IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

The influence of pressure-sampling position on calibration K-factor of gas vortex flowmeter

To cite this article: Haiyang Li *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **300** 022074

IOP Conf. Series: Earth and Environmental Science **300** (2019) 022074 doi:10.1088/1755-1315/300/2/022074

The influence of pressure-sampling position on calibration K-factor of gas vortex flowmeter

Haiyang Li *, **Yuyang Chen, Junlong Xu, Jin Song**

Shanghai Institute of Measurement and Testing Technology, Shanghai 201203, China

*Corresponding author e-mail: lihy@simt.com.cn

Abstract. According to the gas equation of state, the volume of gas at a certain time is related to the current temperature and pressure. Therefore, the calibrated K-factor of gas flowmeter will be affected by the temperature and pressure during the calibration process. Normally, in the ordinary pressure calibration process, the temperature change of calibration medium does not exceed 0.2 degrees, and the influence on the measurement results is about 0.08%. However, the influence on the measurement results can reach 3%~4% due to the different position of the pressure-sampling. An array experiments were carried out on the gas vortex flowmeter (which was most influenced by the pressure-sampling position). It was found that different pressure-sampling positions affect the calibrated K-factor of the gas vortex flowmeters without temperature and pressure compensation, and the degree of influence is proportional to the pressure drop generated by the gas passing through the flowmeter. And the influence is non-linear. The greater the gas flow velocity is, the more obvious the pressure difference among different pressure-sampling positions of the pipeline is and the more serious the deviation of calibrated K-factor from normal value is. So, when the calibrated K-factor deviate greatly at large flow velocity points but linear at other flow velocity points, the correctness of the pressure-sampling position in the calibration process should be considered.

1. Introduction

Gas flowmeter is the instrument for measuring the volume of gas passing through the pipeline. Common gas flowmeters mainly include gas volume flowmeter, gas vortex flowmeter, gas turbine flowmeter, thermal gas mass flowmeter and so on. The initial installation and subsequent use of the flowmeter need to be verified or calibrated by gas flow standard device to ensure the accuracy and reliability of its measurement value. According to the gas equation of state, the calibration results are directly affected by the temperature and pressure of the working medium at the time of calibration. As the change of medium temperature does not change significantly during the primary calibration process, the temperature has little influence on the calibration results. However, the pressure difference caused by different pressure-sampling positions will vary with the type of flowmeter. The pressure drop of the gas volume flowmeter mentioned above is quite small and can even be neglected. However, it is significant to the gas vortex flowmeter at high flow velocity point, and can not be ignored [1, 2]. This will result in great difference on the calibrated K-factor of gas vortex flowmeter due to the different pressure-sampling positions. "Verification Rules for Vortex Flowmeters" of China [3] describes the choosing of

IOP Conf. Series: Earth and Environmental Science **300** (2019) 022074 doi:10.1088/1755-1315/300/2/022074

the pressure-sampling positions as follows "When measuring the fluid pressure passing through the flowmeter, pressure can be sampled directly from the pressure-sampling hole in the body of the flowmeter. If there is no pressure-sampling hole, the measuring position of pressure should be determined according to the requirements of the flowmeter itself. If there is no special requirement, the pressure gauge should be installed at the downstream (2-7) diameter of the flowmeter [4-6]. In actual calibration, there are many cases which there is no pressure-sampling hole in the body of the vortex flowmeter itself. The downstream (2-7) diameter of the flowmeter in the standard device is usually used to sample pressure of the working medium. In order to study the influence of pressure-sampling position on the calibrated K-factor of gas vortex flowmeter, this paper analyses the mechanism of the influence of working medium pressure on calibrated K-factor according to the gas equation of state and carries out a set of calibration experiments to verify this effect.

2. Brief introduction of calibration principle and gas flow standard device

2.1. Brief Introduction of Calibration Method

Real-flow calibration of gas vortex flowmeter is carried out with gas flow standard device of standard meter method. The specific calibration process is as follows: Install the flowmeter on the pipeline of the standard device and then check the airtightness of the calibrated flowmeter and the other connections of the pipeline. Adjust the flowrate of the standard device to the setting flowrate point, and the calibration will begin when the flowrate is stable. Record the initial value of the calibrated flowmeter and standard flowmeter, and after a while, record the final value of the calibrated flowmeter and standard flowmeter.

The K-factor of the calibrated flowmeter at the tested flowrate point is calculated, according to the formulas (1) and (2).

$$K_{ij} = \frac{N_{ij}}{Q_{ij}} \times \frac{p_m}{p_s} \times \frac{T_s}{T_m} \times \frac{Z_s}{Z_m} \tag{1}$$

$$K_i = \frac{1}{n}\sum_{j=1}^{n} K_{ij} \tag{2}$$

Where:

K_{ij} is the factor of the j-th order of calibration point i, $(m^3)^{-1}$ or L^{-1};

N_{ij} is the number of output pulses of the j-th order of calibration point i;

Q_{ij} is the cumulative flowrate value of the calibrated flowmeter of the j-th order of calibration point i, m^3 or L;

P_s and P_m are the medium pressure of the standard device and the calibrated flowmeter of the j-th order of calibration point i, Pa;

T_s and T_m are the medium thermodynamic temperature of the standard device and the calibrated flowmeter of the j-th order of calibration point i, K;

Z_s and Z_m are the medium gas compression factor of the standard device and the calibrated flowmeter of the j-th order of calibration point i, and when the calibration is in the atmospheric pressure, both the value of them is 1;

The formula (1) shows that temperature and pressure are corrected in the process of calculating the K-factor of the flowmeter under calibrated. And K is proportional to p_m/p_s, that is to say, the greater the pressure difference between the calibrated flowmeter and the standard flowmeter is, the greater the K-factor is.

2.2. Brief introduction of gas flow standard device of standard meter method

The gas flow standard device of standard meter method established by Shanghai Institute of Measurement and Testing Technology in 2014 was used in the above calibration process, as is shown in Figure 1. The expanded uncertainty of the standard device is 0.3% (k=2), and the flowrate range is (1-7500) m^3/h. All the calibrations are carried out in DN50 pipeline. The standard flowmeters are Elster RVG G65 DN50 PN16 and Elster RVG G250 DN100 PN16 gas roots flowmeters. The joint-use flow range of the two standard meters is (1-400) m^3/h, which fully covers all the flowrate points in the real-flow calibration process.

Figure 1. The gas flow standard device of standard meter method.

3. Real-flow test and result analysis

In order to study the effect of pressure-sampling position on the K-factor of gas vortex flowmeter, three groups of real flow calibration tests were carried out in the laboratory. A) The influence of different pressure-sampling positions on the K-factor of the same flowmeter at different flowrate points; B) The influence of different pressure-sampling positions on the K-factor of different flowmeters with the same brand at the same flowrate points; C) The influence of different pressure-sampling positions on the K-factor of different brand flowmeters with the same nominal flowrate range.

Test A), the gas vortex flowmeter numbered as 01 with nominal flow range of (35-350) m^3/h, diameter of DN50, accuracy level of 1.0, no pressure-sampling hole and no temperature or pressure compensation in the body was selected to carry out the flow test. The test method and K-factor calculation were in accordance with JJG1029-2007 "Verification Rules for Vortex Flowmeters". Two calibration tests of K-factor have been carried out, and the pressure-sampling positions of the medium pressure of the flowmeter were in upstream 3-D position of the flowmeter and downstream 5-D position of the flowmeter ("-D"refers to Diameter of the tested flowmeter), respectively. The test flowrate points were 350m^3/h, 140m^3/h, 70m^3/h and 35m^3/h. Three times of calibrations were performed at each flowrate point and the average K-factor of the three calibrations was taken as the K-factor of the flowrate point. The test results are shown in Figure 2 and 3.

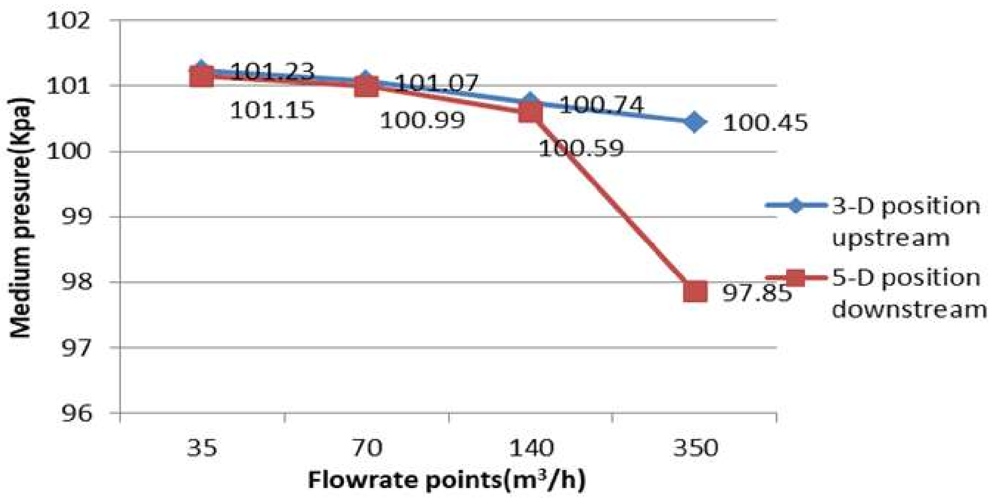

Figure 2. Medium pressure of upstream 3-D position and downstream 5-D position.

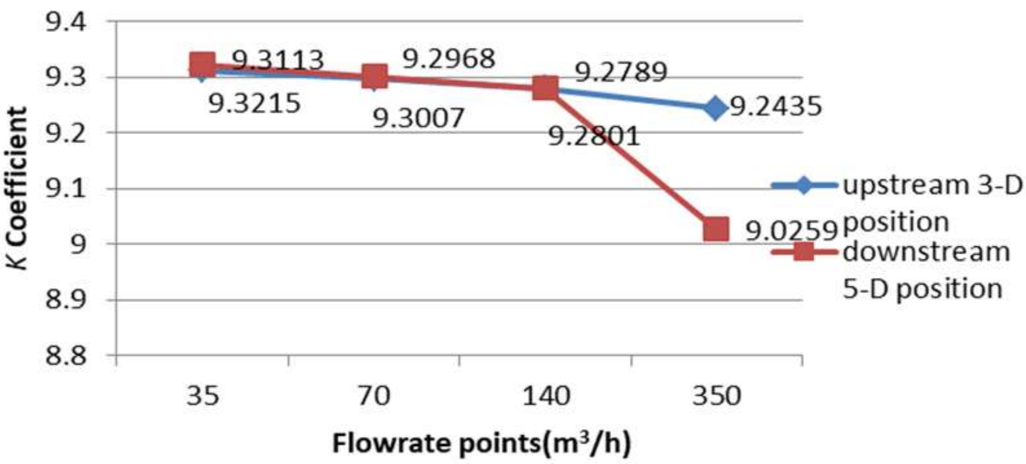

Figure 3. K-factor of 01 gas vortex flowmeter when pressure-sampling positions in upstream 3-D position and downstream 5-D position.

The test result shows that for a non-temperature or pressure compensation gas vortex flowmeter: a) pressure-sampling positions influents the K-factor of the same flowmeter at different flowrate points; b) under high flow velocity, along the gas flow direction, working medium pressure drops obviously; c) the pressure-sampling position has obvious influence on the K-factor at high flow velocity, however, it has little effect on the K-factor at medium and low flow velocity.

Test B), 4 gas vortex flowmeters marked as No. 01, 02, 03, 04 with nominal flowrate range of (35~350) m^3/h, diameter of DN50, accuracy level of 1.0, no pressure-sampling hole and no temperature or pressure compensation in the body, were selected to carry out the flow test. The test method and K-factor calculation were the same with test A. Two calibration tests of K-factor have been carried out successively, and the pressure-sampling positions of the medium pressure of the flowmeter were still in upstream 3-D position of the flowmeter and downstream 5-D position of the flowmeter. The test flowrate point was 350m^3/h. Three times of calibrations were performed with each flowmeter and the average K-factor of the three calibrations was taken as the K-factor of the flowrate point. Test results are shown in Figure 4 and 5.

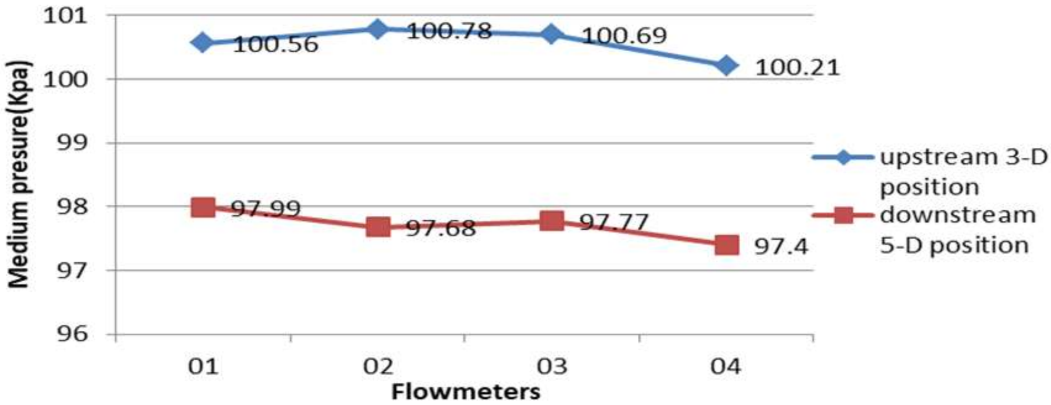

Figure 4. Medium pressure of upstream 3-D position and downstream 5-D position of different flowmeters with the same brand at the flowrate point of 350 m^3/h.

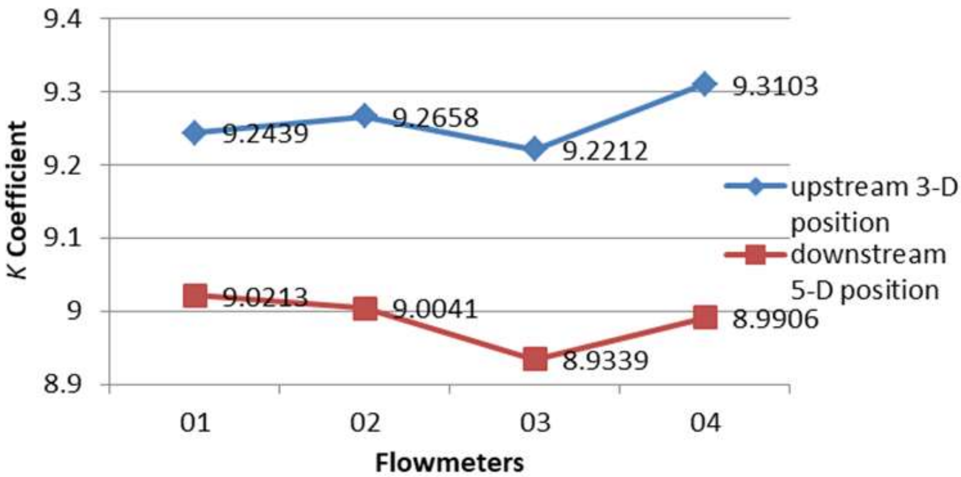

Figure 5. K-factor of 01～04 gas vortex flowmeters when pressure-sampling positions in upstream 3-D position and downstream 5-D position at the flowrate point of 350 m^3/h.

The test result shows that for gas vortex flowmeters without temperature or pressure compensation of the same type, at the high flow velocity, the medium pressure in the downstream 5-D position has a significant decrease trend compared with that in the upstream 3-D position. In addition, as the medium pressure decreasing, the calibration K-factors of all 4 gas vortex flowmeters tested significantly decreased. For them, the medium pressure in the downstream 5-D position decreased by 2.84% on average and the calibration K-factors decreased by 2.95% on average from that at the upstream 3-D position. These are consistent with the description in Chapter 2.1 “K is proportional to p_m/ p_s and the greater the pressure difference between the calibrated flowmeter and the standard flowmeter is, the greater the K-factor is”.

For gas vortex flowmeters with the same diameter, the flow range may vary from different manufacturers. It is found from the preceding test results that the pressure-sampling position influences on the calibration K-factor mainly occurs at the maximum flowrate point with the largest pressure loss. Thus, in test C, flowmeters with approximate nominal maximum-flowrate should be selected. In the following test, 4 gas vortex flowmeters marked as No. 01, 02, 03 and 04 with nominal maximum flowrate among (350~380) m^3/h, accuracy level of 1.0, were selected. None of the flowmeters body has the pressure-sampling hole.

The difference between the 4 four flowmeters lies in that the flowmeters numbered 03 and 04 were intelligent type with temperature and pressure compensation, the flowmeters numbered 01 and 02 were common type without temperature or pressure compensation. The calibration flowrate point was 350m^3/h. The test methods, calculation of the K-factor and the sampling positions were also the same as the test A. The test results are shown in Figure 6 and 7.

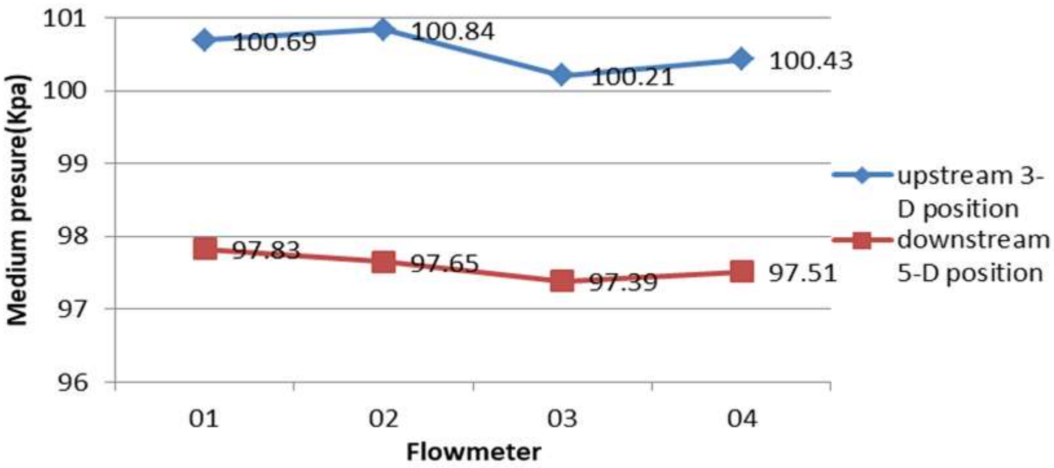

Figure 6. Medium pressure of upstream 3-D position and downstream 5-D position of different flowmeters with different brand at the flowrate point of 350 m^3/h.

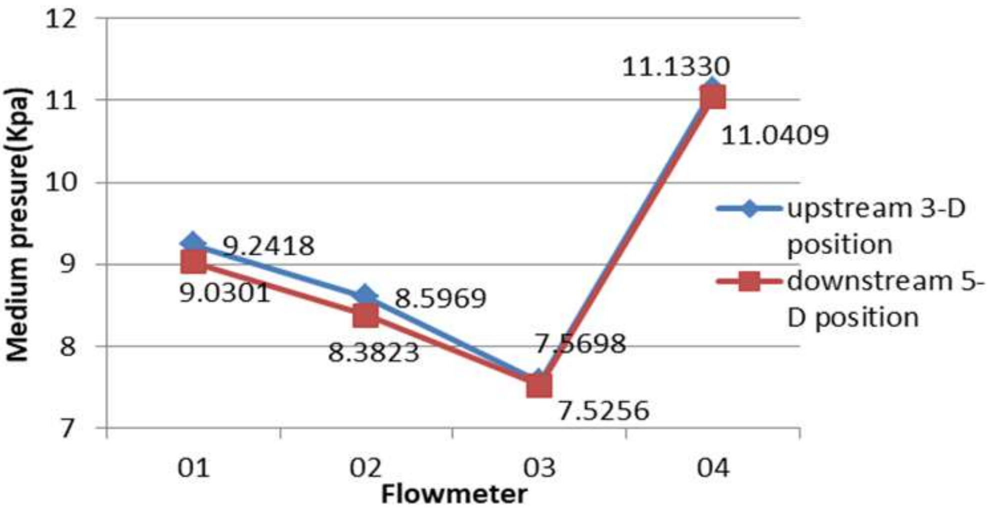

Figure 7. K-factor of different brand gas vortex flowmeters when pressure-sampling positions in upstream 3-D position and downstream 5-D position at the flowrate point of 350 m^3/h.

From the test results, it is found that for the gas vortex flowmeter, the temperature and pressure compensation function plays a decisive role in the degree of the pressure-sampling position affecting the calibration K-factor.

For gas vortex flowmeters numbered 01 and 02 without temperature and pressure compensation, produced by different manufacturers, in the case of high flow velocity, the medium pressure in the downstream 5-D position had a significant decrease trend compared with that in the upstream 3-D position, and the ratio of the decrease of the calibration K-factor was basically consistent with the medium pressure decrease, which matched the result of test B). However, for gas vortex flowmeters

IOP Conf. Series: Earth and Environmental Science **300** (2019) 022074 doi:10.1088/1755-1315/300/2/022074

numbered 03 and 04 with temperature and pressure compensation, produced by different manufacturers, in the case of high flow velocity, the downstream 5-D position, compared with the upstream 3-D position, although the medium pressure dropped significantly, a mere slight change were detected on their calibration K-factors. The reason is that the pressure drop has already been detected and measured by the pressure sensor inside the flowmeter with temperature and pressure compensation. And then the measurement result of the pressure drop is reflected to the pulse output, which corrects the calibration K-factor in the real flow test indirectly.

4. Conclusion

As a metrological calibration laboratory, it is necessary to consider the influence of the pressure-sampling position on calibration K-factor when calibrating a gas vortex flowmeter without temperature or pressure compensation in the real flow test method. Normally, when the pressure-sampling position is set in the downstream (2 ~7) D positions, the calibration K-factor at high flow velocity is significantly different from that of medium and low flowrate points. In this situation, it should be considered to communicate with the flowmeter manufacturer or check relevant references about whether sampling position should be set in the upstream when calibrating the K-factor of the flowmeter. For gas vortex flowmeters with temperature and pressure compensation functions, whenever at high or low flowrate, the influence of the pressure-sampling position on the calibration K-factor can be neglected.

References

[1] Sun Zhiqiang, Zhang Hongjian, Huang Yongmei, Research on Data Value Simulation of Fluid Field Characteristic of Vortex Flowmeter, Process Automation Instrumentation. 25 (2004) 10-13.

[2] Song Jiayi, Li Bin, Fan Chenyang, Numerical simulation on optimal pressure tapping position of vortex flowmeter based on CFD, Electronic Measurement Technology. 38 (2015) 1-4.

[3] State Bureau of Quality and Technical Supervision. Verification Rules for Vortex Flowmeters: JJG1029-2007. Beijing: Standards Press of China. (2007).

[4] ZHENG Dandan, ZHANG Tao, Nonlinear Modified Method on K-factor of Vortex Flowmeter Based on CPLD, Control and Instruments in Chemical Industry.3(2010)58-61.

[5] ZHENG Dandan, TANG Xinghua, Impact of Upstream Single Bend and Gate Valve on the Measurement Performance of Vortex Flowmeters, Journal of Tianjin University.44 (2011)1124-1130.

[6] Volker Hnas, Harald Windorefr, Comparison of pressure and ultrasound Measurements in vortex flowmeters, Measurement. 33 (2003) 121-133.