Calibration of Flow Meter by Standard Meter Method and Evaluation of Uncertainty

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Abstract Flow meter is calibrated by flow standard facilitices by master meter method, is becoming trend of flow meter calibration method. The research of the calibration method and evaluation of uncertainty are focused in science field. This paper analyzes the influence facts of the process of calibration of flow meter by standard meter method around the calibration of turbine flow meter by standard turbine flow meter. establishes the mathematical model and give out the evaluation method and program of calibration uncertainty. The method was verified by test.

Kewords: Standard Meter Method Calibration Uncertainty turbine flowmeter

1. Introduction

Nowadays, using the flow standard facilities by master meter method to calibrate working flow meter is being a development trend of the calibration of the flow meter. It have many distinctive superiorities, such as the simple composition of the standard facility, economy, low measurement cost, high efficiency, easy to achieve dynamic measurement, calibration on site, expanding range etc. the research of its method of calibration and evaluation of uncertainty is concerned in the field of the calibration of flow meter. In this paper using standard turbine flow meter to calibrate working turbine flow meter for the example, the calibration principle and method of the standard meter method is analyzed, the mathematics model of data processed is established, the evacuation method and procedure of the standard uncertainty is give out.

1.1.Standard principle and mathematics model

The Standard meter method yet called the comparison method or the standard flow meter method. It uses a high level flow meter as a standard flow meter. The standard flow meter which has been calibrated by high level flow standard facilities can employ velocity flow meter, displacement flow meter, critical flow meter, mass flow meter and so on. The standard flow meter and the working flow meter are fixed in one pipe, then let fluid pass them with a specified flow rate in the same time interval, finally, compare the reading of the two flow meter' s, thus, working flow meter' s properties is acquired.

The flow standard facility which is employed standard flow meter as the standard instrument is called the flow standard facilities by master meter method. The expanded uncertainty of the reading error of the standard flow meter can't exceed half of the expanded uncertainty of the reading error of the working flow meter, its repeatability must be relatively high, and its long-term stability must be quite good. The facility must install a section of long enough straight pipe in flow meter's upstream and downstream, the difference of inside diameter of the straight pipe and flow meter can't exceed±3% ; when the temperature of liquid which pass through the transducer need measurement, the measurement place must be selected in the site of 5 times the pipe diameter of transducer, the measurement error can't exceed ±0.5℃, when the pressure of fluid which pass through the transducer need measurement , the measurement place must be selected in the site of 10 times the pipe diameter of transducer, the relativity measurement error can't exceed ±1%, when the calibration is beginning, the pipe should fill with fluid, and the flow is stability.

1.1.1. Single standard meter calibration system

As shown in Fig 1, the standard turbine flow meter S and the working turbine flow meter t are fixed in one experimental pipe, in this condition that the fluid flow, the mass flow rate q_m of the two flow meter is equal in any moment.

1.1.1.1. Liquid

1While the fluid is liquid, the mass flow rate of standard turbine flow meter and working turbine flow meter are represented by $q_{ms}$and q_{mt}, then ,

$$\left.\begin{aligned} q_{ms} &= q_{vs}\rho_s \\ q_{mt} &= q_{vt}\rho_t \end{aligned}\right\} \quad (1)$$

where q_{vs}, q_{vt} is the momentary discharge of the standard turbine flow meter and working turbine flow meter, m^3/h, ρ_s, ρ_t is the density of the standard turbine flow meter and working turbine flow meter, kg /m^3.

The instrument coefficient of working turbine flow meter can be expressed as:

$$K_t = \frac{N_t}{N_s} K_s = K_N K_s \quad (2)$$

where K_t is the instrument coefficient of the working turbine flow meter,m^{-3},N_t is the pulse number of the reading of the working turbine flow meter in the same time interval, K_s is the instrument coefficient of the standard turbine flow meter, m^{-3}, N_s is the pulse number of the reading of the standard turbine flow meter in the same time interval, K_N is the ratio of the pulse number of the working turbine flow meter and the standard turbine flow meter in the same time interval.

1.1.1.2. Gas

While the fluid is air, the volume flow rate of standard turbine flow meter and working turbine flow meter are represented by q_{vs} and q_{vt}, then ,

$$q_{vt} = q_{vs}\frac{p_s T_t}{T_s p_t} \quad (3)$$

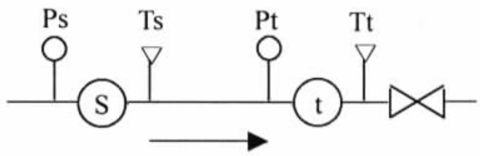

Fig. 1 single standard meter calibration system

in the standard flow meter, Pa, T_s is the thermodynamic temperature of the gas in the standard flow meter, K, p_t is the absolute pressure of the gas in the working flow meter, Pa . T_t is the thermodynamic temperature of the gas in the working flow meter, K.

the instrument coefficient of working turbine flow meter can be expressed as:

$$K_t = K_N K_{PT} K_S \quad (4)$$

where k_{pt} is the revising coefficient of the pressure and temperature.

1.1.2. Standard meter calibration system in Parallel connection

Several standard turbine flow meters are fixed in the way of parallel connection, then the working turbine flow meter is fixed with them in the way of series connection in one experimental pipe, these constitute the calibration system. This system can expand the range. Therefore, this can accomplish the calibration of working turbine flow meter which have high range. Shown as in the Fig 2.

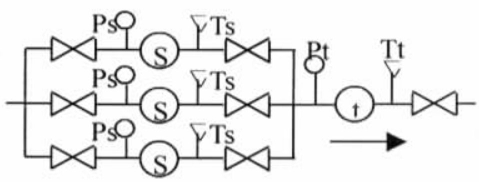

Fig.2 standard meter calibration system in parallel connection

1.1.2.1.Liquid

While the fluid is liquid, the mass flow rate of standard turbine flow meter and working turbine flow meter are represented by q_{mt}, then ,

$$q_{mt} = q_{vt}\rho_t = \sum_{i=1}^{n} q_{vsi}\rho_{si} \quad (5)$$

where ρ_t is the density ahead of the working turbine flow meter, kg /m^3, q_{vt} is the volume flow rate ahead of the working turbine flow meter, m^3/h, q_{vsi} is the volume flow rate of the ith standard turbine flow meter, m^3/h, ρ_{si} is the density ahead of the ith standard turbine flow meter, kg /m^3.

The instrument coefficient of the working turbine flow meter can be expressed as:

$$\frac{1}{K_t} = \sum_{i=1}^{n} K_{Ni} K_{si} \quad (6)$$

where K_{si} is the instrument coefficient of the ith standard turbine flow meter, m^{-3}, K_{Ni} is the ratio of the pulse number of the working turbine flow meter and the ith standard turbine flow meter in the same time interval.

1.1.2.2. Gas

The instrument coefficient of the working turbine flow meter can be expressed as:

$$K_t = \frac{p_t N_t}{T_t \sum_{i=1}^{n} \frac{p_{si} N_{si}}{T_{si} K_{si}}} \quad (7)$$

where p_t is the pressure of the gas in the working flow meter, Pa, T_t is the thermodynamic temperature of the gas in the working flow meter, K, p_{si} is the absolute pressure of the gas in the ith standard flow meter, Pa, T_{si} is the thermodynamic temperature of the gas in the ith standard flow meter, K.

2.Calibration uncertainty analyzing and computing instances

The follow is that a standard turbine flow meter is used for the standard instrument to calibrate a working turbine flow meter at fixed point. The working material is water.

2.1. Mathematics model

The instrument coefficient of the working turbine flow meter can be expressed as:

$$K_t = \frac{N_t}{N_s} K_s \quad (8)$$

where N_t is the accumulative pulse number of the reading of the working turbine flow meter in the same time interval, K_s is the instrument coefficient of the standard turbine flow meter, N_s is the accumulative pulse number of the reading of the standard turbine flow meter in the same time interval.

The instrument coefficient K_{ij} of the ith standard turbine flow meter in the jth calibration can be expressed as:

$$K_t = \frac{N_{tij}}{N_{sij}} K_s \quad (9)$$

where Nt_{ij}, N_{sij} are the accumulative pulse number of the working turbine flow meter and the standard turbine flow meter on the ith flow rate point in the jth calibration in the same time interval. the instrument coefficient K_{ti} of every flow rate point is :

$$K_{ti} = \frac{\sum_{i=1}^{m} K_{ij}}{m} \quad (10)$$

where m is the time of the calibration in the ith flow rate point, normally, m=3 or m=6.

The instrument coefficient K_t of the working turbine flow meter is:

$$K_t = \frac{(K_{ti})_{\max} - (K_{ti})_{\min}}{2} \quad (11)$$

The repeated ability $u_r(K_{ti})$ of the instrument coefficient in every flow rate point is:

$$u_r(K_{ti}) = \frac{1}{K_t}\frac{(K_{ij})_{\max} - (K_{ij})_{\min}}{d_n} \ldots\ldots\ldots (m=3) \quad (12)$$

$$u_r(K_{ti}) = \frac{1}{K_t}\sqrt{\frac{\sum v_i^2}{m-1}} \ldots\ldots\ldots (m=6) \quad (13)$$

where d_n is the coefficient of the difference.

$V_i = K_{ti} - K_{tj}$.

2.2. Computing instances

The calibration is proceeding in the flow standard facility which use standard turbine flow meter as standard instrument, 6 flow rate point should be selected, and 6 times measurement should be done in every point, the calibration recording and the computing result are listed in table 1. The Calibration uncertainty of the turbine flow meter is listed in table 2.

Table 1 the Calibration Recording and the Computing Result of the turbine flow meter

The experimental items	The flow rate of the calibration point (expressed as the percentage of the full range %)						K
	10	20	40	60	80	100	
Frequency $f(1/s)$	53	104	212	213	418	520	
The instrument coefficient $k_{ti}(L^{-1})$	158.41	157.61	156.88	156.74	156.52	156.42	157.42
The repeated ability $E_{ti}(\%)$	0.0079	0.0079	0.0031	0.0031	0.0031	0.0031	

Table 2 the Calibration uncertainty of the turbine flow meter

Serial number	sign	The source of the uncertainty	Inputting uncertainty (%)	Probable distribution	Cover factor	The standard uncertainty of y $u_r(x_i)$/%	Sensitive coefficient C_{ri}	The contribution to the combined uncertainty $u_r(x_i)$/%
1	S	Standard	0.1	Normal distributing	2	0.05	1	0.05
2	T	Temperature	2.5	Rectangular		1.4	4×10^{-3}	0.01
3	t	Time	0.003			0.00	1	0.00
4	Ki	Repeated				0.01	1	0.01
5	L	Fixed site	0.18			0.10	1	0.10
Combine standard uncertainty u_{cr}=0.12%; Expanded uncertainty U_r=0.24, coverage factor k=2								

2.2.1.Standard device uncertainty $\mu_r(s)$

As flow standard facilities by master method, is used for calibrating with turbine flow Meter, its uncertainty is 0.1%, coverage factor k equal to 2.

2.2.2.Temperature measurement uncertainty $\mu_r(T)$

Maximum Permissible Errors of temperature meter in use is ±0.5°C, liquid temperature is 20°C, the result ($\mu_r(T)$ =0.5/20=2.5%) is acquired according to rectangular distribution.

$\mu_r(T)$=1.4%

$$C_r = \beta T = 2.0\times10^{-4}\times 20 = 4\times10^{-3}$$

2.2.3.Time measurement uncertainty $\mu_r(t)$

Maximum Permissible Errors of counter is 0.001s, the shortest time of one calibrating is 30s. The result ($\mu_r(t)$= 0.001/30=0.003 %) is acquired according to rectangular distribution.

2.2.4. Repeatability of meter coefficient at every flow point $\mu_r(K_{ti})$

Repeat Characteristic of Meter Coefficient at Every Flow Point $\mu_r(K_{ti})$ choices the biggest.

2.2.5.Meter Coefficient Changing Uncertainty from Installing Place of Standard Meter $\mu_r(L)$

The difference of Installing place of Standard Turbine Meter in front and back of the working turbine flow meter will result in the changing of the instrument coefficient, and then lead to the measurement uncertainty. Go through testing and calculating, the result ($\mu_r(L)$ =0.18%) is acquired according to rectangular distribution.

2.2.6.Uncertainty of the density measurement $\mu_r(\rho)$

when the temperature is within 20±5℃, $\mu_r(\rho)$ can be ignored, otherwise the influence of density measurement uncertainty will be considered.

In this paper it is supposed that pipe condition of the standard flow facilities by master meter fit the request of the working meter, otherwise the uncertainty of the instrument coefficient changing which aroused by difference length of the straight pipe will be considered.

3.Experimental verification

The above result of the working turbine flow meter which calibrated in standard meter method is validated by using the customary standard flow facilities, two results are anastomosing.

According to the analysis mentioned above, the result of the two calibration method on using standard meter method to calibrate working turbine flow meter and using customary standard flow meter to calibrate working turbine flow meter is anastomosing, it is feasible of the mathematical model of data processing and the evaluation method of standard uncertainty. Flow meter is calibrated by flow standard facilities by master meter method, is becoming a trend of flow meter calibration method. It is because that it is of unique superority such as saving investment, high measurement ratio, low measurement cost etc.

Reference

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