gas cylinder, such that the presence of a liquid state of the gaseous mixture may be insignificant or may at least not pose a risk for the user. Accordingly, even if such status of the gaseous mixture is initially determined, the status is automatically updated upon a detection of an inversion or other movement by the accelerometer or motion sensor.

[0036] In addition, this provides a feedback mechanism to the evaluation unit in the case where the indicator prompts a user to invert the gas cylinder for a predefined number of times based on the determined status. In other words, the actual number of inversions within a predefined period of time may be compared with the prescribed number of inversions and the evaluation unit may accordingly output a signal based on said comparison. If the comparison indicates that the prescribed number of inversions have occurred, a previously determined status corresponding to an increased risk of the presence of a liquid state within the gaseous mixture may be updated, so as to indicate to a user that the gaseous mixture is now safe for use. If the indicator is configured as a display or screen, the display may also indicate the temperature and the remaining time and/or number of inversions required to ensure that the gaseous mixture is safe for use, e.g., in the form of a countdown.

[0037] Since large institutions and facilities generally comprise a plurality of gas cylinders for a plurality of users or patients, which may be used or stored at different and remote locations, it is furthermore preferable that the status, for each of these gas cylinders is remotely retrievable. Accordingly, the gas monitoring device preferably comprises a wireless communication module in communication with the evaluation unit, wherein the wireless communication module is configured to transmit the output signal to a remote device, preferably a remote monitor and/or monitoring system. Thereby, it is possible to locate and track a respective gas cylinder and it is ensured that a required gaseous mixture is available for use. Furthermore, should the evaluation unit of the respective gas cylinder indicate a potential risk due to the determined status of the respective gaseous mixture, e.g. due to an undesirable storage temperature, maintenance or relocation may be provided to ensure a proper storage of said gas cylinder.

[0038] In a medical setting, this may furthermore ensure that medical personnel is alerted, when a status of a gaseous mixture deviates from a predefined status and use of said gaseous mixture potentially poses a risk for a corresponding patient. If the gas monitoring device is furthermore equipped with a valve activation sensor, an actuation or opening of said valve may furthermore invoke an alarm in a monitoring system or in a remote device coupled with the gas monitoring device, such that

the medical personnel may be immediately directed to the respective gas cylinder to avoid further usage.

[0039] In order to facilitate the transmission of the output signal to a remote device, the wireless communication module is preferably configured with Bluetooth, Bluetooth Low Energy, Zigbee, RFID, WLAN, WiFi, and/or similar communication standards to facilitate a nearby or remote communication.

[0040] To facilitate transportation and for ease of implementation of the gas monitoring device, the gas monitoring device is preferably configured as a stand-alone unit comprising an electrical energy storage medium and/or comprises an electrical coupling. For example, the gas monitoring device may be powered by a battery, such as half an AA, an AA or an AAA standard battery, which provides a sufficient longevity to maintain the gas monitoring device between one to five years in standby or low activity mode. Such battery power has the advantage that no further implementations are required other than a correct coupling of the gas monitoring device to the gas cylinder and that the gas monitoring device may be used with a gas cylinder at an arbitrary location. Alternatively, or in addition, the gas monitoring device may be provided with an electric coupling device, such that the gas monitoring device may be charged or powered by an external electrical energy source. Furthermore, the gas monitoring device may be electrically coupled to a powered integrated valve by means of a corresponding interface.

[0041] According to a further aspect of the invention, a valve for a gas cylinder is suggested, comprising a gas monitoring device as described in the above. For example, the gas monitoring device may be coupled to the valve via an attachment or fixation means, such as a screwing attachment, or alternatively via an electromagnetic coupling. Preferably, the gas monitoring device is integrated in the valve, e.g. embedded or otherwise securely fixed to the valve. Accordingly, the gas monitoring device may be provided as a releasable module, which is secured to the valve, e.g., for retrofitting purposes of existing valves, or may be formed as an integral part.

[0042] The valve may furthermore comprise a pressure sensor, which is in communication with the evaluation unit, wherein the evaluation unit is configured to determine the status based on the received ambient temperature measurement and the detected pressure of the gaseous mixture in the gas cylinder. As described in the above, the state of each gaseous component in the gaseous mixture may be dependent on both the pressure and the temperature within the gas cylinder. Although most gaseous components are in a gas state at ambient temperature and even at high pressure, gaseous components may transition into the liquid state below a particular temperature, known as the critical temperature. Accordingly, including the pressure of the gaseous mixture within the gas cylinder in the determining of the status of the gaseous mixture further increases the validity of a determined probability of the presence of a liquid state

within the gaseous mixture. For this purpose the evaluation unit may be in direct communication with the pressure sensor or may communicate with said pressure sensor via an interface provided in the valve.

[0043] The evaluation unit, as described in the above may comprise any computing means, such as a processor or microprocessor to process the various measurements and may furthermore comprise a data storage, storing e.g. lists of critical temperatures for particular gaseous components, and may be configured to compare said measurements with available data, e.g. thresholds or temperature ranges, stored in said storage. In addition, and inputting means may be provided, such that relevant data for determining the status of the gaseous mixture may be manually or automatically inputted.

[0044] The evaluation unit may furthermore be in communication with or be configured as a control unit of the valve, wherein the control unit is configured to control the valve actuation based on the determined status. The evaluation unit may hence be coupled with an existing control unit, e.g. via an interface, or may form an integral part of a control unit.

[0045] The evaluation unit may hence also be configured as being part of a controller or as controller itself and may accordingly be operatively coupled with various actuation components of a valve, e.g. a pressure regulator and/or a valve actuation wheel or knob, either directly or via an interface of the valve.

[0046] Accordingly, based on the determined status of the gaseous mixture, the evaluation unit may actively prevent an activation or actuation of the valve, for example, when the determined status indicates a risk for a user. The control function of the activation may furthermore be provided by a remote device, e.g. a coupled remote device or central monitoring device, by means of a corresponding coupling, e.g. by means of a wireless communication module.

Brief description of the drawings

[0047] The present disclosure will be more readily appreciated by reference to the following detailed description when being considered in connection with the accompanying drawings in which:

Figure 1 is a graphical representation of the physical state of nitrous oxide at different pressures and temperatures;

Figure 2 is a schematic view of a gas monitoring device coupled to a gas cylinder;

Figure 3 is another schematic view of a gas monitoring device securely attached to a valve and gas cylinder wall of a gas cylinder;

Figure 4 is another schematic view of the gas monitoring device according to Figure 3 with further func-

tional features;

Figure 5 is a schematic view of the gas monitoring device according to Figure 4 in communication with a remote device; and

Figure 6 is a perspective view of a valve with an attached gas monitoring device.

Detailed description of preferred embodiments

[0048] In the following, the invention will be explained in more detail with reference to the accompanying Figures. In the Figures, like elements are denoted by identical reference numerals and repeated description thereof may be omitted in order to avoid redundancies.

[0049] In Figure 1 a graph is shown indicating the physical state of nitrous oxide, which may be used in a gas mixture together with oxygen, e.g. at equal parts, and is normally administered to a patient for therapeutic purposes. The physical behavior of nitrous oxide is depicted for the respective pressure (P) and temperature (T) ranges. As shown by curve A and rectangular elements, nitrous oxide may be in a gas state or phase even at high pressures yet reaches a critical point, as indicated by C. Provided that the pressure and temperature of the gas mixture remain to the left of curve A, there will be no separation of the gas mixture, i.e. the nitrous oxide will remain in the gas state. Furthermore, at pressures above the critical point C on the curve, the gas mixture will remain as a gas. However, if the pressure is maintained and the temperature is reduced to below -66°C, the nitrous oxide component of the mixture will start to condense out of the gas mixture, as indicated by curve B and triangular elements. By the same token, if the temperature is further reduced, nitrous oxide will transition into the liquid phase even at lower pressures. Accordingly, with low temperatures, stability of the gaseous mixture is reduced, increasing the probability of a gas separation, which may pose a risk to a patient when using the gaseous mixture.

[0050] Figure 2 is a schematic view of a gas monitoring device 10 coupled to a gas cylinder 12 having a valve 14. As indicated by the dashed line, the gas monitoring device 10 is not required to be in direct contact with the gas cylinder 12 or valve 14. For example, the gas monitoring device 10 may also be coupled to the gas cylinder 12 by means of an attachment to a holder or rack of the gas cylinder 12, such that the gas monitoring device 10 may be associated with a particular gas cylinder.

[0051] The gas monitoring device 10 comprises a first temperature sensor 16, which is configured and arranged to detect an ambient temperature so as to provide a corresponding measurement to the evaluation unit 20. The evaluation unit 20 comprises a computing means in the form of a processor as well as a data storage to compare the measured ambient temperatures with a predefined temperature range stored in the evaluation unit 20. Said temperature range corresponds to a dew point or critical

temperature for a given pressure and specific component, e.g. nitrous oxygen, which is comprised in the gaseous mixture in the gas cylinder 12.

[0052] Accordingly, a provided ambient temperature below said temperature range may indicate that said gaseous component in the gaseous mixture may transition into the liquid phase, e.g. condense, such that the gaseous mixture is at least partly separated and the required concentration of the respective components within the gaseous mixture does not correspond to a prescribed concentration. In order to alert a user handling the gas cylinder 12, the gas monitoring device 10 comprises an indicator 18, which is configured in the form of a display and which is in communication with the evaluation unit 20 to receive an output signal corresponding to a determined status of the gaseous mixture. The display may hence present a text message or graphical icon indicating whether the gaseous mixture and gas cylinder 12 is safe for use based on the received signal. However, alternatively, or in addition, the indicator 18 may also provide an indication of the determined status by means of a light or LED and/or acoustic signal, such as an alarm via a buzzer.

[0053] The embodiment depicted in Figure 3 essentially corresponds to the embodiment of Figure 2, wherein in addition to the first temperature sensor 16 a valve activation sensor 24 is comprised in the gas monitoring device 10. The gas monitoring device 10 is directly coupled to the gas cylinder 12 and the valve 14, e.g. to a wall of the gas cylinder 12, by means of an attachment means, e.g. a screwing fixation, Velcro, or an adhesive. Accordingly, the gas monitoring device 10 is specific for the gas cylinder 12 even in the case of a separation of the gas cylinder 12 from a holder.

[0054] Furthermore, such arrangement facilitates the measurement of an actuation of the valve 14 due to the direct coupling. The valve activation sensor 24 may e.g. be configured as a sensor to detect an opening and closing of the valve 14, but is preferably configured to determine a flow rate of the gaseous mixture exiting the valve 14. In order to avoid any necessary further implementations and to provide a non-invasive measurement of the flow rate, the valve activation sensor 24 may be formed as a second temperature sensor, which measures a temperature of the valve body.

[0055] The valve comprises a primary on-off valve, a flow-regulator valve, and an outlet connection (not shown). The second temperature sensor of the gas monitoring device is in direct contact with the valve body of the valve 14 and is configured as a thermistor, which is mechanically biased via a resilient member such that the thermistor engages the valve body, when the gas monitoring device 10 is assembled onto the valve body.

[0056] The processor of the evaluation unit 20 is operable to calculate a compensated temperature over time, the compensated temperature being the difference between the measured valve body temperature and the measured ambient temperature, and then determines

the first temperature derivative (dCT/dt) and the second temperature derivative (d^2CT/dt^2), which together may be used during operation of the valve to determine the flow rate and pressure change in the cylinder. From the determined flow rates and/or pressure changes, the volume change in the gas cylinder 12, and hence the remaining volume, can be calculated.

[0057] To facilitate the determining of the flow rate the processor of the evaluation unit 20 can store reference data associated with the gas cylinder 12 to which it is attached. The reference data may include valve calibration data which equates temperature change of the valve body to gas flow-rate through the valve body when the flow-regulator valve is opened. The valve calibration data is specific and selected according to the valve 14 and gas cylinder 12 to which the valve 14 is attached, and may include valve material, valve size, filling pressure of the cylinder 12, cylinder volume, and cylinder material.

[0058] The evaluation unit 20 may hence not only indicate a potential risk of using the gaseous mixture below a predefined ambient temperature, but may also provide further information derived from the determined flow rate to indicate a calculated remaining time, provide a warning to user that a flow rate does not correspond to a prescribed flow rate, and/or alert a user that the remaining amount of the gaseous mixture is insufficient for a prescribed treatment and a replacement or refill of the gas cylinder 12 will be required. Said information may be provided by means of the outputted signal to the indicator 18.

[0059] In addition, in order to reduce the energy consumption, the indicator 18 may be configured to present the determined status information by means of a button 22, such that the status is only retrievable upon activation of said button. Therefore, a continuous indication is avoided by the provision of on-demand retrieval. Furthermore, such retrieval may require an identifier, such that a level of security is provided and e.g. only medical personnel is capable to perform the status reading.

[0060] The embodiment according to Figure 4 comprises a wireless communication module 28, which is in communication with the evaluation unit 20 and is configured to transmit the determined status to a remote device, e.g. via Bluetooth or Low Energy Bluetooth. This ensures that a user or medical personnel that is not in direct vicinity of the gas cylinder 12 may monitor the gaseous mixture comprised in the gas cylinder 12 and may be alerted, if the risk of a gas separation is determined based on the measured ambient temperature. To be able to transmit such information the wireless communication module 28 may require a coupling with the remote device, e.g. by providing an identifier or by requiring an initial physical proximity to the gas monitoring device 10, e.g. via NFC or RFID, to ensure that the transmitted information is only receivable by an authorized remote device.

[0061] The gas monitoring device 10 furthermore comprises an accelerometer 26, which is securely attached and is configured to measure a movement and acceleration of the gas monitoring device 10. The accelerometer

26 is in direct communication with the evaluation unit 20 and may be used to ensure that a prescribed number of inversions is performed, as indicated by the indicator 18 or in outputted signal corresponding to the determined status, when the determined status indicates a potential risk for the use of the gaseous mixture.

[0062] For example, the gas cylinder 12 may have been stored at a temperature, which causes a particular gaseous component to separate from the gaseous mixture due to a transition into the liquid state, e.g. due to condensation. In such case, the indicator 18 may present information based on the determined status to maintain the gas cylinder 12 at above a particular temperature for a predefined period of time and/or to invert the gas cylinder 12 a predefined number of times prior to use. While the first temperature sensor 16 measures the ambient temperature and hence provides feedback to the evaluation unit 20 as to whether the gas cylinder 12 is stored at a required temperature, the accelerometer 26 provides feedback to the evaluation unit 20 as to the number of inversions and whether said inversions have been performed correctly. Accordingly, the evaluation unit 20 may periodically or continuously update the determined status and may provide such update via the outputted signal to the indicator 18.

[0063] The wireless communication module 28 may furthermore be in communication with a remote device 30, as indicated in Figure 5 by means of the dashed line, wherein the remote device 30 may be configured as a central monitoring unit or remote central computer system. The transmitter of the wireless communication module 28 may hence transmit the signal corresponding to the determined status to the remote device 30 to alert the operator of the remote device 30, if the determined status poses a risk for a user. In addition, the transmitter may be capable of transmitting data, which in addition to the determined status and depending on the configuration of the evaluation unit 20 may include the gas cylinder 12 details and the remaining volume left in the gas cylinder 12 to the remote device 30 to make the operator of the remote device 30 aware if the cylinder needs changing.

[0064] Although the processor of the evaluation unit 20 processes the ambient temperature, the flow rate data, and the movement data over time and updates the determined status, said processing steps may also be performed by the remote device 30, i.e. when the level of required independency and remoteness is low, such that there is no need for any processing to be done in the gas monitoring device 10. This may furthermore reduce the energy consumption of the gas monitoring device 10.

[0065] The remote device 30 or plurality of remote devices 30 may be positioned e.g. in a ward, surgery, filling station, and/or storage station and may be either stationary or configured as a mobile and/or handheld device. Furthermore, to facilitate the communication between the gas monitoring device 10 and the remote device 30, the

communication may be provided via one or more hubs, wherein the hubs can then communicate with e.g. the central computer using wireless transmission protocols more suitable for longer distances, such as Wi-Fi.

[0066] The evaluation unit 20 is furthermore configured as a controller being in communication with the actuation components of the valve 14, as indicated by the dashed line. Accordingly, the evaluation unit 20 may control an opening and/or closing of the valve and is furthermore preferably configured to set a particular flow rate. For example, when the determined status indicates a potential risk for the use of the gaseous mixture due to an inhomogeneous phase separation of the gaseous mixture, the evaluation unit 20 may control the valve 14 so as to close the valve 14 and may at the same time output an alert to the user via the outputted signal. By the same token, the remote device 30 may be configured to not only receive the information from the wireless communication module, but to also transmit input data for the evaluation unit 20, e.g. by comprising a transceiver, including control commands for the valve 14. Thereby, a medical professional or operator may ensure that only a safe to use gaseous mixture is administered to a patient.

[0067] A more detailed embodiment of the various optional features of the valve 14 including a gas monitoring device 10 is depicted in the perspective view of a valve 14 in Figure 6. The valve 14 is attached to a gas cylinder 12 (only part of which is shown) and is mechanically and fluidly connected via connector 32. The valve 14 comprises a valve body 34 which has a primary on-off valve 36, a flow-regulator valve 38, and an outlet connection 40. Accordingly, using the flow-regulator valve, a flow rate may be set ranging from 0 to 0,5 and from 1 to about 25 L per minute. The gaseous mixture is then administered to a patient via a patient interface, arranged downstream of the outlet connection 40, e.g. via tubing. The valve 14 also has a mechanical pressure gauge 21 to indicate the pressure in the gas cylinder 12, a filling port 44, and a medical quick connector 46.

[0068] Accordingly, the gas monitoring device 10 is coupled to the gas cylinder 12 by means of an attachment to the valve 14. Although said valve 14 may be configured as an analog valve, the gas monitoring device 10 may optionally also be coupled to a digital valve, wherein the gas monitoring device 10 is preferably integrated in the valve as an embedded feature.

[0069] It will be obvious for a person skilled in the art that these embodiments and items only depict examples of a plurality of possibilities. Hence, the embodiments shown here should not be understood to form a limitation of these features and configurations. Any possible combination and configuration of the described features can be chosen according to the scope of the invention.

[0070] List of reference numerals

[0070]

- 10 Gas monitoring device
- 12 Gas cylinder
- 14 Valve
- 16 First temperature sensor
- 18 Indicator
- 20 Evaluation unit
- 22 Button
- 24 Valve activation sensor
- 26 Accelerometer
- 28 Wireless communication module
- 30 Remote device
- 32 Connector
- 34 Valve body
- 36 Primary on-off valve
- 38 Flow-regulatorvalve
- 40 Outlet connection
- 42 Filling port
- 44 Medical quick connector
- A Gas phase
- B Liquid phase
- C Critical temperature

Claims

1. Gas monitoring device (10) for use with a gas cylinder(12), comprising:

a first temperature sensor(16) for measuring an ambient temperature of the gas cylinder (12),
an indicator (18) for indicating a status of a gaseous mixture comprised in the gas cylinder(12), and

an evaluation unit (20) in communication with the first temperature sensor (16) and the indicator (18) and configured to determine a status of the gaseous mixture based on the received ambient temperature measurement and to output a signal corresponding to said status to the indicator (18), when the gas monitoring device (10) is coupled to the gas cylinder(12).

2. Gas monitoring device (10) according to claim 1, wherein the evaluation unit(20) is further configured to determine the status of the gaseous mixture based on an evaluation of the ambient temperature measurement over a predefined time period and/or a comparison of the ambient temperature measurement with a predefined temperature range, and wherein the outputted signal comprises an alarm, when the determined status deviates from a predefined status stored in the evaluation unit (20).
3. Gas monitoring device (10) according to claim 1 or 2, wherein the determined status indicates the probability of the presence of a liquid phase within the gas cylinder (12), wherein the gaseous mixture preferably comprises nitrous oxide, oxygen, helium, ni-

trogen, nitric oxide, carbon monoxide, and/or carbon dioxide.

4. Gas monitoring device (10) according to any of the preceding claims, wherein the indicator (18) is configured to present the status by activating one or more LEDs, by providing a graphical representation or text message on a display, and/or by outputting an acoustic signal.

5. Gas monitoring device (10) according to claim 4, wherein the indicator(18) is configured to present the status on-demand by means of an actuation of a touch-sensitive object of the indicator (18), preferably a button (22) or mechanical switch, or upon actuation due to a coupling with a remote device (30) via NFC, Bluetooth, Zigbee, RFID, WLAN orWiFi.

6. Gas monitoring device (10) according to any of the preceding claims, further comprising a valve activation sensor(24) for a valve (14) of the gas cylinder(12) being in communication with the evaluation unit (20), wherein the evaluation unit (20) outputs the signal based on the determined status and the detected valve activity.

7. Gas monitoring device (10) according to claim 6, wherein the valve activation sensor (24) is configured as a flow sensor for detecting a flow of a gas through the valve (14) of the gas cylinder (12) or wherein the gas monitoring device (10) comprises a second temperature sensor for measuring a temperature of a valve body (34) of the gas cylinder (12) and being in communication with the evaluation unit (20), wherein the evaluation unit (20) determines an activation of the valve (14) based on the first temperature sensor measurement and the second temperature sensor measurement.

8. Gas monitoring device (10) according to claim 6 or 7, wherein the activation state of the valve (14) is factored into the temperature measurement of the first temperature sensor (16).

9. Gas monitoring device (10) according to any of the preceding claims, wherein the indicator (18) is configured to prompt a user to maintain the gas cylinder(12) within a predefined temperature range for a predefined time period and/or to invert the gas cylinder (12) for a predefined number of times based on the determined status.

10. Gas monitoring device (10) according to any of the preceding claims, further comprising an accelerometer (26) or motion sensor in communication with the evaluation unit (20), wherein the evaluation unit (20) is configured to update the determined status based on a received measurement of said accelerometer

(26) or motion sensor.

11. Gas monitoring device (10) according to any of the preceding claims, further comprising a wireless communication module (28) in communication with the evaluation unit (20), wherein the wireless communication module (28) is configured to transmit the output signal to a remote device (30), preferably a remote monitor and/or monitoring system, preferably via Bluetooth, Bluetooth Low Energy, Zigbee, RFID, WLAN, and/or WiFi. 5 10
12. Gas monitoring device (10) according to any of the preceding claims, configured as a stand-alone unit comprising an electrical energy storage medium and/or comprising an electrical coupling. 15
13. Valve (14) for a gas cylinder (12), comprising a gas monitoring device (10) according to any of the preceding claims, wherein the gas monitoring device (10) is preferably integrated in the valve. 20
14. Valve (14) according to claim 13, further comprising a pressure sensor in communication with the evaluation unit (20), wherein the evaluation unit (20) is configured to determine the status based on the received ambient temperature measurement and the detected pressure of the gaseous mixture in the gas cylinder (12). 25 30
15. Valve (14) according to claim 13 or 14, wherein the evaluation unit (20) is in communication with or is configured as a control unit of the valve (14), wherein the control unit is configured to control the valve actuation based on the determined status. 35

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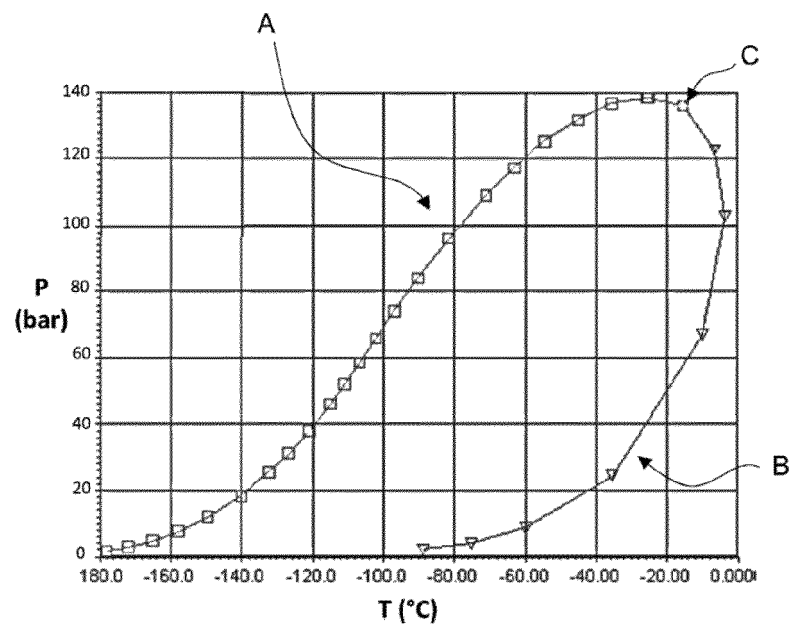


Fig. 1

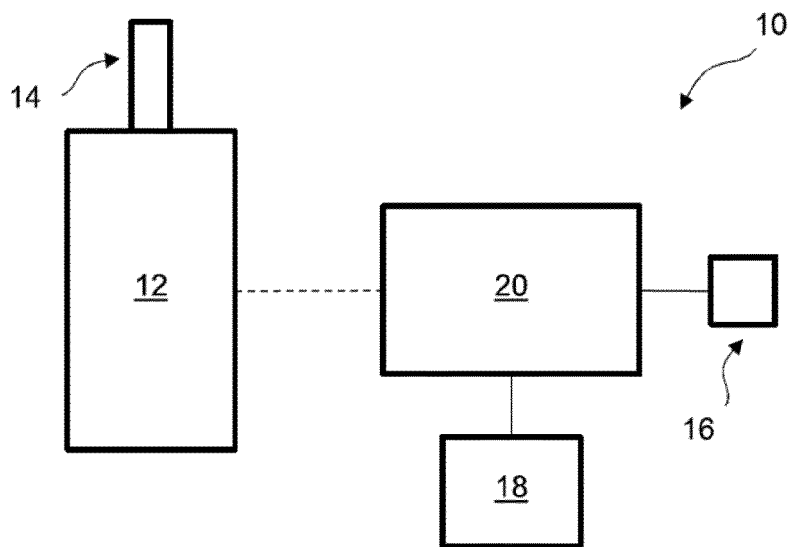


Fig. 2

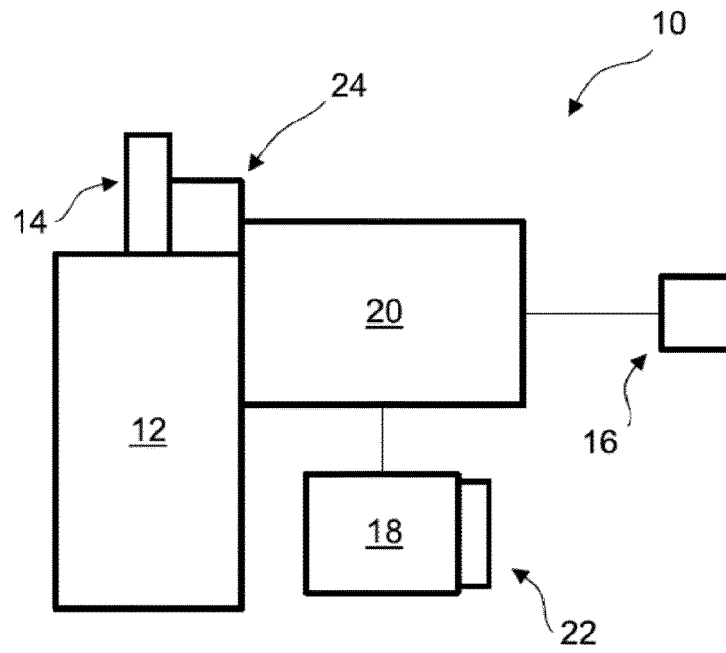


Fig. 3

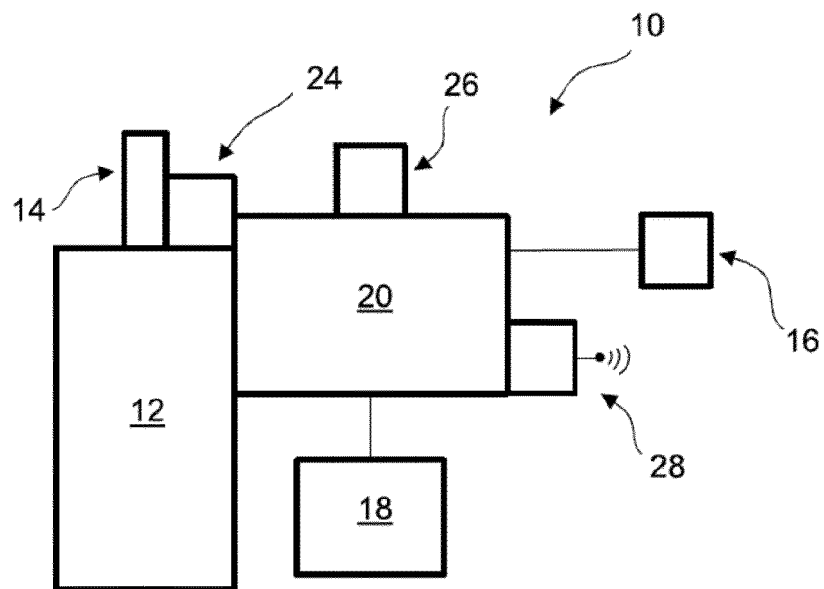


Fig. 4

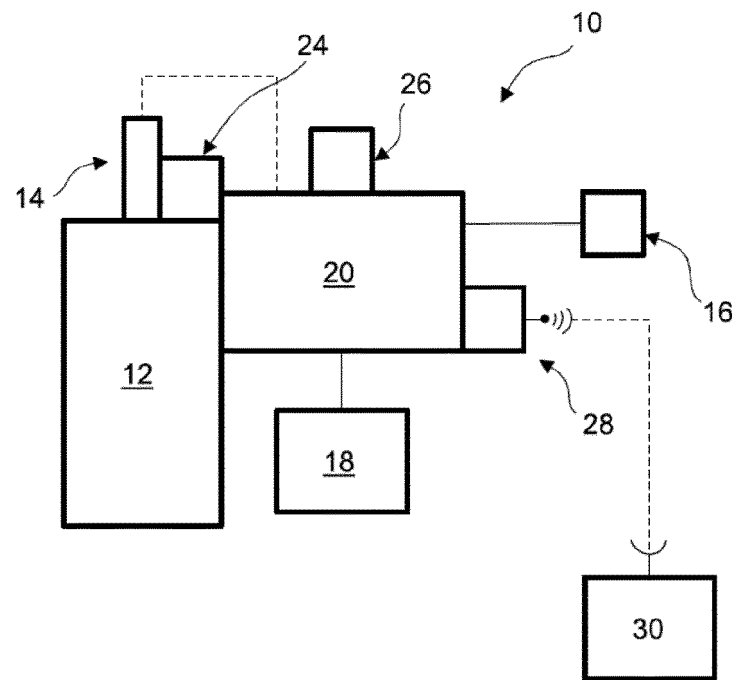


Fig. 5

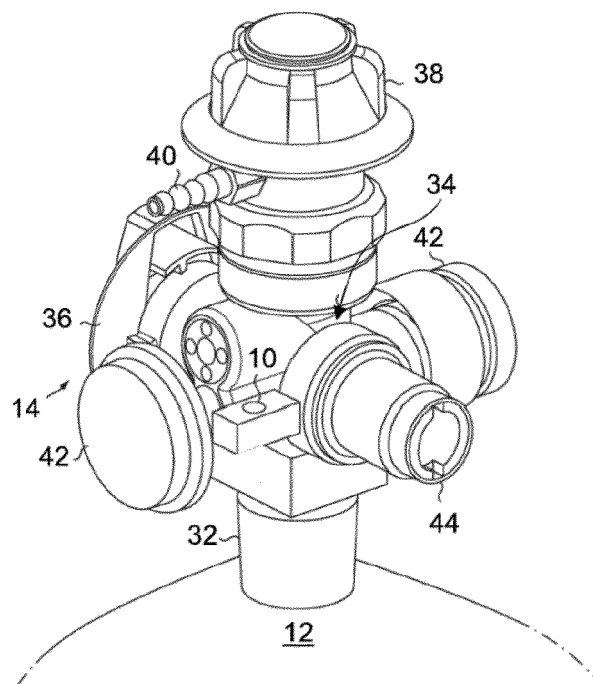


Fig. 6



EUROPEAN SEARCH REPORT

Application Number
EP 19 02 0330

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			F17C
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 8 November 2019	Examiner Papagiannis, Michail
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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