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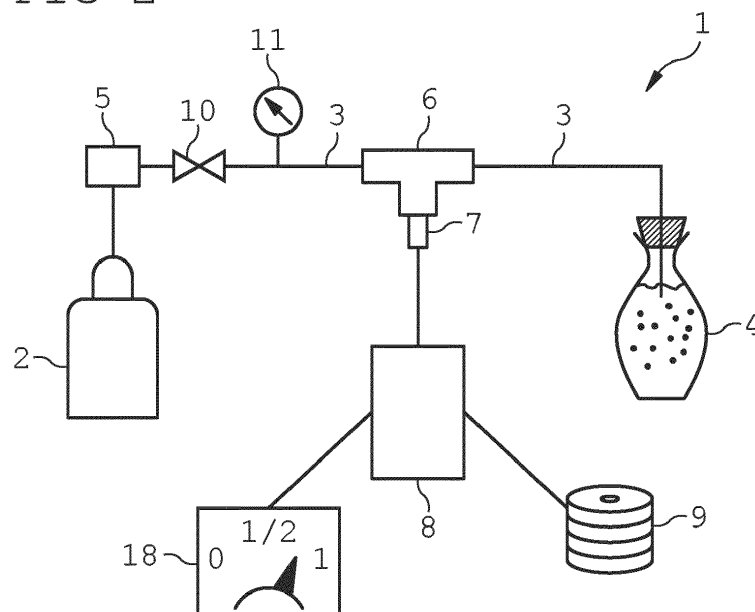
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(54) **METHOD AND DEVICE FOR DETERMINING A FILLING LEVEL OF A GAS BOTTLE**

(57) In a method for determining the cylinder filling level of a gas bottle (2) which is filled with a quantity of gas with a preset gas pressure, a change in a temperature of the withdrawal quantity of the gas in the gas extraction line (3) during a withdrawal operation is detected by a temperature sensor (7) in or at a gas extraction line (3). On the basis of the determined temperature change, the withdrawal quantity of gas that is withdrawn from the gas bottle (2) during the withdrawal operation is determined. A residual quantity of the gas that remains in the gas bottle (2) after the withdrawal operation is determined as the difference between the initial quantity of gas in the

gas bottle (2) before the withdrawal operation, and the determined withdrawal quantity of gas that is withdrawn during the withdrawal operation. A device (1) for determining a filling level of a gas within a gas bottle (2), which is connected via a valve device (5) to a gas extraction line (3), comprises a temperature sensor (7) that is arranged in or at the gas extraction line (3). With the temperature sensor (7) a change in a temperature in the gas extraction line (3) can be detected during a withdrawal operation of a withdrawal quantity of gas from the gas bottle (2) .

FIG 2



Description

Technical Field

[0001] The invention relates to a method for determining the filling level of a gas bottle which is filled with a quantity of gas with a preset gas pressure.

Background of the invention

[0002] Numerous fields of applications are known in which gases are used. In gas heating systems in buildings, a heating gas is usually distributed via a gas pipe from a central heating gas supply system to the individual heating systems, where the heating gas is consumed to create heat which rises the temperature of the building. In large industrial plants, where process gases are used within a production process, the process gas is often distributed from a central gas supply facility via gas pipelines to the respective points of use within the industrial plant. The respective consumed quantities of the heating gas or of the process gas can be measured with suitable measuring devices as well as monitored and controlled with suitable control devices.

[0003] There are also known applications in which the gas is provided in gas bottles and stored on site in order to be removed from the gas bottles and consumed on demand. Such gas bottles are usually filled with gas in a central gas supply facility. Subsequently, the filled gas bottles can be transported to the respective place of use, stored there and used for the withdrawal of the gas. The use of gas bottles is particularly advantageous in the case of low or irregular consumption of gas quantities or in case of the consumption of the gas from the gas bottle at different places of consumption. For example, a hot water supply or a heating system in a motorhome can be operated with a gas bottle that is filled with a suitable gas and carried with the motorhome. In a gas grill, the fuel gas required to operate the gas grill is taken from a gas bottle that can be connected to the gas grill. In a camping gas cooker, the required fuel gas is taken from a replaceable and reusable fuel gas cartridge. In a drinking water bubbler, carbonated drinking water is produced from tap water by adding a quantity of pressurized carbon dioxide to the tap water, which is taken from a reusable and replaceable gas cartridge. From now on, the term gas bottle is meant to cover all containers in which gas can be stored at an excess pressure, e.g. gas cartridges, gas cylinders or gas tanks.

[0004] In many cases it is desirable, especially in the case of irregular withdrawal of the gas from the gas bottle, that the current filling level of the gas bottle is determined and can be used to indicate an imminent emptying and therefore to notify a necessary replacement of the gas bottle at an early stage. In practice, several methods are known for such a task. However, in many cases such methods require considerable effort and cost-intensive measuring equipment.

[0005] A comparatively reliable detection of the filling level of a gas bottle is possible with the aid of gas flow sensors which are arranged in or along a gas extraction line. A gas quantity that is withdrawn from the gas bottle during an extraction process and flows out of the gas bottle through the gas extraction line can be measured with such gas flow sensors. However, the use of gas flow sensors requires expensive and intricate measurement technology.

[0006] With a pressure measuring device, for example with a commercially available manometer, the gas pressure in the gas bottle can be measured and the filling level of the gas bottle can be determined on the basis of the measured gas pressure. Particularly in the case of gas bottles filled with a rather small gas quantity, which is the case with e.g. gas cartridges for drinking water bubblers, the respective gas pressure does not correspond with the remaining quantity of gas within the gas bottle in a reliable manner that allows for a meaningful indication of the filling level. However, for many applications the pressure of the gas quantity that is withdrawn from the gas bottle is reduced by a pressure reduction device or a pressure regulator before forwarding the withdrawn gas quantity through the gas extraction line. A meaningful measurement of the gas pressure in the gas bottle must then be performed before the gas pressure is reduced in such a pressure reduction device. Furthermore, in many cases a significant drop of the gas pressure only occurs when the gas bottle is almost completely empty. Thus, a continuous monitoring of the filling level of a gas bottle as well as a timely notification of an impending emptying of the gas bottle are not feasible with such manometers.

[0007] By withdrawing a quantity of gas from the gas bottle, the weight of the gas bottle is reduced. The weight of both a completely filled gas bottle and of a completely emptied gas bottle can be measured in advance. By means of a weight measurement of the gas bottle, the residual amount of gas remaining in the gas bottle can be determined. Such a weight measurement can be performed continuously or at intervals, or only in case of a user request. The weight of the gas bottle must be measured with a suitable weighing device. During the weighing process, the gas bottle should be solely in contact with the weighing device, thus avoiding any linkage to or interference from the environment, which is impractical for many applications.

[0008] It is also known that the filling level of the gas bottle can be measured with filling level strips that can be attached to the outside of the gas bottle. However, such filling level strips are usually inaccurate and require a user to be able to see the filling level strips that is attached to the gas bottle during use or at least during a level check of the gas bottle, and to read an indication of the filling level strip. An automated recording and evaluation of the filling level strips is not possible.

[0009] Accordingly, there is a need for providing for a method for determining the filling level of a gas bottle in

such a way that a reliable detection and notification of the filling level of the gas bottle is possible that only requires simple and cost-effective means.

Summary of the invention

[0010] The present invention relates to a method in which a temperature sensor detects a change in temperature in the gas extraction line during an withdrawal process of a withdrawal quantity of the gas from the gas bottle through the gas extraction line, wherein the withdrawal quantity of the gas withdrawn from the gas bottle during the withdrawal operation is determined on the basis of the detected temperature change, and wherein a residual gas quantity remaining in the gas bottle after the withdrawal operation is determined as the difference between an initial gas quantity that is present in the gas bottle before the withdrawal operation and the determined withdrawal quantity of the gas during the withdrawal operation. Usually the pressure of the gas that is withdrawn is reduced during the withdrawal operation of the gas from the gas bottle, which results in a reduced temperature of the gas that streams out of the gas bottle. If the gas in the gas bottle is stored in a liquid state and changes to the gaseous state during withdrawal from the gas bottle, the amount of energy required for the phase transition to the gaseous state is at least partially extracted from the thermal energy of the gas, so that the temperature of the withdrawal quantity of gas is also reduced due to the evaporation cooling. It is also possible to keep the gas bottle at a preset temperature level during the withdrawal operation, whereby the preset temperature level differs from the ambient temperature and in particular from the temperature of the gas extraction line connected to the gas bottle, so that even without evaporation of the withdrawal quantity of the withdrawn gas flowing out during a withdrawal operation and without a significant pressure reduction of the outflowing withdrawal quantity of the gas, the withdrawal quantity of gas at the preset temperature level causes a temperature change within the gas extraction line which can be detected and used to determine the withdrawal quantity of gas that is withdrawn during the withdrawal operation.

[0011] It is regarded as an essential aspect of the present invention that the temperature change that occurs in the gas extraction line during a withdrawal operation can be measured and recorded in a simple manner, and can be further used to determine the withdrawal quantity of gas. In case that the initial quantity of gas stored in the gas bottle is known or previously determined, the residual quantity of gas remaining in the gas bottle and thus the filling level of the gas bottle can be evaluated by subtracting the determined withdrawal quantity of the gas from the initial quantity of gas that is stored in the gas bottle before the withdrawal operation. A temperature change in the gas extraction line can be reliably detected with temperature sensors that are commercially available at reasonable low costs.

[0012] The duration of the temperature change can be used to determine the duration of the withdrawal operation and thus, in combination with known flow conditions during the withdrawal operation, the quantity of gas that is withdrawn during the withdrawal operation. It has been found out that for many applications it is often possible to determine the withdrawal quantity of gas that is withdrawn during a withdrawal operation with little efforts, but with sufficient accuracy. As long as the initial quantity of the gas stored in the gas bottle is known and the withdrawal quantity of the gas is recorded during each successive withdrawal operation, the filling level of the gas bottle can be determined over the entire life cycle of the gas bottle and can be displayed or automatically recorded and evaluated, if required.

[0013] For example, in a drinking water bubbler a quantity of carbon dioxide gas that is withdrawn from a connected gas cartridge is fed into a water bottle filled with tap water, thereby producing sparkling drinking water. The withdrawal quantity of carbon dioxide gas that is withdrawn from the pressurized gas cartridge and fed into the water bottle during a withdrawal operation can be at least approximately estimated by measuring the cooling the gas extraction line that connects the gas cartridge with the water bottle. The cooling or in general a temperature change can be detected with help of a temperature sensor that is located in or at the gas extraction line. On the basis of a known cross-sectional area of the gas extraction line and of a pressure difference assumed to be known during the withdrawal operation, the withdrawal quantity of the carbon dioxide gas that flows out of the gas cartridge during the withdrawal operation can be calculated and thus estimated by determining the duration of the withdrawal operation that causes the temperature change.

[0014] According to an advantageous embodiment of the invention, a starting time related to the beginning of the withdrawal operation is determined by the temperature sensor as the time at which a temperature decrease begins, and an end time of the withdrawal operation of the gas is determined by the temperature sensor as the time at which a temperature decrease ends or at which a subsequent temperature increase begins. The beginning of the temperature decrease can be determined as the instant of time at which the temperature measured by the temperature sensor deviates or decreases more than a predetermined decrease change threshold value, or falls below a predetermined decrease temperature value under known ambient conditions. As soon as the withdrawal operation is finished, the temperature of the gas extraction line rises again, which is usually continuously and increasingly cooled down during the withdrawal operation. A subsequent temperature rise of the gas extraction line can be related with the end time of the withdrawal operation. Thus, the end time related to the end of the withdrawal operation is determined e.g. as the first time at which a temperature rise is detected after the cooling during the withdrawal operation. If deemed ap-

propriate, the end time related to the end of the withdrawal operation may be determined as the instant of time at which a changing temperature rises above an increase change threshold value, which helps to exclude the unwanted possibility of unavoidable small temperature variations affecting the evaluation of the measured values of the end time.

[0015] In accordance with a particularly advantageous embodiment of the invention, in order to determine the duration of the withdrawal operation with the temperature sensor as reliably as possible and regardless of the respective ambient conditions, a chronological temperature profile of the temperature in the gas extraction line is recorded, a time derivative of the recorded temperature profile is determined, and a starting time related to the beginning and an end time related to the end of the withdrawal operation of the gas are determined as the instant of time at which an amount of the time derivative of the temperature profile is larger than a predetermined derivative threshold value. At the beginning of the withdrawal operation, the temperature in the gas extraction line drops, so that a time derivative of the temperature profile is negative i.e. less than zero. At the end of the withdrawal operation, the temperature in the gas extraction line rises again, so that the time derivative of the temperature profile is positive i.e. greater than zero. The derivation threshold value can be set to the same value for the starting time and the end time of the withdrawal operation. It is also possible to specify a first derivation threshold value for the beginning of the withdrawal operation and a second, different and usually smaller derivation threshold value for the end of the withdrawal operation. For example, with the aid of evaluation electronics that can be manufactured or is already available at low costs, the temperature profile and its time derivative can be recorded and determined by a change of the time derivative with sufficient precision to reliably determine the starting time and the end time of a withdrawal operation. For most applications several successive or shortly interrupted withdrawal operations can also be recorded, resolved and reliably evaluated with regard to the determination of the filling level of the gas bottle.

[0016] For many applications a sufficiently accurate determination of the filling level of the gas bottle can optionally be carried out by modeling and estimating the withdrawal quantity of gas as a function of a pressure difference between the gas pressure within the gas bottle or after flowing through a pressure reducing device and an ambient pressure and as a function of a cross-sectional area of the gas extraction line through which the withdrawn gas can flow. The cross-sectional area of the gas extraction line can be determined in advance or assumed to be known. In many areas of application, the pressure difference between the gas pressure in the gas bottle on the one hand and the ambient pressure prevailing in the gas extraction line when withdrawing the withdrawal quantity of gas on the other hand does not change at all or only changes to such a little extent that a change

in the pressure difference can be neglected. Furthermore, on the basis of a known cross-sectional area of the gas extraction line that is available for the withdrawal of gas from the gas bottle and at a fixed pressure difference assumed to be known, a flow rate of the gas flowing out of the gas bottle through the gas extraction line during the withdrawal operation can be determined and, in conjunction with the duration of the withdrawal operation recorded by the temperature sensor, the withdrawal quantity of gas can be determined without the need for further measurements.

[0017] According to an advantageous aspect of the invention a lookup table for a reference quantity of gas that is withdrawn through the gas extraction line in a given time unit can be recorded by means of previously performed measurements as a function of the pressure difference between the gas pressure in the gas bottle and the ambient pressure and as a function of the cross-sectional area of the gas extraction line through which the gas can be withdrawn, whereby on the basis of the measured lookup table the withdrawal quantity of gas is determined that is withdrawn from the gas bottle at a predetermined pressure difference and for a predetermined cross-sectional area of the gas extraction line during a withdrawal operation. With the help of suitably predetermined lookup tables, various aspects can be taken into account when determining the withdrawal quantity of gas that is withdrawn during individual withdrawal operations, and appropriate corrections can be made. For example, it can be taken into account that in the case of a decreasing residual quantity of gas which is stored in the gas bottle at the respective beginning of subsequent withdrawal operations, the gas pressure of the gas remaining in the gas bottle also decreases and thus the pressure difference during subsequent withdrawal operations becomes somewhat smaller. However, in some applications and in particular with drinking water bubblers, there is no proportional decrease in the gas pressure with respect to the decreasing residual amount of gas in the gas bottle. A lookup table can also be used to correct for non-linear changes of the gas pressure during the service life of the gas bottle. The values stored in the lookup table can be measured by reference measurements performed in advance, or can be calculated on the basis of a suitable model that is adapted to previously measured measurement values.

[0018] Furthermore, it is also possible to record a change in the pressure difference due to an increase in pressure in the gas extraction line during a withdrawal operation and to take this into account for determining the duration of the withdrawal operation with the help of a suitable lookup table. For example, the gas pressure in the water bottle and thus also the pressure in the gas extraction line that connects the water bottle with the gas cartridge of a drinking water bubbler increases continuously during the withdrawal operation, so that the pressure difference continuously changes during the withdrawal operation. With the help of a suitably adapted

model or with a predetermined lookup table, it can be taken into account that at the beginning of a withdrawal operation a larger quantity of gas per time unit flows out of the gas bottle due to an initially large pressure difference, while towards the end of the withdrawal operation the pressure difference decreases and only a smaller quantity of gas per time unit flows out of the gas bottle.

[0019] In yet another embodiment of the invention and in order to enable a reliable determination of the filling level of the gas bottle even in case of difficult or changing ambient conditions, the pressure difference between the gas pressure of the gas quantity that is withdrawn from the gas bottle and the ambient pressure that prevails in the gas extraction line is detected by a pressure difference measuring device and taken into account for determining the withdrawal quantity of gas that is withdrawn from the gas bottle during the withdrawal operation. In case that a pressure reducing device or a pressure regulator is used for reducing the gas pressure of the withdrawn gas quantity to a gas pressure that is adapted to the further use of the withdrawn gas quantity, the gas pressure of the gas quantity that is withdrawn is preset and precisely known without need for an additional pressure measuring device. Many pressure regulating devices already include a pressure measuring device in order to be able to control the gas pressure and to reduce the gas pressure to a preset value. Such a pressure measuring device can be used for measuring the pressure difference.

[0020] In practice, various methods and commercially available pressure measuring devices as well as pressure difference measuring devices are known which can be used to measure pressure differences at the beginning of a withdrawal process or during the duration of the withdrawal operation. An actually measured pressure difference may replace an assumed or estimated constant pressure difference or a pressure difference that is determined in advance and stored in suitable lookup tables. Thus, the filling level of the gas bottle can be determined in a more precise manner by actually measuring the relevant pressure difference than by assuming fixed estimation values for the pressure difference.

[0021] The invention also relates to a device for determining the filling level of a gas bottle which is filled with a pressurized gas quantity, whereby a gas extraction line is connected to the gas bottle. The gas pressure in the gas bottle can be preset during the filling of the gas bottle with the gas. It is also possible to continuously preset the gas pressure at the beginning of each withdrawal operation by means of a suitable pressure generating device, and thus the gas pressure can be maintained at a constant level or adjusted depending on specific requirements during the service life of the gas bottle.

[0022] Manometers are known from practical experience that allow for the measurement of a gas pressure within the gas bottle. If an initial gas pressure is preset at the time of the filling of the gas bottle and subsequently decreases in a known way with each withdrawal operation,

the residual amount of gas that remains in the gas bottle can be determined on the basis of the respective gas pressure that is measured with the manometer. This method of determining the filling level of the gas bottle requires a sufficiently large change in the gas pressure within the gas bottle during the service life. If the gas pressure does not change significantly over the time of several withdrawal operations, or if the gas pressure changes independently of the withdrawal quantity of gas that is withdrawn during subsequent withdrawal operations, e.g. due to changing ambient conditions, such a measuring principle is not useful and will not give reliable results. Furthermore, an appropriate measuring device that is required for a reliable detection and display of the gas pressure is costly.

[0023] It is also known from experience that a flow measuring device can be used for determining the withdrawal quantity of the gas that flows through the gas extraction line during a withdrawal operation. However, the use of a flow measuring device is considered elaborate and expensive.

[0024] Filling level measuring strips, which can be attached to the outside of a gas bottle, are usually inaccurate, and thus it is not possible to determine the filling level of the gas bottle with the desired precision. Furthermore, such filling level measuring strips do not allow for automated recording and further evaluation of the filling level of the gas bottle. It is also regarded as a disadvantage of such filling level measuring strips that they must be visible to a person that wants to read the filling level, so that its use e.g. in a non-transparent housing around the gas bottle is not practical.

[0025] Thus, there is a need for a device for determining the filling level of a gas bottle which is filled with a quantity of pressurized gas in such a way that a filling level of the gas bottle can be determined with small efforts and at low cost, but as reliably as possible.

[0026] The present invention also relates to a device that comprises a gas extraction line with a temperature sensor being arranged in or at the gas extraction line in such a way that a change in a temperature in the gas extraction line can be detected during an withdrawal operation of a withdrawal quantity of the gas from the gas bottle, and whereby the device also comprises an evaluation device within which the withdrawal quantity of the gas withdrawn from the gas bottle during the withdrawal operation can be determined on the basis of the temperature values measured by the temperature sensor, in order to be able to determine a residual quantity of gas remaining in the gas bottle after the withdrawal operation as a difference between an initial quantity of gas stored in the gas bottle before the withdrawal operation and the determined withdrawal quantity of the gas that is withdrawn during the withdrawal operation. With the temperature sensor, the beginning and end of a withdrawal operation can be detected by measuring a temperature change in the gas extraction line during and after the withdrawal operation. For many applications the relevant

changes of the temperature amount to several degrees Celsius within a period of seconds to minutes. A temperature measurement of a change of temperature in the gas extraction line during a withdrawal operation and afterwards, which is sufficiently accurate to determine the filling level of the gas bottle, is possible with temperature sensors of very simple design. A suitable temperature sensor is commercially available at low cost. By determining the duration of the withdrawal operation by means of the temperature sensor, a simple and inexpensive evaluation device can be provided to determine or estimate the withdrawal quantity of gas that is withdrawn during the withdrawal operation. Starting with the initial quantity of gas stored in the gas bottle it is possible to evaluate and display the resulting filling level of the gas bottle after each withdrawal operation. By knowing of or assuming a pressure difference between the gas pressure within the gas bottle and of an ambient pressure within the gas extraction line, and by knowing of or assuming a cross-sectional area of the gas extraction line, an average flow rate of gas during the duration of the withdrawal operation can be predetermined. Then the withdrawal quantity of the gas that is withdrawn during a withdrawal operation can be estimated as the product of the average flow rate multiplied with the duration of the withdrawal operation that is determined on the basis of the measurements of the temperature sensor. The respective current filling level of the gas bottle is calculated as the difference between the initial quantity of gas filled into the gas bottle and the respective withdrawal quantities of the gas for all of the withdrawal operations that have been performed up to now.

[0027] The evaluation device can also be used for automated evaluation and further processing of the filling level of the gas bottle and of the individual withdrawal quantities of gas that are withdrawn during each withdrawal operation. This enables the device to activate a separate display if the filling level of the gas bottle falls below a preset minimum filling level, which indicates that the gas bottle is about to be drained. The time course of the filling level over the service life of the gas bottle can also be taken into account and, for example, a future instant in time can be displayed at which, assuming a uniform and constant use of the gas bottle, complete emptying and therefore necessary replacement of the gas bottle should be expected.

[0028] The temperature sensor can be located inside the gas extraction line or within a wall of the gas extraction line. It is also possible to arrange the temperature sensor at the outside of a thin-walled gas extraction line made of a material with a sufficiently high thermal conductivity, and to record the change of temperature of the wall of the gas extraction line. By this, existing systems with gas bottles and gas extraction lines can also be retrofitted without major conversions with a device for determination of the filling level according to this invention.

[0029] According to an advantageous aspect of the invention, the temperature sensor is arranged in a T-con-

nector in the gas extraction line. The T-connector can be arranged in a section of the gas extraction line preferably close to the gas bottle in such a way that the gas extraction line runs in a straight line through the T-connector, resulting in an undisturbed flow of the gas without any noticeable interference of the flow conditions along the gas extraction line. The temperature sensor can be arranged in the section of the T-connector that protrudes perpendicularly to the straight line of the gas extraction line. Preferably, this section is sealed gas-tight. The necessary effort for inserting the temperature sensor into a commercially available T-connector and for the subsequent arrangement of the T-connector within the gas extraction line is low. The temperature sensor can be arranged in the T-connector in such a way that the gas flowing through the gas extraction line flows around the temperature sensor during a withdrawal operation, thus enabling a direct and precise measurement of the temperature of the gas that flows through the gas extraction line.

[0030] Various measurement methods are conceivable, which can be used to measure the temperature and with can be implemented by using the temperature sensor. Optionally, the temperature sensor is a thermistor. For many applications and environmental conditions, a thermistor is a suitable temperature sensor that is commercially available at a reasonable price and can be easily connected to an evaluation device for automated evaluation of the temperature measurements. A thermistor may have a measuring range as well as accuracy and response characteristics that are advantageous for sensing the temperature or a change in temperature of the gas flowing through the gas extraction line during a withdrawal operation. Furthermore, a thermistor has a very low inertia and therefore a very fast response.

[0031] In another embodiment of the invention, the evaluation device is connected to a storage device in which a lookup table of a reference flow rate of gas flowing out of the gas bottle. The lookup table of the reference flow rate can be compiled as a function of a gas flow during a predetermined unit of time through the gas extraction line at a predetermined differential pressure between the gas pressure and an ambient pressure. By using a previously determined lookup table stored in a storage device to determine the quantity of gas withdrawn during a withdrawal operation, it is easily possible to improve the accuracy of determining the cylinder filling level without the requirement of additional measuring devices. Thus, for example, a change in the gas pressure within the gas bottle as a function of a decreasing residual quantity of gas remaining in the gas bottle after successive withdrawal operations, a change in the pressure difference during the duration of a withdrawal process or a correction in the case of non-linear changes in the pressure difference during the service life of the gas bottle can be taken into account by referring to a lookup table that has been determined and compiled in advance in a suitable manner.

[0032] In order to enhance the accuracy of the determination of the filling level, the device may optionally comprise a pressure measuring device for recording a gas pressure in the gas bottle or of the gas quantity that is withdrawn from the gas bottle. For many applications a pressure reducing device is attached to the gas cartridge and the gas pressure of the gas quantity that is withdrawn during a withdrawal operation is reduced to a preset gas pressure before forwarding the withdrawn gas quantity through the gas extraction line. If a pressure regulator is used, many common pressure regulators comprise a pressure measuring device that can be used for recording the already reduced gas pressure that is withdrawn from the gas bottle. Pressure measuring devices that are suitable for many areas of application and for many different gas bottles are commercially available at a reasonable price. The pressure measuring device can be easily mounted or arranged in or on the gas bottle in such a way that the gas pressure in the gas bottle or a pressure difference between the gas pressure in the gas bottle and the ambient pressure prevailing in the gas extraction line during a withdrawal operation can be monitored, recorded and considered for the evaluation of the filling level. Knowing the duration of the withdrawal operation and the cross-sectional area of the gas extraction line, a measurement of the pressure difference during a withdrawal operation can be used to calculate the withdrawal quantity of gas flowing out during the withdrawal operation.

[0033] According to an embodiment of the invention the device comprises a valve that controls the withdrawal operation. Such a valve may allow for manual control of successive withdrawal operations. However, it is also possible to make use of fully automated valves that can be automatically controlled e.g. by computers or control loops within a large plant.

Brief description of the drawings

[0034] The present invention will be more fully understood, and further features will become apparent, when reference is made to the following detailed description and the accompanying drawings. The drawings are merely representative and are not intended to limit the scope of the claims. In fact, those of ordinary skill in the art may appreciate upon reading the following specification and viewing the present drawings that various modifications and variations can be made thereto without deviating from the innovative concepts of the invention. Like parts depicted in the drawings are referred to by the same reference numerals.

Figure 1 illustrates a schematic representation of a device designed in accordance with the invention for determining the filling level of a gas bottle, from which a pressurized gas previously stored in the gas bottle can be withdrawn via a gas extraction line,

Figure 2 illustrates a schematic representation of another embodiment of a device, whereby the device also comprises a storage device, a valve and a pressure measuring device,

Figure 3 illustrates a schematic representation of a time-dependent temperature curve measured by a temperature sensor arranged in the gas extraction line, whereby the temperature curve extends over two withdrawal operations,

Figure 4 illustrates a schematic representation of a time derivative of the temperature curve shown in Figure 3, and

Figure 5 illustrates the accumulated quantity of gas that has been withdrawn from the gas bottle during numerous withdrawal operations, whereby a comparison is shown between the results determined with the device according to the invention and the results that have been actually measured by weighing the gas bottle with the remaining gas quantity that is stored in the gas bottle.

Detailed description of the invention

[0035] By way of example, the invention is illustrated for a drinking water bubbler. Figure 1 depicts a device 1 for determining the filling level of a gas cartridge 2, whereby the device 1 has a gas extraction line 3 which connects the gas cartridge 2 with a drinking bottle 4 which is filled with tap water. In the gas cartridge 2, namely a carbon dioxide cartridge, a quantity of a gas is stored, namely pressurized carbon dioxide. The pressure of the carbon dioxide within the gas cartridge 2 is reduced to an operation pressure by use of a pressure regulator 5. By actuating the pressure regulator 5 or in case that the pressure within the drinking bottle 4 falls below the reduced carbon dioxide pressure, a small proportion of the gas stored in the gas cartridge 2 called a withdrawal quantity of gas is withdrawn from and flows from the gas cartridge 2 through the gas withdrawal line 3 into the drinking bottle 4. The withdrawal quantity of the carbon dioxide gas reacts with the tap water in the drinking bottle 4, resulting in carbonated drinking water.

[0036] A T-connector 6 is arranged in the gas extraction line 3 in such a way that the gas extraction line 3 runs along a straight line through two connection openings of the T-connector 6. A temperature sensor 7 is arranged in a third connection opening of the T-connector 6. With the temperature sensor 7 a temperature can be detected within the T-connector 6 and thus within the gas extraction line 3. The temperature sensor 7 can be designed as a thermistor. The temperature sensor 7 is connected to an evaluation device 8 in order to transmit the measurement signal of the temperature sensor 7 to the evaluation device 8, whereby the signal transmission can be wired or wireless, as illustrated in Figure 1.

[0037] The temperature sensor 7 detects the temperature in the gas extraction line 3 during a withdrawal operation of a withdrawal quantity of gas from the gas cartridge 2. Starting from an ambient temperature, the temperature drops after the start of extraction during the withdrawal operation, since the pressurized gas flowing out of the gas cartridge 2 expands and cools down in the gas extraction line 3. After the withdrawal of the withdrawal quantity of gas has been completed, no further cooling occurs and the temperature in the gas extraction line 3 rises again until the temperature in the gas extraction line 3 returns to the ambient temperature.

[0038] Figure 2 illustrates another embodiment of the device 1 shown in Figure 1. The device 1 also comprises in addition to the embodiment of Figure 1 a storage device 9 connected to the evaluation device 8 for storing lookup tables with additional information about e.g. withdrawal operations that are performed at different conditions and circumstances. The device 1 also comprises a valve 10 for manual control of a withdrawal operation, and a pressure measuring device 11 that is arranged downstream of the valve 10 and allows for a measurement of the gas pressure of a gas quantity that is withdrawn from the gas cartridge 2.

[0039] Figure 3 shows an example of a chronological development of the temperature represented by a solid line 12 in the graph of Figure 3. The temperature was measured over two successive withdrawal operations with the temperature sensor 7 in the gas extraction line 3 shown in Figure 1. A first withdrawal operation 13 starts after about 5 seconds and lasts about 5 seconds. A second withdrawal operation 14 starts after about 45 seconds and also lasts about 5 seconds. The temperature in the gas extraction line 3 drops during the first withdrawal operation 13 from an ambient temperature of almost 23 °C to a reduced temperature of slightly more than 18 °C, before rising again. At the beginning of the second withdrawal operation 14, the temperature sensor 7 measures a temperature of about 21.5 °C, which drops down to about 17 °C by the end of the second withdrawal operation 14, and then rises again. The respective duration of the withdrawal operations 13, 14 can be determined on the basis of the measured chronological development of the temperature. The duration of a withdrawal operation 13, 14 can be determined, for example, as the duration between those instants in time at which a sharp drop in temperature begins and ends.

[0040] Figure 4 illustrates the chronological development of a time derivative dT/dt of the measured temperature curve shown in Figure 3, whereby the time derivative dT/dt is represented by a solid line 15. The instant of time of the respective start and the respective end of each withdrawal operation 13, 14, corresponds to the instant of time at which the time derivative 15 is significantly less than zero or significantly greater than zero. In the example case illustrated in Figures 2 and 3, the beginning of each withdrawal operation 13, 14 can be determined as the instant of time at which the time de-

ivative 15 of the temperature curve drops below a value of, for example, less than or equal to a derivation threshold value of -1 K/s that significantly differs from a temporally stable initial value of about 0 K/s. At the end of each withdrawal operation 13, 14, the corresponding instant of time can be determined at which the time derivative 15 of the temperature curve assumes a value of, for example, more than or equal to 1 K/s from a value less than zero. The amount of the respective derivation threshold value can be the same in both cases and can be 1 K/s, for example. It is also possible, for example, to specify a negative derivation threshold of less than -1 K/s for the start of a withdrawal operation 13, 14, while the end of a withdrawal operation 13, 14, is specified or determined for a positive derivation threshold of 0.5 K/s. The system then determines the derivation threshold for the start of a withdrawal operation 13, 14.

[0041] If the beginning and the end of a withdrawal operation 13, 14, and thus a duration of the withdrawal operations 13, 14 are known, the quantity of gas withdrawn from the gas cartridge 2 during this withdrawal operation 13, 14 can be determined in various ways. For example, a constant pressure difference can be assumed between the gas pressure of the gas stored in the gas cartridge 2 on the one hand and the pressure prevailing at the other end of the gas extraction line 3 in the drinking bottle 4 on the other hand. In combination with a cross sectional area of the gas extraction line 3, which is also assumed to be known, a flow rate and thus, for example, the quantity of gas flowing out of the gas cartridge 2 every second during a withdrawal operation 13, 14 can be estimated. Starting from the flow rate which can be assumed to be constant, the temperature sensor 7 can then be used to determine the start and end of the withdrawal operation 13, 14 or its duration. The withdrawal quantity of gas withdrawn during the withdrawal operation 13, 14 is then determined as the product of the flow rate multiplied by the determined duration of the withdrawal operation 13, 14.

[0042] In order to allow for a more precise determination of each withdrawal quantity of gas to record the increasing internal pressure in the drinking water bottle 4 during a single withdrawal operation 13, 14 by reference measurements previously performed as a function of the duration of the withdrawal operation 13, 14, and to take into account the variation of the pressure difference, which changes during the withdrawal operation 13, 14. On the one side the gas pressure in the gas cartridge 2 or after flowing through a pressure regulator might drop during the withdrawal operation 13, 14, and on the other side the internal pressure in the drinking water bottle 4 rises during the withdrawal operation 13, 14, which both affects the flow of the gas that is withdrawn from the gas cartridge 2 during the withdrawal operation 13, 14. If no pressure regulator 5 is used, it is also possible to take into account a decrease in the gas pressure of the gas stored in the gas cartridge 2 with increasing emptying of the gas cartridge 2. However, the gas pressure usually

does not decrease linearly as a function of the residual quantity of gas remaining in the gas cartridge 2. Measurements can be performed in advance to generate a lookup table of reference pressure values as a function of preset parameters and to store these reference values in the storage device 9, which is continuously connected or can be connected on demand to the evaluation device 8 by means of a wireless or wired connection for data transmission. The evaluation device 8 can then be used to determine the withdrawal quantity of gas that is withdrawn during a withdrawal operation 13, 14, taking into account the previously measured reference values stored in the lookup table within the storage device 9.

[0043] It is also possible to record and to consider the relevant pressure difference during a withdrawal operation 13, 14 between the gas pressure in the gas cartridge 2 or of the withdrawn gas quantity after a pressure regulator 5 on the one hand and the gas extraction line 3 on the other hand by means of additional pressure measuring devices. For this purpose, for example, the pressure measuring device 11 can be arranged at an outlet of the gas cartridge 2 or downstream after the pressure regulator 5 and, if applicable, after the valve 11, as shown in Figure 2. With such a pressure measuring device 11 any possible change of gas pressure of the gas stored in the gas cartridge 2 or withdrawn from the gas cartridge 2 can be measured and transmitted to the evaluation device 8. One or more pressure measuring devices can also be arranged at or in the drinking water bottle 4, or in other sections at or in the gas extraction line 3.

[0044] On the basis of a previously known or determined initial quantity of gas that is stored in the gas cartridge 2 at the beginning, a current filling level of the gas in the gas cartridge 2 can be evaluated by determining a withdrawal quantity of gas that is withdrawn during each withdrawal operation that is performed thereafter, and by calculating the residual gas quantity remaining in the gas cartridge 2 as the difference between the initial gas quantity and the accumulated withdrawal quantities of gas. By way of example, Figure 5 illustrates a chronological development of the total amount of gas that is withdrawn from the gas cartridge 2 over many successive withdrawal operations. In Figure 5, the accumulated amount of gas 16 that is determined by the invention-based method described above is compared to the accumulated amount of gas 17 determined by measurements with a weighting device that measures the gas quantity that remains in the gas cartridge 2 after each of the successive withdrawal operations, with the respective masses M in grams being represented for the total amounts 16 and 17 of gas over a time t in seconds representing the chronological development starting from an arbitrary starting value t of zero. It can be seen that by simply measuring the time development of the temperature in the gas extraction line 3 and by performing a suitable evaluation of these measured temperature values, the accumulated amount of gas 16 determined by method described above hardly deviates from the accumulated amount 17 measured with a

gas flow meter. A filling level of the gas cartridge 2 can be calculated as the difference between the previously specified or otherwise known gas quantity that is initially stored in the gas cartridge 2 and the total withdrawal quantity of gas that is determined by the method in accordance with the invention. The filling level can be calculated with the evaluation device 8 and, for example, displayed via a separate display device 18 shown in Figure 2, or made available for further evaluations performed with an external computing device not shown in the Figures.

Claims

1. Method for determining a filling level of a gas bottle (2) which is filled with a quantity of gas with a preset gas pressure, **characterized in that** a change in a temperature in a gas extraction line (3) is detected by a temperature sensor (7) during an withdrawal operation of a withdrawal quantity of the gas from the gas bottle (2) through the gas extraction line (3), **in that** the withdrawal quantity of the gas withdrawn from the gas bottle (2) during the withdrawal operation is determined on the basis of the detected temperature change, and **in that** a residual gas quantity remaining in the gas bottle (2) after the withdrawal operation is determined as the difference between an initial gas quantity that is present in the gas bottle (2) before the withdrawal operation and the determined withdrawal quantity of the gas during the withdrawal operation.
2. Method according to claim 1, **characterized in that** a starting time related to the beginning of the withdrawal operation is determined by the temperature sensor (7) as the time at which a temperature decrease begins and an end time of the withdrawal operation of the gas is determined by the temperature sensor (7) as the time at which a temperature decrease ends or at which a subsequent temperature increase begins.
3. Method according to claim 1 or claim 2, **characterized in that** a chronological temperature profile of a temperature in the gas extraction line (3) is recorded, **in that** a time derivative of the recorded temperature profile is determined, and **in that** a starting time related to the start and an end time related to the end of the withdrawal operation of the gas is determined as the instant of time at which an amount of the time derivative of the temperature profile is larger than a predetermined derivative threshold value.
4. Method according to one of the preceding claims, **characterized in that** the withdrawal quantity of gas that is withdrawn during the withdrawal operation is estimated as a function of a pressure difference be-

tween the gas pressure within the gas bottle or after flowing through a pressure reducing device and an ambient pressure and as a function of a cross-sectional area of the gas extraction line (3) through which the withdrawn gas can flow.

5. Method according to Claim 4, **characterized in that** a lookup table for a reference quantity of the gas that is withdrawn through the gas extraction line (3) in a predetermined unit of time can be recorded by means of previously performed measurements as a function of the pressure difference between the gas pressure in the gas bottle and the ambient pressure and as a function of the cross-sectional area of the gas extraction line (3) through which the gas can be withdrawn, and **in that** the quantity of gas that is withdrawn from the gas bottle (2) is determined on the basis of the measured lookup table at a predetermined pressure difference and for a predetermined cross-sectional area of the gas extraction line (3) during a withdrawal operation.
6. Method according to claim 4 or claim 5, **characterized in that** the pressure difference between the gas pressure of the gas quantity that is withdrawn from the gas bottle (2) and the ambient pressure is detected by a pressure measuring device (10) and taken into account for determining the withdrawal quantity of gas withdrawn from the gas bottle (2) through the gas extraction line (3) during the withdrawal operation.
7. Device (1) for determining a filling level of a gas bottle (2) which is filled with a quantity of pressurized gas, whereby the device (1) comprises a gas extraction line (3) that is connected to the gas bottle (2), **characterized in that** a temperature sensor (7) is arranged in or at the gas extraction line (3) in such a way that a change in a temperature in the gas extraction line (3) can be detected during an withdrawal operation of a withdrawal quantity of the gas from the gas bottle (2), and **in that** the device (1) also comprises an evaluation device (8) with which the withdrawal quantity of the gas withdrawn from the gas bottle (2) during the withdrawal operation can be determined on the basis of the temperature values measured by the temperature sensor (7), in order to be able to determine a residual quantity of gas remaining in the gas bottle (2) after the withdrawal operation as a difference between an initial quantity of gas stored in the gas bottle (2) before the withdrawal operation and the determined withdrawal quantity of the gas that is withdrawn during the withdrawal operation.
8. Device (1) according to claim 7, **characterized in that** the temperature sensor (7) is arranged in a T-connector (6) in the gas extraction line (3).

9. Device (1) according to claim 7 or claim 8, **characterized in that** the temperature sensor (7) is a thermistor.

10. Device (1) according to one of the claims 7 to 9, **characterized in that** the evaluation device (8) is connected in a data-transmitting manner to a storage device (9) in which a lookup table for a reference quantity of gas flowing out in a predetermined unit of time through the gas extraction line (3) can be stored in a retrievable manner at a predetermined differential pressure between the gas pressure and an ambient pressure.
11. Device (1) according to one of the claims 7 to 10, **characterized in that** the device (1) comprises a pressure measuring device (10) for detecting a gas pressure in the gas bottle (2) or of the gas quantity that is withdrawn from the gas bottle (2).
12. Device (1) according to one of the claims 7 to 11, **characterized in that** the device (1) comprises a valve (10) that controls the withdrawal operation.

FIG 1

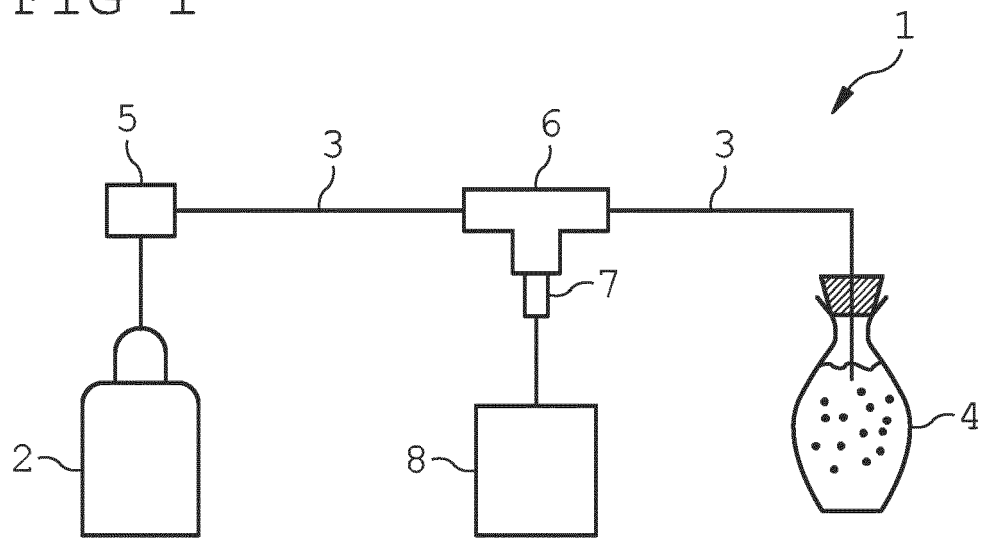


FIG 2

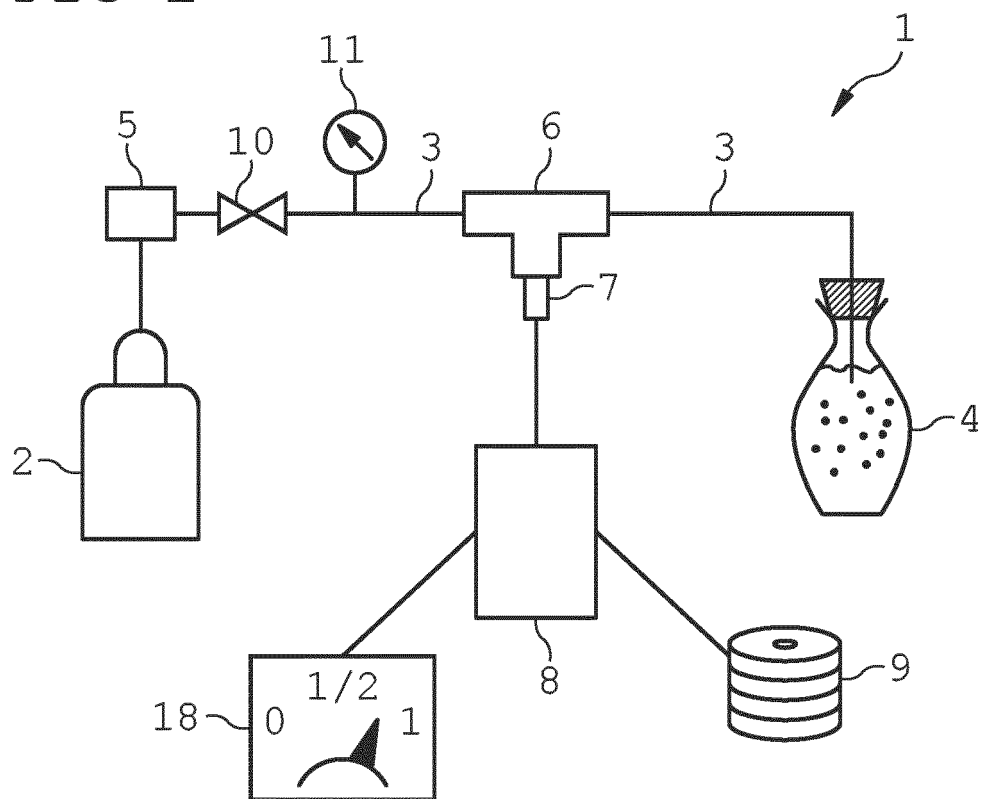


FIG 3

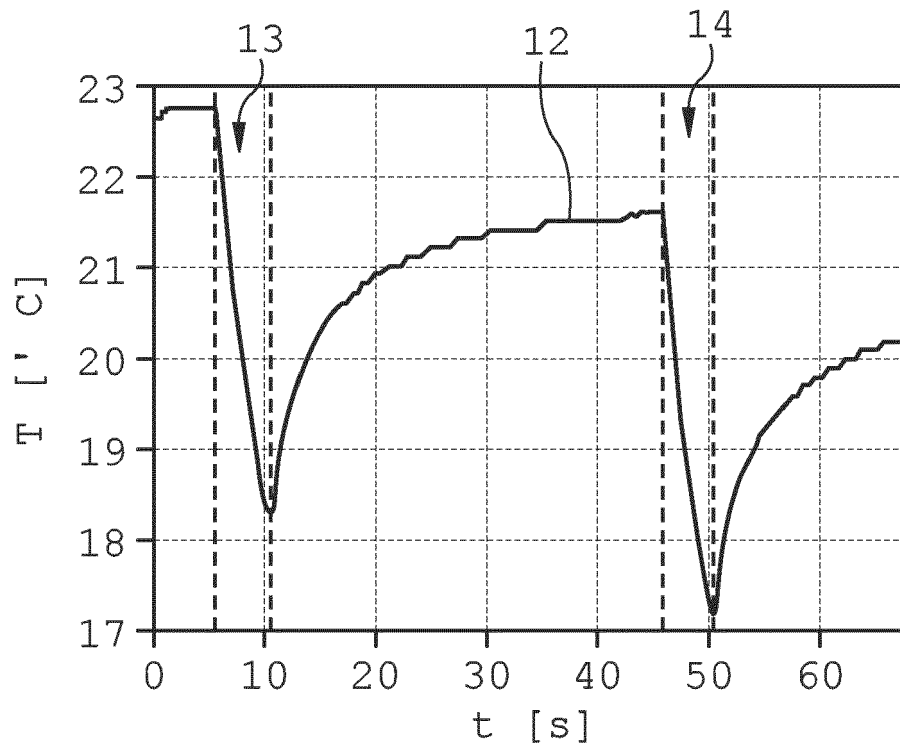


FIG 4

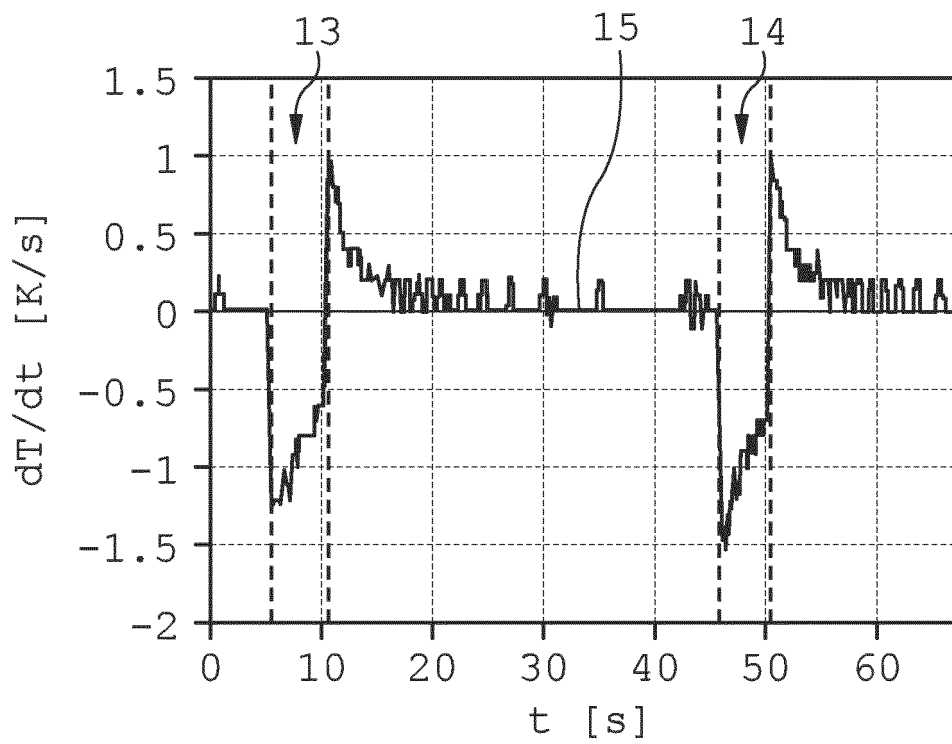
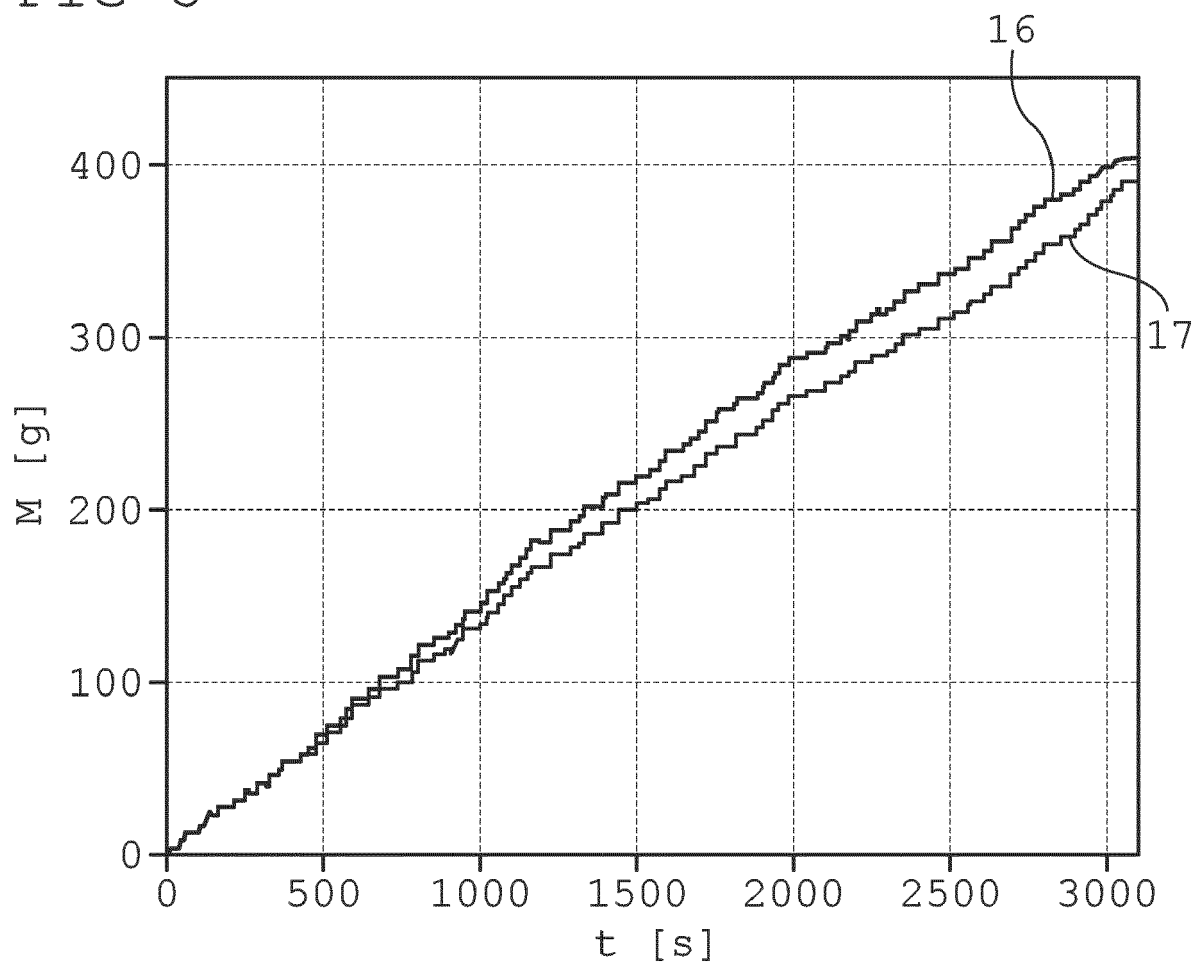


FIG 5





EUROPEAN SEARCH REPORT

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