A kind of New Calibration Method for the Volume of Bell Prover

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Abstract: A new $1m^3$ bell prover is developed by flow laboratory in china national institute of metrology. Laser tracker and laser interferometer is applied to measure the volume of the bell prover. The result suggests this kind of geometric method is feasible and the uncertainty of result is less than 0.1%.

Keywords: Bell prover Volume Geometric Laser interferometer Laser tracker

1. Introduction

$1m^3$ bell prover gas standard facility is developed by flow laboratory in NIM (China National Institute of Metrology). Compare to the old bell prover in NIM the structure of the new is optimized and the oil with low viscosity is taken as sealing liquid. The main body is precision-machined to acquired fine roundness and roughness of inner and outer surface. The temperature and humidity inside of the bell prover are measured to make gas condition inside of the bell prover certain. A simplified drawing is given in figure 1, and the main characteristics are given in figure 2.

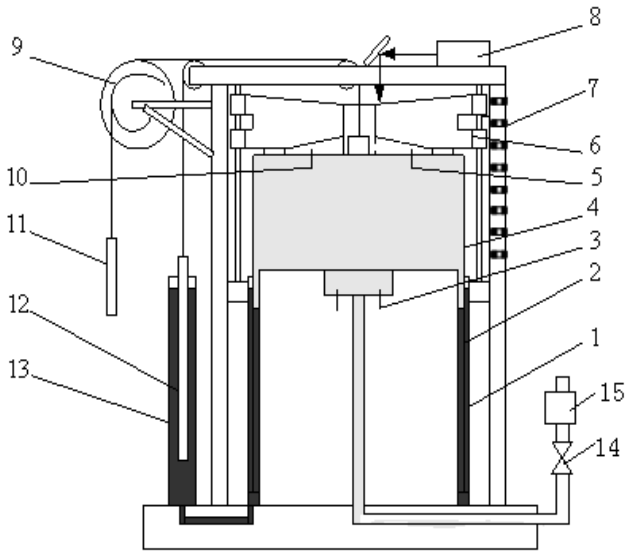

figure 1 simplified drawing of $1m^3$ bell prover facility

1-sealing tank 2-sealing liquid 3-humidity sensor 4-bell prover 5-thermometry meter 6-bearing 7-optic-electricity sensor 8-laser interferometer 9-buoyancy compensation structure 10-pressure sensor 11-buoyancy compensation weighing 12-liquid level compensation weighing ; 13- liquid level compensation tank 14-valve 15-flowmeter under test

figure 2 main characteristics

Main characteristics of 1m3 bell prover	
Volume	1 m^3
Flow range	(0.5～60)m^3/h
Pressure	2000Pa
Pressure fluctuation	±5Pa
Uncertainty	≤0.1%

In earlier times the 100 dm^3 bell prover in NIM is calibrated by volume method. The constant room temperature is necessary to make the result of volume to be good repeatability. The 500 dm^3 bell prover or the larger is calibrated by geometric method. The π ruler commonly is used to measure the outer diameter and the caliper is used to measure the stroke of the bell prover. The uncertainty of result from the geometric method is difficult to be estimated because of manipulation difference from different operator. Base on above another geometric method is adopted to calibrate the volume of newly-developed 1 m^3 bell prover. Laser interferometer and Laser tracker is advantaged obviously with their non-invasion and high precision. And two of these geometric instrumentations are applied to measure stroke and inner diameter of the new bell prover.

2. Analysis and result

Because of fine roundness of new bell prover the shape of inner wall is considered to be shape of cylinder. The volume of bell prover is a function such as,

$$V = \frac{p}{4} d^2 \cdot h[1 + 2a_B(q - 20)] \tag{1}$$

V —the volume of the bell prover; d —inner diameter of bell prover h —the stroke between two optic-electricity sensors； α_B——Coefficient of thermal expansion of bell's materials； θ—— the temperature of the bell body

According the function above the diameter of the cylinder, stroke of between two optic-electricity sensors and temperature of the bell must be measured.

Diameter

Laser tracker is used to acquire the coordinate value in pre-built air coordinates. The results those are coordinate values of totally 176 points being distributed in 16 sections on the inner wall surface is fitted to 16 round curves. The mean of all these diameter values are taken as inner diameter value of the bell prover. The measurement basic way is given in figure 3. The result is given in figure 4.

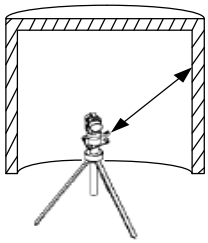

Figure 3 The measurement basic way of inner diameter

Figure 4 The results of inner diameter

SN	Diameter（mm）
1	1046.580
2	1046.342
3	1046.202
4	1046.254
5	1046.292
6	1046.198
7	1046.174
8	1045.622
9	1046.052
10	1046.154
11	1045.962
12	1045.962
13	1045.854
14	1045.890
15	1046.048
16	1046.092
Mean（mm）	1046.105
Standard deviation（%）	0.02

Stroke

To calibrate flow meter conveniently 11 optic-electricity sensors is fixed in the moving direction of bell prover. The any 2 sensors can been taken as the starting-point and the end-point. When the different sensors are selected the stroke and the volume of bell are different. The distance between two optic-electricity sensors, i.e., stroke is measured by laser interferometer the resolution of that is 1 μ .during the process of measurement the synchronization of laser interferometer and optic-electricity must been guaranteed. To realize the synchronization the pulse from optic-electricity controls the begin and stop of laser interferometer. The MPE of the method is less than 0.1 μ that is equal to a pulse from laser interferometer. The principle is given in figure 5. The result of $1m^3$ and 100 dm^3 stroke is given in figure6.

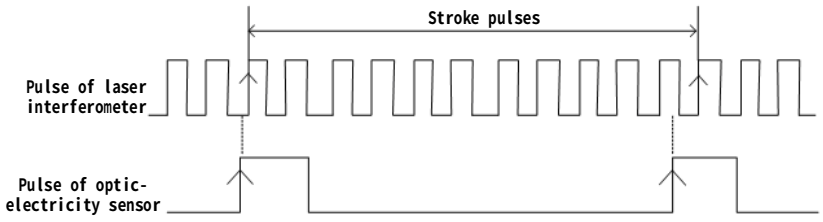

figure 5 synchronization measurement principle

figure 6 The results of stroke

The volume	Start trigger position(mm)	End trigger position(mm)	stroke(mm)
	The laser interferometer reading		
100 dm³	1038.516	922.432	116.084
	1038.523	922.437	116.087
	1038.522	922.438	116.085
	1038.512	922.426	116.085
	1038.517	922.430	116.088
	1038.517	922.438	116.079
	Mean		116.085
	Standard deviation		0.0030
1m³	382.903	-777.873	1160.776
	382.906	-777.879	1160.784
	382.911	-777.873	1160.783
	382.911	-777.863	1160.774
	382.906	-777.852	1160.758
	382.915	-777.862	1160.776
	Mean		1160.775
	Standard deviation		0.0096

Result

According the measurement result of diameter and stroke the volume can been calculated by formula (1),

$$V_{100\ dm^3} = 99.774\ dm^3 \tag{2}$$

$$V_{1m^3} = 997.676 dm^3 \tag{3}$$

Where, $q = 20.2°C$, $a_B = 16.2\times10^{-6} m/°c$

Uncertainty

figure 7 uncertainty of volume 100dm³

Symbol	Source of Uncertainty	type	Valve of standard uncertainty $u(x_i)$	Sensitivity coefficient $c(x_i)$	$\lvert c(x_i)\rvert u(x_i)$
u(d)	Diameter measurement	B	$4.33\times10^{-5} m$	$8.26\times10^{-6} m^2$	$8.26\times10^{-6} m^3$
u(h)	Stroke measurement	B	$3.06\times10^{-6} m$	$2.63\times10^{-6} m^2$	$2.63\times10^{-6} m^3$
$u(q)$	Temperature measurement	B	0.016℃	$3.73\times10^{-8} m^3/°c$	$3.73\times10^{-8} m^3$
u_{rel}	0.009%				
$U_{rel}, k=2$	0.018%				

3Conclusion

In this paper, Based on the geometric calibration method laser interferometer and laser tracker is applied to measure the volume of bell prover. the experimental result and uncertainty evaluation suggests the rationality and accuracy that is less than 0.1% at 95% of confidence level of new calibration method.

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