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Capacity improvement of MT primary standard facility

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Abstract

MT primary standard facility is the highest standard of natural gas metering field in China. In order to improve the capability level of the facility, the station took a series of measures. By adding a spherical tank insulation layer,changing the sampling position of the chromatograph and so on. After that, a new method was used to re-evaluate the uncertainty of the facility. At the same time, two nozzles were selected to carry out the repeatability and stability test, and the test results met the requirements of uncertainty. Afterall, the uncertainty level of the facility is increased from 0.1% (k=2) to 0.05% (k=2), and the uncertainty of the venturi nozzle outflow coefficient of calibration critical flow is 0.14%. The capacity improvement work makes the level of the mt primary standard facility improved significantly, and it's very important for the valuation transfer and traceability system.

1. Introduction

One station is equipped with 3 sets of standard devices, which are: primary mass time gas standard facility, secondary critical flow Venturi nozzle gas standard facility, working level standard meter gas flow standard facilities. The primary standard facility of the station first passed the standard construction assessment in 2012, and the uncertainty of standard construction is 0.1%, k=2[1]. After years of development, the primary standard facility of the station is currently responsible for the transmission of natural gas flow value of many metrological verification institutions. With the development of economy and metering technology of natural gas measurement accuracy demand is higher and higher, the trade consumption metering transition relationship between national economy and people's livelihood, the accuracy of each 0.05% difference can cause tens of million of the loss. So how to improve the capacity level of the primary standard facility is very important.

2. Laboratory conditions

2.1 Introduction of the primary standard facility

The high pressure natural gas flow primary standard facility can operates in the mass and time method as well as consists of the gyro electronic scale, the weighing tank, the fast acting valves and the data-collection and control system, as shown in Figure1. The gyro electronic scale means the secondary balance having sensitivity weight of 5g and has the weighing upper limit of 10t. The capacity of the weighing tank is 10 m^3, and its empty weight is 7t. The linkage fast acting valves cost less than 50ms as the time of their one-way reversing action and cost less than 5ms as the time difference of their two-way reversing action and the time difference of their linkage. After capacity improvement, the device operates in the uncertainty of 0.05 % and at the flow range between 8 m^3/h and 443 m^3/h as well as mainly applies to the calibration of the critical flow venturi nozzles, as seen in the paper of Guo [2].

Figure 1: The mass-time method high pressure natural gas flow primary standard facility.

2.2 Testing process of the primary standard

The testing process of the primary standard has three parts which include pre-run stage, inflation stage and calculation stage.

1) Pre-run stage. The upstream gas passes through the nozzle directly into the downstream pipeline. After the pressure at the inlet of the nozzle is stable and the temperature fluctuation is less than 0.1℃, the quick connector is removed,

and the mass of the spherical tank before inflation is weighed by an electronic balance. Meanwhile, the atmospheric pressure, ambient temperature, humidity and other parameters are obtained to calculate the buoyancy of the spherical tank before inflation, and then the quick connector is connected to prepare for inflation,which is shown in Figure2.

2) Inflation stage. Through the control system, the two fast reversing valves are combined to connect the downstream fully closed, and connect the full open of the ball tank, and the natural gas enters the weighing tank. When the preset time is reached, the quick reversing valves automatically switch again, allowing the upstream gas directly into the downstream pipeline. The charging time is set according to the throat diameter of the nozzle to ensure that the mass of natural gas poured into the spherical tank is between 100kg and 340kg.

3) Calculation stage. The quick connector is removed, and the mass of the inflatable spherical tank is weighed by the gyro electronic scale. Meanwhile, atmospheric pressure, ambient temperature, humidity and other parameters are obtained again to calculate the buoyancy of the inflatable spherical tank. The mass of natural gas flowing through the nozzle was calculated by the mass change of the weighing tank before and after charging, and the mass flow was calculated by combining the charging time measured by the system, and then the Reynolds number and discharge coefficient of the nozzle were further calculated to complete the value transfer process.

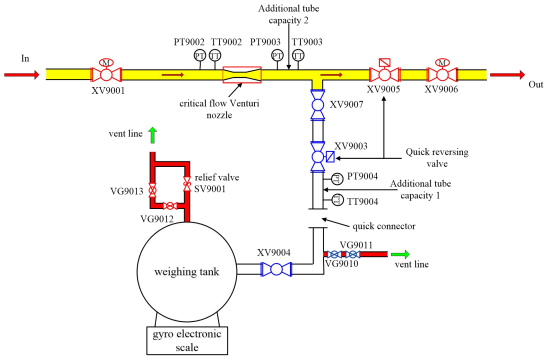

Figure 2: The pre-run stage of the mass-time method high pressure natural gas flow primary standard facility.

3. Promotion measures

3.1 Strictly control environmental parameters

Buoyancy is an important index affecting uncertainty. Under standard atmospheric pressure, the buoyancy of the spherical tank is about 35g when the temperature changes by 1℃.By studying the changes of the temperature field in the primary weighing process, adding a spherical tank insulation layer to reduce the influence of buoyancy component uncertainty. (e.g. Figure 1).

3.2 Improve the accuracy of natural gas composition measurement

Temperament components are used in mass calculations. Through the study of the components of the standard gas and the analysis of the impact on the uncertainty, the chromatograph matching standard gas from secondary standard gas to primary standard gas. The uncertainty of the primary standard was reduced to 0.05%(k=2) at large flow rate and 0.06%(k=2) at small flow rate through the research and equipment renovation of the sub-subject of the project.

By changing the sampling position of the chromatograph from the inlet of the station to the upstream manifold of the secondary standard facility. The time of gas flowing through a pipe as shown in table 2. Found that sampling sensor installed in different locations would get different results. The closer the sampling probe installation device, the closer it gets to the actual measured gas composition analysis results. Ultimately, the corresponding critical flow function calculation results are more accurate.

Table 1: The time of gas flowing through a pipe

Flow rate (m^3/h)	Length (m)	Inner diameter （m）	Time （min）	Total time （min）
448.00	125.795	0.813	8.75	9.93
448.00	15.5	0.813	1.08	
448.00	25	0.168	0.07	
448.00	5.77	0.219	0.03	
161.62	125.795	0.813	24.23	27.50
161.62	15.5	0.813	2.99	
161.62	25	0.168	0.21	
161.62	5.77	0.219	0.08	
80.61	125.795	0.813	48.58	55.14
80.61	15.5	0.813	5.99	
80.61	25	0.168	0.41	
80.61	5.77	0.219	0.16	

3.3 Evaluation of critical flow function uncertainty

In JJG 620, the uncertainty of critical flow function is specified as follows: 7.4.1 stipulates “Appendix B gives the value of common gases. The relative uncertainty of obtained from Appendix B is at the confidence level”. 8.3.1.7 stipulates the uncertainty value of the critical flow function in special cases, that is, “the formula can be regarded as zero if the gas and its state are the same while using or calibrating the nozzle”. For the critical flow venturi nozzle used with medium and high pressure natural gas, the calibration and using conditions are different, and the uncertainty should not be taken as zero. In order to evaluate the appropriate uncertainty, the use conditions of the nozzle calibrated by the primary standard facility and the change of the critical flow function since the establishment of the primary standard facility are statistically analyzed[3][4].

The typical operating conditions of the nozzle are various. Taking a nozzle as an example, the value of critical flow function is calculated under the high and low restrictions of the operating conditions. The calculation results are shown in table 2. When the nozzle calibrated by the primary standard facility is applied, the maximum deviation of the value of critical flow function is 5.49%.

Table 2: The calculation results of the Critical flow function in different conditions

SN	**Critical flow function**
Station 1	0.713988
Station 2	0.720081
Station 3	0.725261
Station 4	0.725456
Station 5	0.753270
Station 6	0.715314

For the test results of nozzle last ten years, the statistics of the value of critical flow function are detailed in table 4, the maximum deviation is 6.91% , which is no more than 7%. And 7% is used in the uncertainty evaluation as an uncertainty component.

Table 3: C_* of the last ten years

$C_{*\max}$	$C_{*\min}$	$\overline{C_*}$	Max deviation %
0.767000	0.715530	0.744762	6.91%

4. Uncertainty evaluation

The mass flow of the primary standard facility is calculated by Equation (1).

$$q_m=\frac{\Delta m}{t} \tag{1}$$

Where, q_m stands for mass flow, Δm stands for the quality of Natural gas through the measured flowmeter, t stands for the actual inflation time.

According to Equaion (1) and the method from JJF 1059.1, relative standard uncertainty of mass flow is calculated by Equation (2).

$$u_r(q_m)=\sqrt{u_r(\Delta m)^2+u_r(t)^2} \tag{2}$$

Where $u_r(q_m)$ stands for the relative standard uncertainty of mass flow, $u_r(\Delta m)$ stands for the relative standard uncertainty of natural gas quality by measured flowmeter, $u_r(t)$stands for the relative standard uncertainty of actual inflation time.

When calibrating the critical flow venturi nozzle with the primary standard facility, the discharge coefficient is calculated by Equation (3).

$$C_d=\frac{q_m\sqrt{\left(\frac{R}{M}\right)T_0}}{AC_*P_0} \tag{3}$$

Where q_m stands for the mass flow which recurrenced by the primary standard facility, R stands for universal gas constant, M stands for apparent molecular weight of natural gas, T_0 stands for the stagnation temperature at upstream inlet of critical flow nozzle, A stands for throat area of critical flow nozzle, C_* stands for critical flow function, P_0 stands for the stagnation pressure at upstream inlet of critical flow nozzle.

According to Equation (3), the uncertainty of discharge coefficient of critical flow venturi nozzle can be calculated by the Equation (4).

$$u(C_{di})=\sqrt{\begin{aligned}&u^2(A)+u^2(q_m)+u^2(p_0)+u^2(C_*)+\\&\frac{1}{4}[u^2(R_u)+u^2(M)+u^2(T_0)]+{E_{ri}}^2\end{aligned}} \tag{4}$$

Where $u(C_{di})$ stands for standard uncertainty of discharge coefficient of calibrated critical venturi nozzle, $u(A)$ stands for standard uncertainty for throat area of critical flow nozzle, $u(q_m)$ stands for standard uncertainty of recurrent mass flow in standard facility, $u(p_0)$ stands for standard uncertainty of stagnation pressure at upstream inlet of critical flow nozzle, $u(C_*)$ stands for the standard uncertainty of critical flow function, $u(R_u)$ stands for standard uncertainty for common gas constants, $u(M)$ stands for standard uncertainty for molecular weight of natural gas, $u(T_0)$ stands for standard uncertainty of stagnation temperature at upstream inlet of critical flow nozzle, E_{ri} stands for the repeatability of outflow coefficient at the th pressure point (Reynolds number).

The relative expanded uncertainty of mass flow of the original standard device for natural gas flow rate by mass time method is 0.05% (k=2). The combined expanded uncertainty of discharge coefficient of the critical flow venturi nozzle is 0.10% (k=2) .

5. Repeatability and stability results

The allowable variation of stability is the relative extended uncertainty of the standard device, i.e. 0.05%. Two ring throat critical flow Venturi nozzles were selected for stability assessment. During each test, the primary standard facility was used to measure the outflow coefficient of the venturi nozzle of critical flow for six consecutive times. The stability of the standard device was measured by dividing the difference between the maximum and minimum outflow coefficient during the stability assessment period by the average value of the maximum and minimum outflow coefficient. At the same time, two nozzles were selected to carry out the repeatability and stability test, and the test results met the requirements of uncertainty.

Table 4: The stability of one nozzle.

SN	1	2	3	4	5	6
Pressure (MPa)	6.23	6.22	6.22	6.23	6.23	6.23
$\overline{C}_d$	0.993 218	0.993 201	0.993 038	0.993 091	0.992 860	0.992 881
Stability (%)	0.036					
Permissible variation(%)	0.05					

The allowable variation of the repeatability test is the repeatability of the critical flow Venturi nozzle calibration, i.e., 0.02%. Two venturi nozzles were selected as test objects, and the mass time (MT) method was used to measure the gas flow standard device for six consecutive times, and the relative standard deviation of the outflow coefficient was used as the measurement repeatability of the standard device.

Table 5: The repeatability of one nozzle.

SN	1	2	3	4	5	6
Pressure (MPa)	6.23	6.22	6.22	6.23	6.23	6.23
$\overline{C}_d$	0.993 218	0.993 201	0.993 038	0.993 091	0.992 860	0.992 881
Repeatability (%)	0.005	0.005	0.012	0.014	0.011	0.012
Permissible variation(%)	0.02					

6. Conclusion

The technical measures given in this paper can effectively improve the measurement accuracy and uncertainty level of the primary standard facility of MT method. The uncertainty level of the facility is increased from 0.1% (k=2) to 0.05% (k=2), and the uncertainty of the venturi nozzle outflow coefficient of calibration critical flow is 0.14%. The capacity improvement work makes the level of the mt primary standard facility improved significantly, and it's very important for the valuation transfer and traceability system.

References

[1] MC Guo, B Yang, “The Uncertainty Evaluation and Confirmation of mass-time Method High Pressure Natural Gas Flow Primary Standard Facility”, *China Journal of Industrial measurement*, 25, 57-63, 2015.

[2] MC Guo, M Yang, B Yang, QQ Hou, ZL Li, “The Analysis of Influence Factors and Control Measures of mass-time Method High Pressure Natural Gas Flow Primary Standard Facility”, *China Journal of Industrial measurement*, 28, 1-6, 2018.

[3] ISO 9300: *Full Title of StandardMeasurement of gas flow by means of critical flow Venturi nozzles*, 2005.

[4] Zhang Zeguang, Li Xinwu,“Uncertainty Evaluation of Mass Substitution Weighing Method”, Metrology&Measurement Technology,24(04):23-35, 2004.