A gas meter test facility with multifunction

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Abstract. Based on the master meter principle and negative pressure method, a multifunctional facility is developed for gas meter testing. A high accuracy roots flowmeter and two wet gas meters are selected as master meters. A thermostat is applied to control gas temperature. This facility is suitable for type evaluation and verification of gas meters, such as testing their measurement performance, temperature adaptability, pressure loss, and overload flow rate. The expanded uncertainty of the facility is better than 0.3% (k=2). Its applicable temperature range and flowrate range are (-40~60)°C and (0.016~16)m³/h respectively. Experimental results show that the proposed facility is effective in testing ultrasonic gas meter under different temperatures.

1. Introduction
A number of gas meters with new types of measuring principles have emerged in recent years, such as ultrasonic gas meters and thermal mass gas meters [1,2]. Some of their performances are different from traditional diaphragm gas meters [2,3]. For example, ultrasonic gas meters can achieve a better accuracy, but are more sensitive to temperature. As a result, more types of test are required in type evaluation and verification of gas meters, such as temperature adaptability test and pressure loss test. To meet these requirements, the facilities which are used to implement the tests need to have wider temperature range as well as higher accuracy.

Metrology institutions have paid much attention to developing gas meter testing facilities, including verification device, temperature test device, durability test device, etc. [4,6]. However, the cost of developing the facilities increases sharply and it is time-consuming to use them alternately. Besides, most existing facilities are designed based on the traditional principles, such as bell prover and nozzles, the accuracy class of which is generally 0.5 [1,2]. They have disadvantages of high maintenance cost, flow rate limitation, and unreliability after long working hours. More research should be undertaken to improve the gas meter test facilities.

The aim of this paper is to develop a gas meter test facility with multifunction. The master meter principle and negative pressure method are adopted. A thermostat is applied to control gas temperature, so that the test temperature is adjustable. High accuracy roots flowmeter and wet gas meters are selected as master meters. The measurement model for gas meter testing is given and the uncertainty of the developed facility is better than 0.3% (k=2) has been achieved. This facility can be used in type evaluation and verification of gas meters, to test their measurement performance, temperature adaptability, pressure loss, overload flow rate, etc..
2. Facility structure
The facility is developed on the basis of master meter principle and negative pressure method. It mainly consists of four systems: a power system which produce the gas source, an adjustable temperature system, a measurement system, and a control system, as shown in figure 1.

The power system comprises two variable frequency fans, which provides the negative pressure gas source. According to the tested flow rate, a corresponding fan is selected automatically during the test.

The adjustable temperature system is composed of a dehumidifier, a condenser, a thermostat, and a heat exchanger. Heating tubes are installed in the thermostat. The condenser is responsible for cooling the gas when low temperature gas is needed. The thermostat is equipped with a control panel that is applied to adjust and maintain the gas temperature to the set point. The capacity of the temperature system could guarantee an adjustable gas temperature range of (-40~ 60)°C within flow rate range of (0.016~16)m³/h, with temperature fluctuation less than ±0.5°C.

The measurement system consists of three master meters, three tested gas meters, measurement units of temperature and pressure, and data acquisition unit. A roots flowmeter and two wet gas flowmeters with different measurement ranges are applied as the master meters and connected in parallel mode. Each master meter has a measurement uncertainty better than 0.2%. In the practical test, a single master meter is selected by switching on a corresponding pneumatic angle valve to ensure that the selected master meter is working in the most accurate flowrate range. The tested gas meters are installed inside of the thermostat. The heat exchanger is installed between the thermostat and the master meters, to convert the gas from the thermostat to normal atmospheric temperature gas which is to be measured by the master meters. Photosensors and image recognition sensors are utilized to acquire the indication value of the tested gas meters. Temperature sensors and pressure sensors are installed to obtain the temperature and pressure at each tested gas meter and each master meter. Data acquisition unit is adopted to transmit various parameters to a computer, including indication value of the tested gas meters, tested temperature and pressure, pressure loss, pulse output of the master meters, etc.. The measurement performance of tested gas meters can be obtained by comparing their indication value and the actual flowrate measured by the master meters.

The control system is responsible for temperature control inside the thermostat, switching on/off the dehumidifier and pneumatic valves, selection of the fans and master meters, and flowrate regulation (which is implemented by regulating the rotational speed of the variable-frequency fans).

![Figure 1. Facility structure](image-url)

3. Uncertainty evaluation
3.1. Measurement model and uncertainty components
Assuming that the actual gas flowrate flowing through the tested gas meter is \( V_{\text{int}} \), the measurement model can be expressed as:
\[ V_{ms} = f(V_s, P_s, T_s, P_m, T_m, P_a) = \frac{(P_a + P_s)T_a}{(P_m + P_s)T_m} V_s \]  

where:

- \( V_{ms} \)——accumulated volume flowrate obtained by the tested gas meter, \( m^3 \);
- \( V_s \)——accumulated volume flowrate obtained by the master meter, \( m^3 \);
- \( V_{am} \)——actual accumulated volume flowrate flowing through the tested gas meter, \( m^3 \);
- \( P_m \)——gage pressure at the tested gas meter, Pa;
- \( P_s \)——gage pressure at the master meter, Pa;
- \( P_a \)——atmospheric pressure, Pa;
- \( T_m \)——temperature at the tested gas meter, K;
- \( T_s \)——temperature at the master meter, K;

The combined relative uncertainty of \( V_{ms} \) is denoted as \([14]\):

\[
u_{rel}(V_{ms}) = [\nu_{rel}(V_s)^2 + \nu_{rel}(P_s + P_m)^2 + \nu_{rel}(P_m + P_s)^2 + \nu_{rel}(T_s)^2 + \nu_{rel}(T_m)^2]^{1/2} \]  

3.2. Evaluation of the uncertainty components

1) The relative standard uncertainty of the master meter \( \nu_{rel}(V_s) \)

The measurement uncertainty of the master meter is 0.2% \((k=2)\), so

\[
u_{rel}(V_s) = 0.2\% / 2 = 0.1\% \]  

2) The relative standard uncertainties \( \nu_{rel}(P_s + P_m) \) and \( \nu_{rel}(P_m + P_s) \) introduced by pressure transducers

The atmospheric pressure transducer has a measurement range of \((0-110)kPa\) and an uncertainty of 0.065%Fs, \(k=2\). The pressure transducers that are used to measure the pressures at the master meters and tested gas meters have the same uncertainty but much narrow range of \((0-6)kPa\). Because \( P_s \) is much greater than \( P_m \) and \( P_m \), \( \nu_{rel}(P_s + P_m) \) and \( \nu_{rel}(P_m + P_s) \) are approximately equal to \( \nu_{rel}(P_s) \):

\[
u_{rel}(P_s + P_m) \approx \nu_{rel}(P_s) = 0.065\% / 2 \times 110000 / 101325 \approx 0.035\% \]  

\[
u_{rel}(P_m + P_s) \approx \nu_{rel}(P_m) = 0.065\% / 2 \times 110000 / 101325 \approx 0.035\% \]  

3) The relative standard uncertainties \( \nu_{rel}(T_s) \) and \( \nu_{rel}(T_m) \) caused by temperature transducers

According to the calibration certificates, each temperature transducer has the same measurement uncertainty of 0.2°C \((k=2)\). Assuming that the gas temperature is 20 °C during the calibration, the relative standard uncertainties caused by \( T_s \) and \( T_m \) are:

\[
u_{rel}(T_s) = \nu_{rel}(T_m) = 0.2 / (2 \times 293.15) \times 100\% = 0.03\% \]  

3.3. Combination of uncertainty components

By combining all the uncertainty components above, the combined uncertainty of the actual gas volume \( V_{ma} \) (i.e. the uncertainty \( U \) of the facility) is calculated as:

\[
u_{rel}(V_{ma}) = [\nu_{rel}(V_s)^2 + \nu_{rel}(P_s + P_m)^2 + \nu_{rel}(P_m + P_s)^2 + \nu_{rel}(T_s)^2 + \nu_{rel}(T_m)^2]^{1/2} \approx 0.12\% \]  

The relative expanded uncertainty of \( V_{ms} \) is:

\[
u_{rel}(V_{ms}) = 2 \times \nu_{rel}(V_{ma}) = 0.24\%, (k = 2) \]

4. Experiment results

To verify the effectiveness of the proposed facility, temperature adaptability of an ultrasonic gas meter was tested on this facility. The tested ultrasonic gas meter has a flowrate range of \((0.025-4)m^3/h\) and maximum permissible error of \( \pm 1.5\% \). The indication error \( E \) of the gas meter was obtained at 9 flowrate points and each flowrate point was tested under 5 temperature points. Each test was conducted after the temperature in the thermostat reach the target temperature and both of the temperature in the thermostat and the temperature at the master meter remain stable (the temperature fluctuation is less than 0.5°C).
Figure 2 shows the indication errors of the tested ultrasonic gas meter derived from different flowrates and temperatures. It can be seen from the test results that the facility is effective in testing the gas meter. When the flowrate is greater than 0.075 m$^3$/h, the tested gas meter has satisfactory metrological performance (E ≤ ±1.5%) whatever the tested temperature is. However, its temperature adaptability deteriorates at the minimum flowrate 0.025 m$^3$/h. The maximum indication error at this flowrate is 5.8%, which is obtained at 40°C. There is a trend that the temperature deviation from room temperature will give rise to greater indication errors.

![Figure 2. Test results of an ultrasonic gas meter](image)

### 5. Conclusion

Based on master meter principle and negative pressure method, a multifunctional gas meter test facility with uncertainty better than 0.3% (k=2) is developed. Gas temperature is regulated and controlled by a thermostat, so that the working temperature condition of the gas meter is simulated and gas meters can be tested inside the thermostat under the simulated temperature. The tested flow rate ranges from 0.016 m$^3$/h to 16 m$^3$/h, and the corresponding application temperature ranges from -40°C to +60°C. This facility can be used in type evaluation and verification of gas meters, to test their measurement performance, temperature adaptability, pressure loss, and overload flow rate, etc.. Because multiple functions are integrated within one facility, the utilization efficiency of the high-cost fans and master meters is enhanced, which contributes to cost reduction as well as efficiency increase of the whole facility. Meanwhile, the overall accuracy and reliability of the facility is improved due to the introduction of the high accuracy master meters.

An ultrasonic gas meter was tested under different temperature conditions. Experimental results show that the proposed facility is effective, and in these experiments, temperature deviation from room temperature will lead to greater indication errors of the tested gas meter.

### 6. References

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