FLOMEKO 2022

Research on the traceability verification technology of quantity value of standard water flow facility based on mobile comparison method

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Abstract

Standard water flow facility (hereinafter referred to as the standard facility) is used for the calibration of cold and hot water flow meters. According to JJF1001-2011 *General Metrology Terms and Definitions* the standard facility needs to be verified that the quantity value stays in the original status in order to ensure the quantity value can meet the requirements during operation. And the verification will help to identify the inaccuracy, to shorten the traceability time after that, and to minimize the test costs and quality risk as far as possible.
This project studies a technical method for verifying the traceability of quantity value of standard water flow facility based on mobile comparison method. According to JJG164-2000 *Standard facilities for Liquid Flowrate*, the total uncertainty of the standard facility for cold and hot water flowrate is determined by calibrating the timer, commutator, scale, calibrated measuring volumetric tank, etc. and the traceability of the quantity value of the facility is completed. This project designs a removable measurement component that keeps it in use free from the influence of pipeline system, hydraulic stability, air tightness, flow fluctuation and so on on its recurrence value.

1. Introduction

1.1 Build a mobile measurement kits

The principle of the mobile measurement kits (hereinafter referred to as the MMK) is shown in Figure 1. The MMK are connected to the verified facility with two DN20-fixtures, there are the enough straight pipe section sealed on the front and back of DN20-fixtures. The test medium through the DN20 fixture to another DN20 fixture. Then the flow moves in the system by the order of: an upstream main pipe, an upstream straight pipe, two master meters, a downstream straight pipe, valve1 and/or valvel2, downstream main pipe, Afterwards the flow goes back to the pipeline through the DN20 fixture to the facility, After all it forms a verified circulation system.

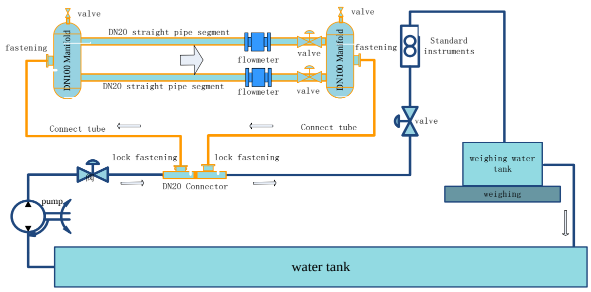

Figure 1: The working principle of the standard facility for the verification of the mobile measurement MMK.

1.2 Test theory and the measurement characteristics of the MMK

1.2.1 Concept of equal accuracy transfer

According to the principle of unequal accuracy of adjacent classes, the calibrated flowmeter of the same accuracy level cannot be calibrated with a standard flow facility with an accuracy level δ. But for the standard flow facility of "master meter method", regardless of whether the master meter is type A instrument or type B instrument, when used at a fixed point, the accuracy δ of the flow standard facility is:

$$\delta = \pm[E_z^2 + E_r^2]^{1/2}. \tag{1}$$

In the equation (1) E_z is the accuracy of the standard flow facility used to calibrate the master meter. E_r is the limit relative error of a single measurement of the master meter. The maximum values of Equation (2) and Equation (3) are taken when the instrument coefficient is used or not used.

$$(E_r)_i = \pm t_\sigma \frac{(\delta_k)_i}{\bar{K}} \times 100\%. \tag{2}$$

$$(E_r)_i = \pm t_\sigma \frac{(\delta_q)_i}{\bar{q}_i} \times 100\%. \tag{3}$$

In the formula δ_k and δ_q are the standard deviation of the instrument coefficient at a calibration point (when using the instrument coefficient) and the standard deviation of the flow correction value (when the instrument coefficient is not used) are respectively.

From Equation (1), it can be seen that:

a) When the master meter is fixed at a calibration point, the value of E_r is the repeatability of the master meter at the calibration point;

b) When $E_r \ll E_z$, the accuracy of the standard flow facility $\delta \cong E_z$, which is the concept of equal accuracy transfer. That is, if the repeatability of the master meter is high enough, the accuracy of the "master meter method" facility is roughly the same as that of the standard facility of the higher level.

1.2.2 Component metering characteristics

As can be seen from Equation (1), the MMK as a transfer criterion require excellent repeatability.

The first factor that can influence the repeatability is the impact that coming from installation of the MMK. The design of the MMK is as shown in Figure (1), the straight pipe section can fulfill the calming section of 20D in front and 10D at back. The DN100 sink at both ends plays a role in stabilizing the pressure. This overall design makes the MMK have good hydraulic characteristics, eliminating the influence caused by installation on different facilities.

The second factor that can influence the repeatability is the measurement performance of the electromagnetic flowmeter. This design selects two flowmeters with repeatability better than 0.07% to use in parallel. The repeatability of parallel usage is $1/\sqrt{2}$ of the repeatability of the single usage. It can be seen that with the design of parallel usage, the repeatability value is only a few tens of thousands and it is almost negligible. According to Equation (1) knows: compared with the facility with 0.2 class, the uncertainty transmitted by the MMK is almost the uncertainty of the facility.

2. Protocols

The test was carried out using the static mass method.

Experimental design:

1. Calibrate the electromagnetic flowmeter to obtain the indication error and repeatability;
2. Calibrate the MMK with three water flow standard facility to obtain the indication error, repeatability, measurement uncertainty;
3. Calibrate a water flow standard facility of a lower level with value transmission with the MMK to verify the facility if it meet requirement.
4. At different medium temperatures, calibrate the MMK to obtain the indication error and repeatability. The specific scheme is shown in Table 1

Table 1: Protocols.

	Description	Measuring point m^3/h	Number	Medium temperature (℃)	trial Master standardizer information
1	Calibrate a single electromagnetic flowmeter	3.50	6	19.8 (room temperature).	Number: 12180008 Standard facility for hot water flow Level 0.2
		2.625	6		
		1.75	6		
		0.875	6		
		0.35	6		
2	Calibrate the MMK	7.00	6	18.7 (room temperature).	Number: 12180018 Number: 12186688 Number: 12180057 Hot water flow standard facility 0.2
		5.25	6		
		3.50	6		
		1.75	6		
		0.70	6		
3	Calibrate the water flow verification facility (No. LL10267) with components	7.00	6	19.2 (room temperature).	subassembly
		5.25	6		
		3.50	6		
		1.75	6		
		0.70	6		
4	Calibrate MMK at different media temperatures	7.00	6	25、40、52	Number: 12180018 Hot water flow standard facility 0.2
		3.50	6		
		0.70	6		

3. Experimental implementation

3.1 Test 1: Calibration of Electromagnetic flowmeter at 19.8 ℃

The calibrated indication error and repeatability data are shown in Table 2:

Table 2: Electromagnetic flowmeter calibration data.

Parameter	Electromagnetic flowmeter 1 test data					Overall metering performance
flowrate (m^3/h).	0.352	0.875	1.746	2.621	3.447	
Indication error (%)	0.32	0.71	0.88	0.94	1.23	1.23
Repeatability (%)	0.06	0.07	0.05	0.04	0.03	0.07
Parameter	Electromagnetic flowmeter 1 test data					Overall metering performance
flowrate (m^3/h).	0.354	0.872	1.748	2.633	3.442	
Indication error (%)	0.51	0.62	0.64	0.7	0.91	0.91
Repeatability (%)	0.04	0.03	0.02	0.02	0.01	0.04

3.2 Test 2: Calibrate the MMK at normal temperature

3.2.1 Calibration data

Use three 0.2-Class facility to calibrate the MMK. The facilities that are used have the same accuracy level. The arithmetic average value of each facility calibration is used as the measurement result of the components, as shown in Table 3.

Table 3: Data of the MMK calibration.

	Hot water flow standard facility (number: 12180008).		Hot water flow standard facility (number: 12180018).		Hot water low standard facility (number: 12180057).		The attributes of kits	
Measurement point (m^3/h)	Relative indication error (%)	*u*(%)	Relative indication error (%)	*u*(%)	Relative indication error (%)	*u*(%)	Average indication error (%)	*u*(%)
6.889	1.10	0.081	1.08	0.098	1.25	0.091	1.14	0.052
5.254	0.83	0.083	0.85	0.104	0.84	0.094	0.84	0.054
3.494	0.69	0.077	0.85	0.098	0.66	0.085	0.73	0.050
1.747	0.64	0.074	0.72	0.094	0.71	0.084	0.69	0.049
0.706	0.46	0.071	0.45	0.091	0.45	0.081	0.45	0.047

3.2.2 Repeatability Comparison

With the facility 12180008, 12180018, 12180057 to calibrate the MMK, respectively, to obtain the Repeatability 1, Repeatability 2, Repeatability 3 of the MMK. The repeatability comparison with the repeatability of flowmeter alone is shown in Figure 2. It shows that the repeatability of the flowmeter in parallel usage is better than the repeatability of the flowmeter 1, which proves that the design of the MMK has excellent repeatability and is consistent with the theory.

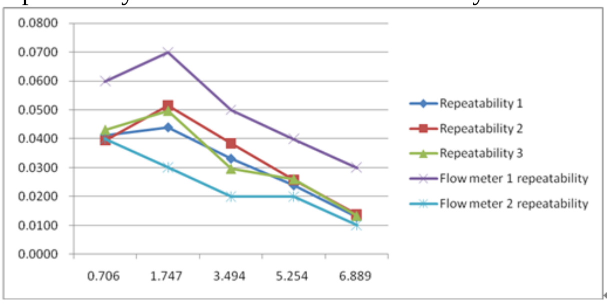

Figure 2: Repeatability comparison.

3.3 Test 3: Calibrate the water flow standard facility with MMK

Table 3 shows that the component already carries the calibrated quantity values of the three facilities, and this quantity value is used as a reference standard to calibrate the water flow calibration device (No. LL10267) using the total quantity method. By the calibration of the scale, commutator and timer, the uncertainty is U_{rel}=0.18%, k=2. This test uses the MMK to verify the reproduced quantity value of the device in use. The validation data were processed according to the same level of device comparison, and the data are shown in Table 4.

Table 4: Validation Data.

	Water flow verification facility (Number: LL10267).		Data processing		
flowrate point (m^3/h)	Relative indication error (%)	u (%)	y average	u(%)	$\lvert y_{lab}-y \rvert$
6.889	0.93	0.081	1.03	0.041	0.10
5.254	0.7	0.083	0.85	0.042	0.15
3.494	0.86	0.085	0.79	0.043	0.08
1.747	0.62	0.091	0.70	0.046	0.08
0.706	0.47	0.089	0.46	0.045	0.01

Table (4) shows that under each flow point

$$|y_{lab} - \bar{y}| \le \sqrt{\frac{n-1}{n}}\, U_{lab},$$

verifies that the quantity value of the facility reproduction meets the requirements.

3.4 Test 4: The temperature effect test to the MMK

The repeatability and relative indication error of each calibration point of the MMK at 19.8 ℃, 25 ℃, 40 ℃, and 55 ℃ are shown in Figures 4 and 3. The maximum difference between the indication error is 0.1% at different temperature change, and the maximum difference between repeatability is 0.016% at different temperature, which can be seen at (19.8~55) ℃ the indication error and repeatability of the electromagnetic flowmeter do not change much with temperature and the difference can be ignored. Accordingly, the MMK can complete the verification of the quantity value of the standard flow facility in the medium temperature range of (19.8 ~ 55) ℃.

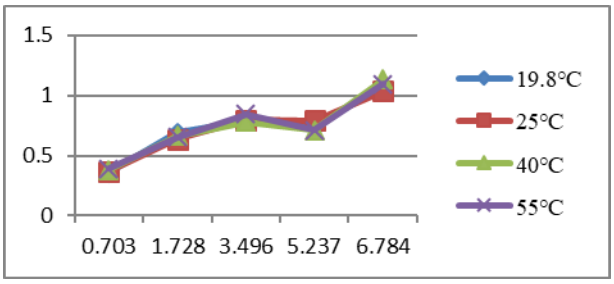

Figure 3: The indication error varies with temperature.

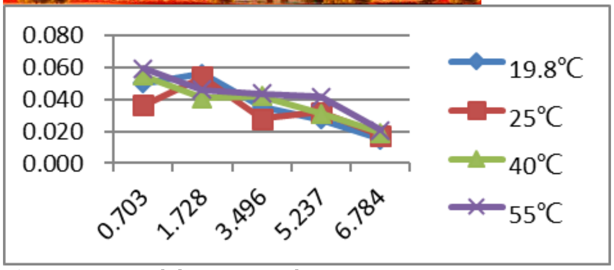

Figure 4: Repeatability varies with temperature.

4. Conclusions

This study adopts the theory of equal accuracy transmission, designs the mobile measurement reference standard MMK composed of two electromagnetic flowmeters connected in parallel. And with the reference of the standard hot water flow facility with multiple sets of test pipe segments and multiple meter fixtures, it carries out the research on the traceability verification technology of quantity value of standard water flow facility based on mobile comparison method. This study also focuses on analysis of repeatability and reproducibility of reference standards and implementation of measurement comparisons.

The experimental results show that:

a) The uncertainty of the reference standard measurement result is better than the uncertainty of the single flowmeter measurement result;

b) The reference standard has a more generous measurement uncertainty. For the perturbation of very individual standard device, it can play a certain offset, to ensure 0.2% uncertainty of the measurement results.

c) The electromagnetic flowmeter is less affected by the temperature of the test medium, and is more suitable as a reference standard for the traceability verification of the flow standard facility.

d) The standard facility for completing traceability is used to compare the quantity value. And the comparison results prove that the experimental study can ensure that the traceability of the quantity and value is consistent.

e) This study adopts the total amount calibration method, and verifies the quantity value reproduced by the traceable facility with reference standards. This method can be used for comparison and verification between facilities, and can also be used to reproduce the quantity value of the 0.2 class standard water flow facility of our institute, and the accuracy can be transmitted to the test equipment of various cities.

5. Next steps

a) The quantity of facility samples participating in this study is limited. The next step is to expand the quantity and scope of facility samples, especially representative facility, to provide more basic measurement data for this method.

b）This study takes the electromagnetic flowmeter as the transmission standard, but whether other flowmeters (such as ultrasonic flow meters, turbine flow meters, etc.) can be adapted as transmission standard. This requires follow-up experimental studies.

c) In this test, the medium temperature is measured up to 55 ℃. With the increase of the medium temperature, the affection of the temperature to the MMK can not be determined. The next step to increase the water temperature above 55 ℃ for experimental study.

d) Keep accumulating experimental experience, optimizing the operation steps, and completing the standardization of experimental methods.

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