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DEVELOPMENT OF THE GAS METER WITH THE THERMAL FLOW SENSORS ARRANGED ON THE SURFACE OF THE RECTIFIED FLUID PATH

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Abstract: Tokyo Gas Co., Ltd. has developed the new electronic gas meter with several thermal flow sensors for industrial use. We designed the proper structure of the rectifier and the arrangement of sensors experimentally. The paper describes the result of the experiment and the specifications of the meter.

Keywords: Electronic gas meter, Flow sensor, Rectifier

1. INTRODUCTION

Tokyo Gas Co., Ltd. has developed the new electronic gas meter with several thermal flow sensors for industrial use. [1] So far the rotary meters have been mainly installed in our large industrial customers. But there are following defects on costs and installation;

(1) Rotary meters, especially with electronic volume corrector, are expensive.
(2) The large installation space is required, because rotary meters are not only large but also require that the flow direction should be vertical.
(3) Because of the heavy weight, the installation is uneasy.

To improve the defects mentioned above Tokyo Gas has developed the new electronic gas meter to aim for compactness, lightweight, low cost. The configuration of the meter is based on our original ideas and unique in the world.

2. MEASUREMENT PRINCIPLE

The new electronic gas meter has several thermal flow sensors as the fluid velocity detector, which is produced by silicon micro-machining technology. [2] The structure of the flow sensor is shown in Figure 1. A heater (Rh), an upstream temperature sensor (Ru), and a downstream temperature sensor (Rd) made by platinum film are formed on the silicon chip, which is approximately 1.7 mm square. Moreover owing to the structure, the sensor has characteristics of high-speed reply. (Approx. 2 ms)

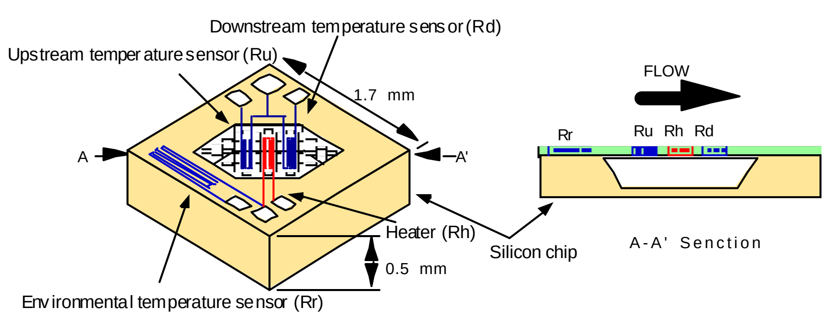

Figure 1 The structure of the flow sensor

The measurement principle is shown in Figure 2. Without flow, the temperature distribution between two temperature sensors is symmetrical. With flow, the temperature distribution becomes unsymmetrical. The temperature difference between two temperature sensors is detected as a difference of resistance value. It is in proportion to the fluid velocity. In this way, the mass flow can be measured.

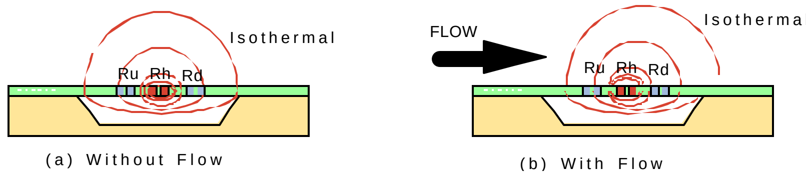

Figure 2 Measurement principle

3. SYSTEM CONFIGURATION

3.1 Structure of a fluid path

The new electronic gas meter has several thermal flow sensors as the fluid velocity detector. The structure of the fluid path is shown in Figure 3. It is known that the flow velocity distribution within a pipe is parabolic orbit and the flow velocity of the surface is slower than that of the center of the pipe. Arranging the sensors on the surface of fluid path enables the measurement range to be wider. It is favorable in terms of the pressure loss and assembles of the meter.

The rectifier that consists of wire netting and a honeycomb is installed in the straight fluid path. The circular component of the gas flows into the meter is removed as it passes through the rectifier. As the result, the proper fluid distribution is formed. [3]

To cover the wide measurement range of OIML recommendations, the meter has the sensors with two kinds of sensitivity: two low-velocity sensors and two high-velocity sensors. These sensors are arranged on the same circumference every 90 degrees.

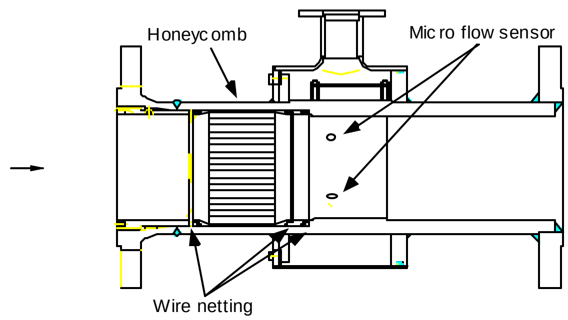

Figure 3 The structure of a fluid path

3.2 Structure of the circuit

Since the meter is required to work on batteries for more than ten years, the low power-consumption design should be applied to the meter. Therefore the sensor is driven every second intermittently. The CPU controls the sensor driver circuit according to the flow rate. When the flow velocity is lower than about 1.5 m/s, two low-velocity sensors are driven alternately. If the flow rate exceeds the level, all sensors are driven every second in turn. Furthermore, when the flow rate increases, the high-velocity sensors are driven. Since the level of sensor's switching has hysteresis, the sensor doesn't switch frequently, in case the fluid fluctuates.

The gas meter measures the fluid velocity and indicates the integrating volume in a liquid crystal display. The instantaneous flow rate and pressure are also indicated for a few seconds when a user pushes the button of the meter body. The meter has the pulse output of the integrating volume and the 4-20 mA output of the instantaneous flow rate.

4. CHARACTERISTICS

Compared with the conventional gas meter, such as a rotary meter or a turbine meter, this meter has following characteristics.
The meter has simple structure: The rectifier that consists of wire netting and a honeycomb is installed in the straight fluid path. It enables the meter to be compact and lightweight as shown in Figure 4. The volume of 80A (3 inch) type meter is 1/2 smaller than that of the conventional rotary meter and the weight is 1/3 lighter. It enables easy installation. The meter has no mechanical moving parts. Therefore the meter can work for a long period.
The meter can be installed whether the flow direction is vertical or horizontal. On condition that the meter is installed horizontal, the large installation space is no longer required and the cost of installation can be reduced. Since the length between flanges of the meter equals that of the conventional rotary meter, we can replace the rotary meter with the new meter easily.
The gas meter, which measures the mass flow doesn't need the volume corrector using Boyle-Charles law. It helps the cost reduction.
Now we are manufacturing two types of the meter. The specifications of the meter are shown in Table 1.

Table 1 The specifications of the meter

Diameter	80A (3 inch)	100A (4 inch)
The maximum flow rate (Qmax)	400 (Nm^3/h)	650 (Nm^3/h)
Measurement accuracy	1/160 Qmax to 1/10 Qmax: less than plus or minus 3 % 1/10 Qmax to Qmax: less than plus or minus 1.5 %	
Pressure	0.05 – 0.3 MPa	
Power supply	Lithium batteries	
Life of the batteries	Over 10 years	
Weight	16 (kg)	21 (kg)
Flow direction	Either horizontal or vertical	

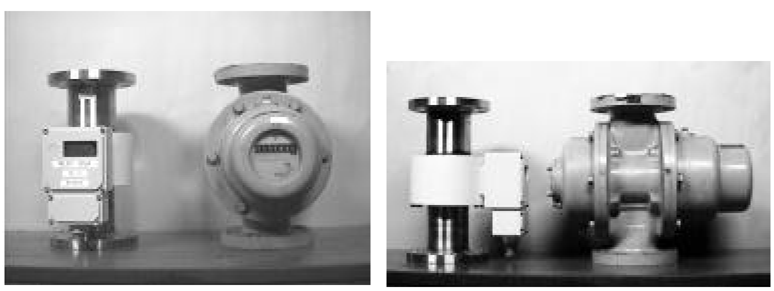

Figure 4 Appearance of the new meter and a rotary meter

5. PERFORMANCE OF THE METER

5.1 Design of the rectifier

The proper rectification is necessary for stable measurement in the whole range. At first we examined the most effective distance between downstream wire netting and the sensor. The rectifier consists of a sheet of upstream wire netting, a honeycomb, and a sheet of downstream wire netting. For example, we show the results on condition that the distance is 16mm, 24mm, 32mm, and 40mm. The relation between the average velocity and the sensor output is shown in Figure 5 and the relation between the average velocity and the standard deviation of the sensor output is shown in Figure 6. As a result, it turns out that the standard deviation is smallest on condition that the distance equals to 16mm. It assumes that the flow becomes disorderly as the distance increases. Moreover, it turns out that the deviation of the sensor output increases and the sensor output isn't smooth, when the average velocity reaches nearly 7-8 m/s.

These things mean that the rectification is not sufficient for stable measurement.

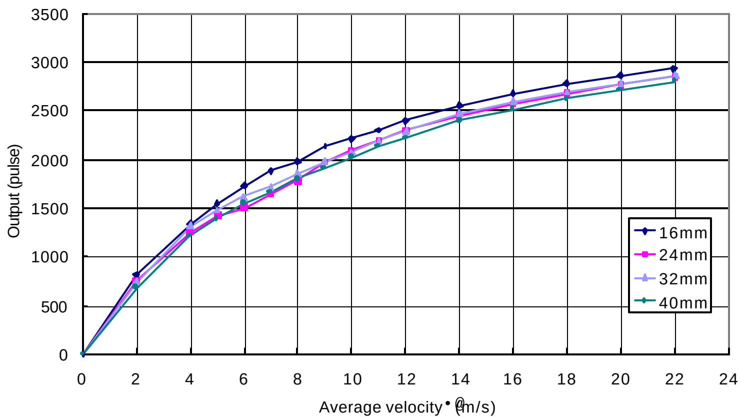

Figure 5 The relation between the average velocity and the sensor output

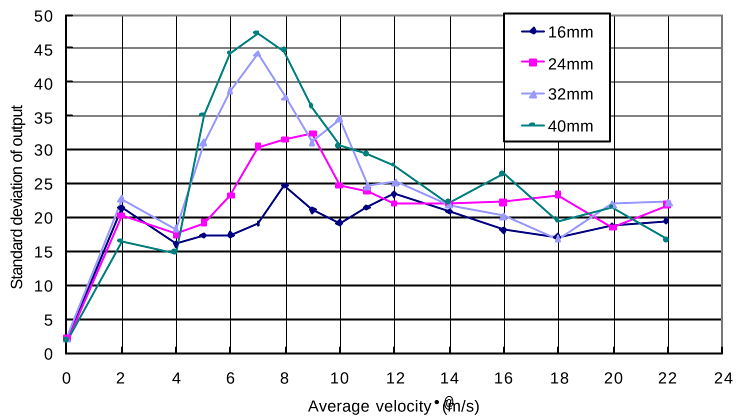

Figure 6 The relation between the average velocity and the standard deviation of the sensor output

Then, a sheet of wire netting is added between the downstream wire netting and the sensor. Namely, the rectifier consists of a sheet of upstream wire netting, a honeycomb, and two sheets of downstream wire netting. Here, the distance between the second downstream wire netting and the sensor equals to 19 mm in terms of the manufacture. The sensor output and the standard deviation is shown in figure 7 when the rectifier is installed in the meter. It turns out that the deviation of the whole range as well as in 7-8 m/s is reduced to less than ten. The structure is adopted to the meter.

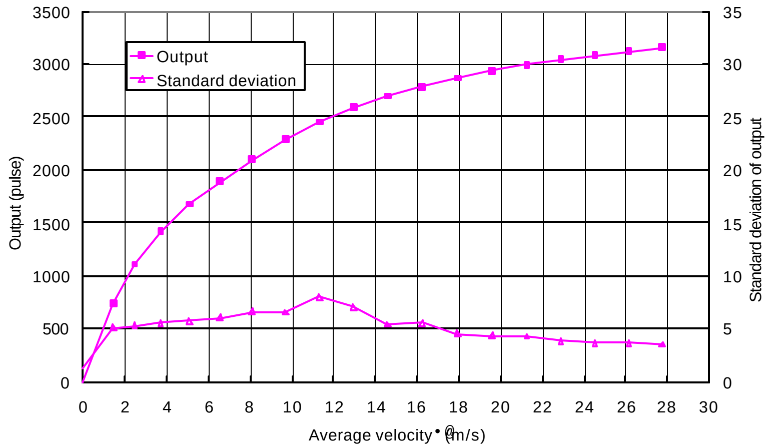

Figure 7 The sensor output and the standard deviation after adding a sheet of wire netting

5.2 PRESSURE LOSS

The pressure loss that is measured under atmospheric pressure is shown in Figure 8. The performance is enough to satisfy our target value of pressure loss.

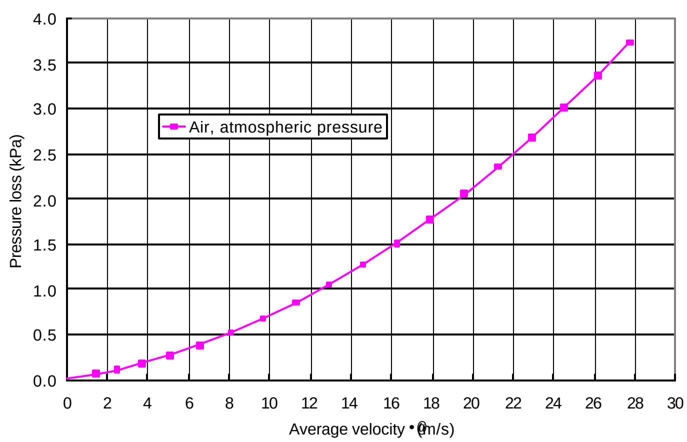

Figure 8 Pressure loss

5.3 ACCURACY

The accuracy of 100A model is shown in figure 9. Figure 10 expands on the low flow region.
Since the compensation parameter couldn't be preset up to 400 m^3/h on account of ability of our equipment and expected compensation parameter was preset from 400 m^3/h to 650 m^3/h, the accuracy in nearly Qmax got worse. We assume that the accuracy will improve by preset the proper compensation parameter. We confirm that the accuracy satisfy the OIML recommendation even in the low flow region.

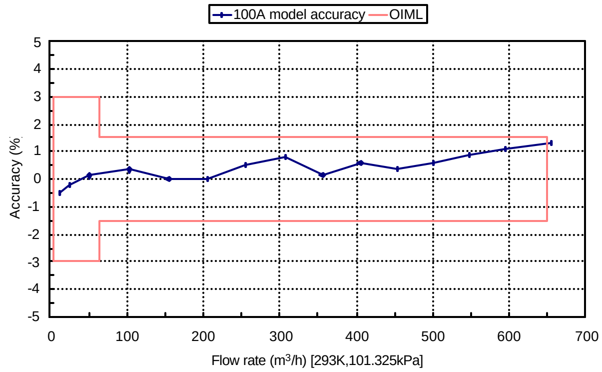

Figure 9 The accuracy of 100A model

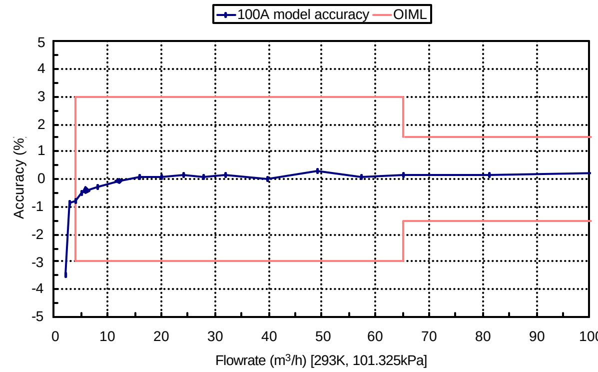

Figure 10 The expansion of low flow region

5.4 Pressure dependence of the sensor

Although the micro flow sensor in the meter is able to measure mass flow, it has some pressure dependence. The pressure dependence of the sensor is shown in Figure 11 on the condition that the pressure changes from atmospheric pressure to 0.3 MPa.

The accuracy tends to be larger as the pressure becomes higher. The difference between in the atmospheric pressure and 0.3 MPa is about 2.5% maximum.

We intend to install a pressure sensor in the meter and adjust the sensor output according to the pressure.

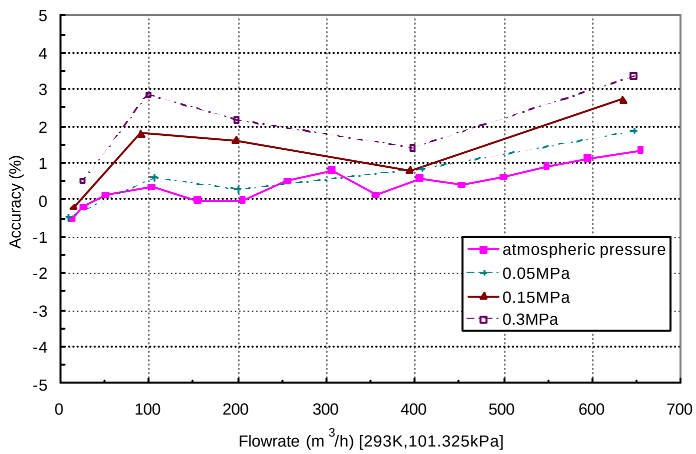

Figure 11 The pressure dependence of the sensor

6. FUTURE PLANS

We have been conducting the field test at several industrial users for a year. There is no problem about the endurance and the accuracy. The meter is planed to be put into commercial use in 2000.

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