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Design of Portable Gas Flow Meter Box for Monitoring Low-flow Gas

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Abstract

The article designs a portable gas flow meter for monitoring low-flow gas. The gas flow meter is composed of gas volume collection unit, control circuit and portable box body. The gas volume collection unit is the core part of the flow meter, which contains a glass sleeve installed a rubber plunger, a spring and a push rob within it. The continuous gas flow to be measured is converted to the multiple measurement of the volume of the glass sleeve in the limited time. The automatic measurement is achieved by the self-locking circuit and the work of the spring. All of the mechanical parts and electrical component of the gas flow meter are integrated in a suitcase, and thus it is suitable for on-site measurement.

Keywords

Gas flow meter; Portable; Low-flow gas; Control circuit.

1. Introduction

The gas flow measurement for low-flow gas is necessary in the biogas production experiment during the biochemistry process in the lab, such as methane and hydrogen production process, because the biogas production rate indicates the operation performance of the biochemistry process. It is also useful to measure the gas flow with the relative low flow rate in the fields of leak rate detection for the sealed products, the release rate determination for the coal-seam gases, the measurement of gas contained in the rock and etc [1]. The gas with low flow is difficult to be measured by the traditional commercial varieties of gas flow meters that are commonly suitable for the measurement of high-flow gas or piping gas. The wet gas flow meter is always used to measure the cumulative biogas volume in the certain period of time in the lab, while the problem of the rotating error for wet gas flow meter leads to the low accuracy in low-flow gas determination [2]. The measurement and control technologies are also applied in the design of flow meter, and it is efficient to reduce the manual labor and achieve the automatic measurement. The ultramicro flow meter that is the core part of the methane production potential system developed by the Bioprocess Control Sweden AB is highly precise with an accuracy of 10 ml, and it can automatically collect the gas flow data of the produced biogas and also the data of fermentation time [3]. However, the flow meter is too expensive to be widely utilized. There are also many low-flow gas meter developed based on the measurement and control technology [2], but most of them were not convenient to carry and utilize for on-site detection. Therefore, this article designs a portable gas flow meter box that is suitable for low-flow gas monitoring in field work.

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2. Structure Component

2.1 Structure Unit of the Flow Meter Box

The portable gas flow meter box used for monitoring the gas flow with low-flow rate is comprised of gas volume collection unit, control circuit and portable box body. The former two units are integrated into the portable box body. The plan view of the open box is shown in Fig. 1, and the front view of the close box is illustrated in Fig. 2.

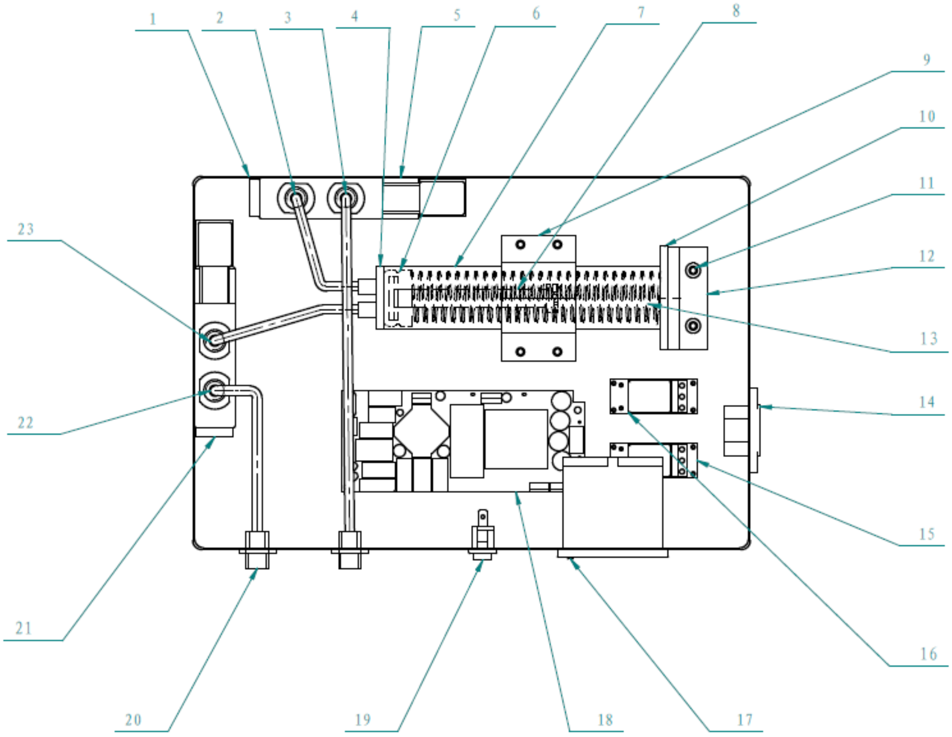

Fig. 1 The plan view of the open box

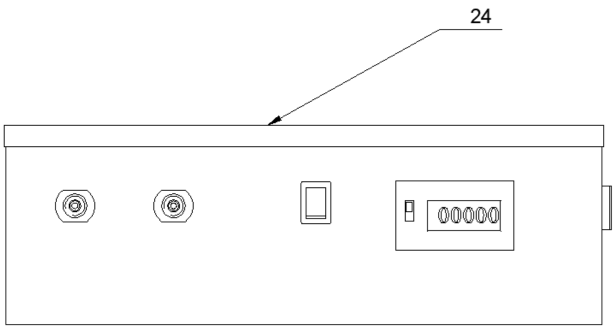

Fig. 2 The front view of the closed gas flow meter box

1-Box body; 2, 3-Gas intake pipe; 4-Gas cap; 5-Solenoid valve for gas intake; 6-Rubber piston; 7-Glass sleeve; 8-Push rod; 9-Air collector middle bracket; 10-Glass sleeve bottom drag; 11-Bottom support plate; 12-Air collector end bracket; 13-Reset spring; 14-220 V socket; 15-Relay one; 16-Relay two; 17-Counter; 18-Power adapter; 19-Ship type switch; 20-Joint; 21-Solenoid valve for gas discharge; 22, 23-Gas discharge pipe; 24-Upper cover of the box.

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2.2 Gas Volume Collection Unit

The gas volume collection unit is the core part of the flow meter box, which comprises of the glass sleeve with special internal structure, gas intake pipe and gas discharge pipe. The gas intake pipe is connected to the low-flow gas to be measured through the joint on the exterior surface of the box, and the gas discharge pipe provides a path to discharge the gas from the measurement system. As shown in Fig. 1, the gas pipelines connect to gas cap installed on the left side of the glass sleeve. Inside of the glass sleeve, the reset spring is connected to the bottom support plate on the right side of the glass sleeve, and a rubber piston is attached to another side of the spring.

For the application of the flow meter box, the low-flow gas go into the gas intake pipe, the accumulation of gas volume in the glass sleeve would result in the compression of the reset spring, and thus the gas volume flow-in are gradually converted into the storage volume of the glass sleeve. Besides, the corresponding time spending on the gas collection should also be recorded, which is used to calculate the gas flow through dividing the storage volume by the spending time. However, the volume of glass sleeve is restricted by the size of the box so that the measurable volume of low-flow gas is also limited. It could be assumed that the measurement errors would be enlarged in the case of gas collection with extreme low volume.

In order to be capable of obtaining the large volume of the low-flow gas, the limited storage space for gas collection in the glass sleeve is repeatedly utilized during the gas flow measurement in the modified design. Therefore, the continuous gas flow to be measured is converted to the multiple measurement of the volume of the glass sleeve in the limited time. The design of control circuit and the modification of the gas volume collection unit are performed to overcome the problem of the limitation of the sleeve volume. A long and thin push rod is inserted into the rubber piston and placed inside of the spring. It should be mentioned the length of the push rod is lower than the elastic range of the spring. It is also important to install travel switch at each end of glass sleeve, fixing on the glass sleeve bottom drag and the gas cap, which are the keys to activate the control circuit.

2.3 Control Circuit

The control circuit diagram is shown as Fig. 3. The access to power supply is provided from the 220 V socket and controlled by the ship type switch, as shown in Fig. 1 and Fig. 3. The solenoid valves, travel switches and electromagnetic relay are the main components of the control circuit, and the actions of them are accompanied by the gas volume variation in glass sleeve and also spring deformation.

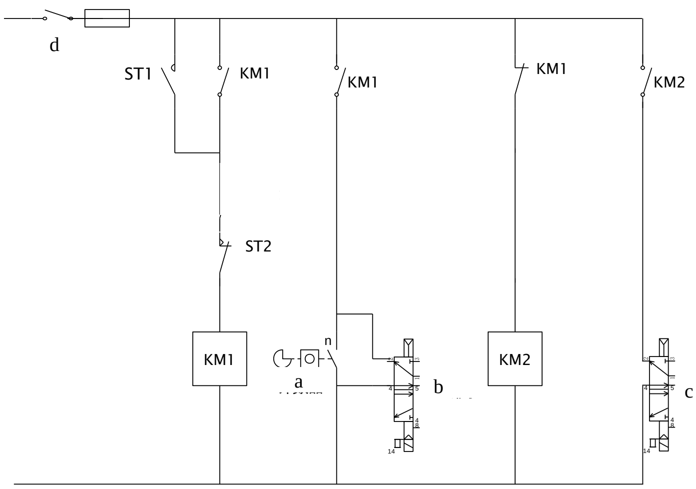

Fig. 3 The control circuit diagram

a-Counter; b-Solenoid valve for gas discharge; c-Solenoid valve for gas intake

d-Ship type switch; ST1, ST2-Travel switch; KM1, KM2-Electromagnetic relay

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Before the gas flow measurement, the low-flow gas is connected to the inlet joint and the external power is plugged into meter box by opening the ship type switch, and also the timing is started. At the beginning of the measurement, the electromagnetic relay KM2 is energized, and thus the normally closed solenoid valve for gas intake (solenoid valve c) opens, and the gas to be measured starts to flow into the glass sleeve. It should be noticed that the solenoid valve for gas discharge (solenoid valve b) is still closed when the gas is coming into the glass sleeve. As the increase of the gas volume in the glass sleeve, the spring is compressed. Once the push rod has attached to the travel switch (ST1) fixed on the glass sleeve bottom drag, the electromagnetic relay KM1 is energized. At this moment, the electromagnetic relay KM2 is deenergized, the solenoid valve (c) for gas intake is closed and the gas inlet stops. Besides, the solenoid valve (b) for gas discharge is open and the display of counter increase one unit. As the reduction of the accumulative gas, the push rod will gradually leave the travel switch (ST1) and the electromagnetic relay KM1 will deenergized again and the situation of control circuit returns to the beginning one. However, the glass sleeve is still filled with gas at that moment.

In order to guarantee that glass sleeve has enough volume for the gas inlet in the next batch, the electromagnetic relay KM1 must stay energized until all the stored gas has discharged. Therefore, the self-locked circuit is further designed by concatenation of electromagnetic relay KM1 and parallel circuit with combination of ST1 and normally open KM1. When the electromagnetic relay KM1 is energized, the normally open KM1 switches on and thus the continuous power supply for electromagnetic relay KM1 is achieved. The discharge of gas is continued by the function of the self-locked circuit and the elastic force of the reset spring. When the rubber piston reaches the travel switch ST2 that installed in the gas cap at the left end of the glass sleeve, the electromagnetic relay KM1 is inenergized and electromagnetic relay KM1 is energized. At that time, the situation of both the control circuit and glass sleeve recovered to the beginning one, and gas collection and discharge could be repeated to facilitate to monitoring the gas flow under a large sample volume.

During the gas discharge from the glass sleeve, the gas inlet to the glass sleeve is stopped by the control of the solenoid valve (c). However, the gas flow from the gas source to the meter box still continues and the pressure in the inlet pipes would increase in the process of gas discharge. Therefore, the gas discharge rate should be high enough to avoid excessive pressure in the inlet pipes. Gas discharge mainly relies on the elastic force of the reset spring, so the spring should be carefully selected.

3. Gas Flow Caculation

The gas flow should be calculated through the division of the collection volume of the low-flow gas by the measurement time. The collection volume (V_c) should be obtained by the data of the total volume of glass sleeve available (V_t), display on the counter (N) and also the residual gas volume in the sleeve at the end of measurement (V_r). The calculations of the gas flow (Q_c)are showed in Eq. (1) and Eq. (2).

$$V_c = V_t \cdot N + V_r \tag{1}$$

$$Qc=V_c/T \tag{2}$$

The gas flow calculated (Q_c) could be further converted to that in standard condition (100 kPa, 273 K), and thus the data on local air temperature (T_l, K)and pressure (P_l, kPa)should be also collected. The gas flow in standard condition (Q_s) is calculated following Eq.(3).

$$Q_s=273Q_c \cdot P_1/(100T_1) \tag{3}$$

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4. Summary

This article designs a portable low-flow gas meter box and describes its work method. The flow meter achieves automatic trace gas flow measurement by the glass sleeve, the inner spring, the self-locking circuit and etc. The simplification of the design process and the control circuit improve the stability of the low-flow gas meter, and the integration of the main components of each unit in the electric box increases the feasibility in different occasions for field survey.

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