Flow Measurement and Control by Time-Based Method

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This study aimed to investigate flow measurement by using a 'bucket and stop-watch'method of flow measurement. Most flow measurement systems measure pressure or other fluid properties to infer flow rate, though time is a variable which can be easily and very accurately measured. The main principle behind the method was to fill up a reservoir until a set pressure had been reached. This reservoir would then be emptied and the cycle would repeat itself. The prototype was designed to control flow rate using the method. It made use of computer control with an analogue digital converter and fast acting solenoid valves which controlled the flow into a reservoir. Reservoirs were available with internal diameter of 1mm up to 5.5mm to cope with a range of flow rate.

1. Introduction

Flow rates are very difficult to measure directly. The conventional flow control and measurement device(so called, Mass Flow Controller, MFC) can be classified mainly into the thermal type, which work by detecting the difference in the amount of heat transfer according to a calorimetric principle, and the pressure-based ones, which work on the relation between mass flow and pressure loss in a flow passage [1-3].

The thermal type Mass Flow Controller tend to have a relatively slow response time and are not accurate enough because of heat loss to the outside. Also, they require very accurate mechanical parts such as a bypass pipe(capillary) and laminar flow elements.

The flow control and measurement method reported here(bucket and stop-watch method) is a simple design and easily measures flow, based on a different concept from the conventional types. The basic principle behind such a system is the filling of a reservoir with air until a predetermined pressure has been reached. The reservoir will then be emptied to the equipment side of the system. The cycle of filling and emptying then be repeated. Time is a variable that can be easily and very accurately measured and will form the basis of the method. The aim is to be able to measure/control flows of 0.1ml/min to 10ml/min with an accuracy of 2% and this irrespective of the supply pressure. The market for such a flowmeter is the electronics industry where many gases and chemicals is employed in the production of silicon chips.

2. Prototype Design

A simple prototype was built to demonstrate the principles of the flow control method. Figure 1 shows the schematic layout of flow measurement system. The system consists of several key components: solenoid valves, reservoir, pressure sensor, analogue/digital conversion, and control software. The reservoir is a hole which is located between the two solenoid valves. The reservoir internal diameters ranged from 1.0mm to 5.5mm to cope with various flow rates with different volumes. Two valves are used for control the flow rate which manufactured by Takasago Electric(MTV-2-NM6) with an elastomer-seal Teflon diaphragm. A pressure sensor was chosen which had a good repeatability of reading and provided an output which could be used to control the system. It was decided to use a piezo-resistive pressure transducer with a measuring of 0-5 psi. The analogue signal from the pressure transducer requires amplification before being read by analogue/digital converter. The analogue signal converted into a digital signal with a A/D card. A personal computer used for the control of the flow measurement/control system which use a Pascal language based software.

3. Results and Discussion

On the initial filling of the reservoir a considerable amount of time is required as the pressure in the reservoir needs to rise from 0 Bar up to the required pressure of 0.05 Bar while the supply line is also empty'. However once the reservoir has filled for the first time, the filling process takes just a fraction of the time. Reservoir emptying takes less than 5ms. Figure 2 shows the flowrate result of the 4mm reservoir size case. The flow rate was found to be linearly proportional to the loop rate. All the reservoirs(1, 2.5, 4, 5.5mm size) considered in this study have a straight best-fit lines passing through the origin. This means that in terms of calibrating the individual reservoirs the gradient of the line produced could be used and entered directly into the program.

4. Conclusions

From many literature search it is evident that a time-based flow measurement system offers one of the most accurate flow measurement technique as time is a parameter which can be readily, cheaply and very accurately measured. This research project has gone to prove this and also highlight the problems associated with the measurement of extremely low flows where frictional losses become increasingly significient.

This study was successful in demonstrating a time-based flow measuring system. Flow measurements down to 0.1ml/min were achievable, though at the top end of the specification, flows in the order 3.5ml/min could be measured before the system became overloaded. The system was limited by the response of its components such as the solenoid valves. The pulsations in the system continued to pose a problem as well as the pressure losses and small leaks in the outlet tubing.

This study has successfully proven the theory behind the `bucket and stop-watch' technique and developed the foundations for an accurate time-based flow measurement system.

References

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[2] Brinicombe, MW., `Introducing Electronic Systems', Thomas Nelson & Sons, 1985

[3] Ower, G, `The measurement of Air Flow' 5th edition, Pergamon Press, 1997

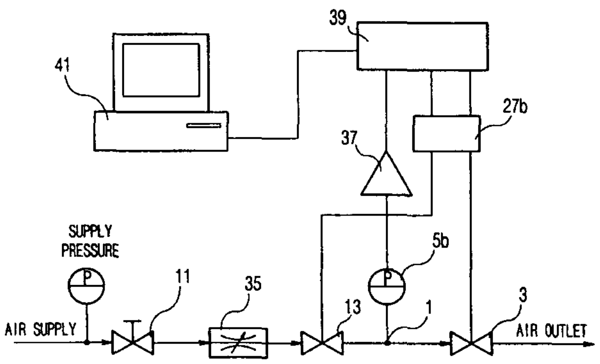

Fig. 1 Schematic layout of the flow measurement system (main valve:11, pressure regulator:35, inlet valve:13, reservoir:1, outlet valve:3, transducer 5b, amplifier:37, power driver:27b, analogue/digital interface:39, PC:41)

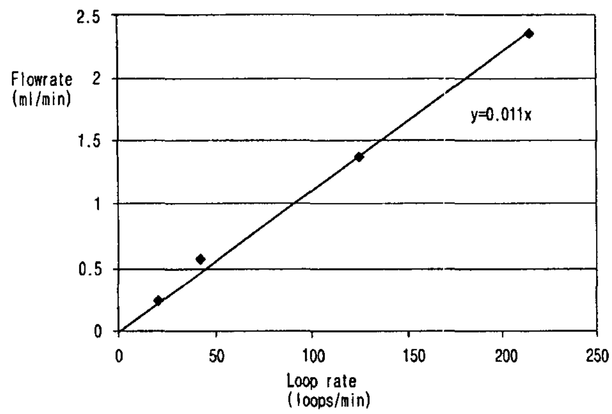

Fig. 2 A relationship between the flow rate and the loop rate for the fill pressure of 0.05 Bar and the empty pressure of 0.002 Bar in a 4mm diameter reservoir