Establishment of a new hydrocarbon flow standard facility at NIM

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Abstract: A new oil flow standard device is built with dual-standard by National Institute of Metrology(NIM). The two types of standards are installed in the device, namely, new-type auto-load electronic scale and standard volumetric tube. Working medium: transformer oil, with a kinematic viscosity of [2]1mm2/s; flow range: (1.2~120) m^3/h; the extended uncertainty of the oil flow meter with double standards: $U_{rel}\leqslant0.05\%$ (k=2); the extended uncertainty for mass method: U_{rel}=0.04%; the extended uncertainty for volumetric tube U_{rel}=0.03%. The repeatability is less than 0.02%. The large-caliber standard comparison group uses turbine flowmeter as the master meter and ultrasonic flowmeter as the auxiliary monitoring meter; in the small-caliber group, only Coriolis mass flowmeter is exclusively used as comparison standard. According to the test results of two types of flowmeter, the measurement uncertainty and repeatability are less than 0.05% and 0.02%, respectively. In order to raise the uncertainty of mass method, researchers specially design auto-load calibration system for electronic scale and a new-type rotary Diverter.

Key words: oil flow meter, double-standard meter, comparison standard group, uncertainty, Diverter, auto-load calibration system

1. Introduction

The hydrocarbon flow standard facility built by National Institute of Metrology is a comprehensive hydrocarbon flow reference that combines volumetric method with mass method. The highest standard for the facility is the standard volumetric meter and the electronic scale with auto-calibration system. It is also equipped with high-accuracy process instrumentation (including timer, calculator, and sensors for pressure, temperature, density and viscosity). They are all traced to the the highest standards at NIM. The working medium for the facility is transformer oil. Besides, standard or standard group is installed in the pipeline. Research, verification, testing and calibration can be conducted on the metrological characteristics of oil flow meter.

In order to carry out value comparison between oil flow standard, a set of standard group is built to conduct experiments based on volumetric method and mass method. In this way, the influencing factors for the standard in different methods are studied in order to unify the measurement results by means of volumetric method, mass method and conventional flow meter method.

2. Double-standard hydrocarbon flow facility

Figure 1 is the sketch for the exterior of double-standard oil flow meter. Figure 2 is the process flow diagram.

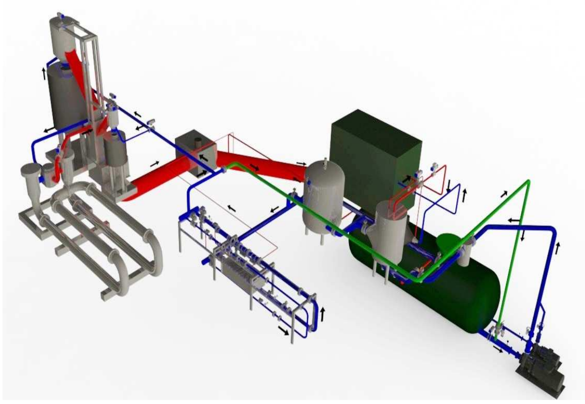


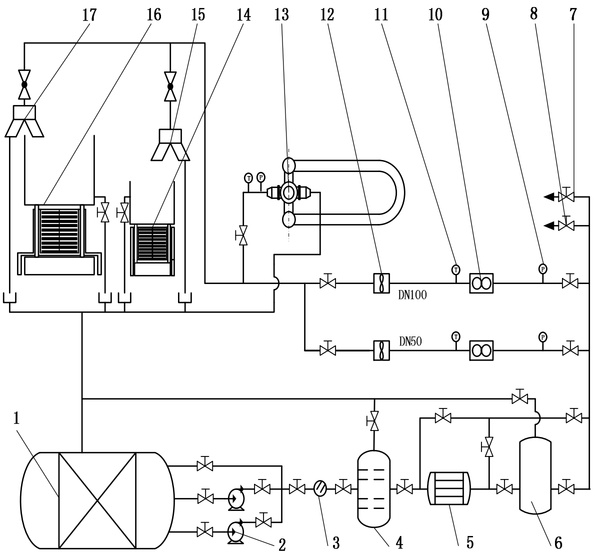
Figure 1 Diagram for the exterior of hydrocarbon flow standard

2.1 Mass method

The structure and working principle of the oil flow standard device based on mass method are shown in Figure 2.

(1) Standard

With two high-accuracy electronic scales as the mass standard, real-time measurement of temperature and pressure is conducted to correct the liquid density and convert the mass value to standard volume value. The measuring ranges for the two electronic scales are 300 kg and 3, 000 kg



1.storage tank 2.pump 3.filter 4.gas-departed vessel 5.heat exchanger 6.pressure stabilized vessel 7.viscosity meter 8.density meter 9.pressure meter 10.reference meter 11.thermormetry meter 12. MUT 13.volume pipe 14.300Kg auto-load system 15.DN50 diverter 16.300Kg auto-load system 17. DN100 diverter 18.3t auto-load system

Figure 2 The process flowchart for the double-standard oil flow meter

respectively, with the composite extended uncertainty exceeding 0.05%. In order to ensure the accuracy, stability, repeatability and detection efficiency of the electronic scale, a meticulous design and processing based on anti-vibration and auto-load calibration structure is carried out for the base.

The specially designed stainless steel weighing storage is equipped with liquid level sensor, temperature sensor and anti-overflow structure so that the detection process is accurate, stable and swift. Equipped with corresponding oil drain valve with pneumatic switch and autoloading calibration system, the electronic scale can be conveniently installed or separate from electronic scale.

(2) Diverter

A special open diverter r and duckbill-shaped nozzle are developed for the oil flow meter to reduce the impact of uncertainty in commutation process on the flow rate measurement. The diverter is equipped with different calibers and allows the forward and reverse fluid flow. The duration of the Diverter switch is triggered. The pulse counting of the flow meter is simultaneously controlled. It also combines the computer-based data processing. The Diverter is pneumatically driven and electronically controlled, and has a host of advantages such as fast speed, high symmetry, low stroke difference, high accuracy and high stability.

(3) Container with pressure stabilizing function

The oil flow standard device is equipped with pressure stabilizing module, because the pressure stability in the oil flow meter has a direct bearing on the stability of the flow in the experiment, the uncertainty of the device and the reliability of the flow rate data measured.

In order to improve the stability of the device, the oil pump relies on the double pressure stabilizing methods that combine frequency conversion with container capable of pressure stabilizing, to effectively eliminate all the effects of high-frequency pulses produced by the change in oil pump displacement. The container with pressure stabilizing function is a sealed container, the interior of which can be divided into two parts, for working and pressure stabilizing respectively. The oil pump drives the oil to the container through the valve and oil inlet. After passing the metal mesh of varying specifications to reduce the kinetic energy and release gas, the oil climbs over the specially designed partition plate to flow out through the outlet. Then, the pressure, temperature and flow reach their balance through the pressure regulating valve to realize the goal of pressure stabilizing.

(4) Oil storage tank

According to the overall requirements of oil flow standard device, the oil storage tank should keep the liquid level inside unchanged when the weighing load in the container reaches its maximum, so that the oil absorption level of the oil pump will not affect the stability of oil feeding. The liquid level change in the oil storage tank should be elaborately calculated and designed according to the stability and accuracy grade of the oil flow meter. The device should also possess such functions as oil storage, air venting, microwave heating, heat preservation and the measurement for the liquid level and oil temperature.

(5) The instruments

This device is equipped with a certain number of meters performing the functions of remote transmission and on-site parameter inspection (measuring temperature, pressure, density and viscosity).

The accuracy of temperature and pressure sensor can make a great difference to the accuracy of the oil flow meter. Therefore, it is of vital importance to select high-accuracy and high-stability instruments. The measurement ranges of the pressure and temperature sensors are as follows respectively: 0～1. 0MPa, accuracy ≤0.1%; 0~50℃, accuracy ≤0.1%.

2) The measurement model for flow calculation based on mass method

(1) When the standard for the balance is used, the measurement model for the mass flow rate is calculated:

$$M = m\left[1-\rho_a\left(\frac{1}{\rho_m}-\frac{1}{\rho_w}\right)\right] \quad (1)$$

where

where M is the mass of oil (kg);

m is standard weight for balancing the mass (kg);

ρ m is the density of the balance weight (kg/m^3);

ρ a is the air density (kg/m^3);

ρ w is the density of oil (kg/m^3);

Mass flow rate

$$q_m = \frac{m}{t}\left[1-\rho_a\left(\frac{1}{\rho_m}-\frac{1}{\rho_w}\right)\right] \quad (2)$$

When the standard for electronic scale is used, the measurement model for the mass flow rate is calculated.

$$q_m = \frac{m_{示}}{t}\left(1+\frac{\rho_a}{\rho_w}\right) \quad (3)$$

where m is the mass reading from the electronic scale;

All other symbols have the same meanings as those in Formula (1).

2.2 Volume method

Volumetric tube is a type of circular tube, with its internal surface precisely machined. It has a certain length and constant inner diameter. It is composed of measurement standard section, displacement meter (sphere or piston), the detection switch that accurately measures the position of the displacement meter and the auxiliary devices.

Volumetric tube is used to detect the standard of integrating flow meter. When the oil steadily passes through the volumetric tube, the oil volume displaced in the standard measurement section between the two detection switches (displaced volume) is measured by the displacement meter. Then the volume flow rate through the volumetric tube within this time interval could be known.

The measurement model for the displaced volume calculation in the standard measurement section in the volumetric tube

After concrete derivation, the mathematical model for the displaced volume calculation under standard state (20℃,101325Pa) is expressed as follows:

$$V_{p,20} =$$

$$\mathrm{V}_{P,20} = V_s\left\{1+\beta_s(t_s-20)+\beta_w(t_P-t_s)-\beta_P(t_P-20)-P_P\left(\frac{D}{Et}+F_w\right)\right\} \quad (4)$$

V_s is the nominal volume read from the standard at t_c℃.

$\beta_s(t_s-20)$ is the corrected value for the standard;

$\beta_w(t_P-t_s)$ is the corrected value for the oil expansion caused by temperature difference;

$\beta_P(t_P-20)$ is the corrected value for the volumetric tube wall;

$\left(1+P_P\frac{D}{Et}\right)$ is the corrected value for the compression of the volumetric tube material;

The measurement model for the integrating volume flow rate V_c when integrating volumetric tube to detect the flow meter

$$\mathrm{V}_t = V_s\left[1+\beta_w(t_P-t_s)\right]\left[1+P_P\frac{D}{Et}\right] \quad (5)$$

The symbols in the formula are similar with those in (4).

3 Uncertainty analysis

When the electronic scale is used as the standard, the uncertainty of the oil flow meter is given by Formula (3). The calculation results of relative uncertainty of input and sensitivity are listed in Table 1.

Table 1 Uncertainties based on mass method

	symbol	$u_{ri}(x_i)$	$c_{ri}(x_i)$	$c_{ri}(x_i)u_r(x_i)$
1	m	156×10^{-6}	1	156×10^{-6}
2	t	107×10^{-6}	-1	-107×10^{-6}
3	ρ_a	9550.06×10^{-6}	0.0015	14.30×10^{-6}
4	ρ_w	3608.34×10^{-6}	-0.0015	-5.42×10^{-6}

$U_r(q_m) = 0.04\%$ (k=2)

The uncertainty of volume method $u_{cr}(q_v)$

According to (4) and the representation

The relative uncertainties of input and sensitivity coefficients are listed in Table 2.

Table 2 Uncertainties of volumetric tube

	symbol	$u_{ri}(x_i)\%$	$c_{ri}(x_i)$	$c_{ri}(x_i)u_r(x_i)\%$
1	V_s	0.0144	1	144×10^{-4}
2	t	2.98×10^{-4}	-1	-2.98×10^{-4}
3	β_s	5.57	-165×10^{-6}	-9.525×10^{-4}
4	β_w	14.4	4×10^{-5}	5.76×10^{-4}
5	β_p	11.5	-184.5×10^{-6}	-21.22×10^{-4}
6	t_s	0.577	-3340×10^{-6}	-19.27×10^{-4}
7	t_p	0.577	3262×10^{-6}	18.82×10^{-4}
8	P_p	0.577	-210×10^{-6}	-1.21×10^{-4}
9	D	0.029	6.48×10^{-5}	0.014×10^{-4}
10	E	5.77	6.48×10^{-5}	2.70×10^{-4}
11	t	2.89	6.48×10^{-5}	1.3×10^{-4}
12	F_w	5.77	-147×10^{-6}	-8.48×10^{-4}
13	V	0.013	1	0.013

$$u_{cr}(q_{vp_s}) = 148.75\times10^{-4} \approx 0.015\%$$

$$U_{cr}(q_{vp_s}) = 0.03\%$$

5. Conclusion

A dual-standard hydrocarbon flow facility is established at NIM. The uncertainty of mass method is 0.036% and volume method is 0.026. The stability of facility is less than 0.18%. The two method can be compared directly.

The auto-load calibration system for the electronic scale is specially designed. It can be used for timely calibration and detection of the electronic scale in flow rate calculation based on mt method. It is a self-checking device that ensures the accuracy and reliability of the weighing system. The self-checking without changing the installation position of the weighing bottle can be achieved.

The specialized open diverter for the oil flow meter is also ingeniously designed. The diverter is equipped with different calibers and allows the reverse and forward fluid flow. The duration of the switching is triggered. The pulse counting the flow meter is initiated simultaneously. It also combines the function of computer-based data processing. It is pneumatically driven and electronically controlled, with high accuracy and stability. The uncertainty of the flow rate measurement results is thus improved.

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