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Influence of Verification Volume and Flow rate on Verification Facility for Water Meters of Piston

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Abstract

According to the JJG1113-2015 “Verification Facility for Water Meters” calibration regulations, when testing the verification facility for water meters of Piston, the indication error and repeatability of the main standard implement are determined by two parameters, namely the verification volume and flow rate. Experiments show that the setting of two parameters affects the verification results, when the flow rate is set to 25L/h and the verification volume is 2L, the indication error and repeatability of the main standard implement meet the requirements of the verification regulation; while when the flow rate increases to 50L/h, or even larger, the test results do not meet the requirements, i.e. the test results produce a misjudgment of the piston cylinder's metering performance. The main purpose of this paper is to verify the influence of the verification volume and flow rate settings on the piston cylinder's indication error and repeatability through testing.

1. Introduction

The verification facility for water meters is the main measurement standard to determine whether the water meter measurement performance is qualified, so whether the verification facility for water meters measurement performance meets the requirements is to ensure the quality of the water meter calibration work premise. According to existing verification facility for water meters, the main standard of the testing device can be divided into three categories: a) tank, b) weighing, c) piston cylinder; For the verification facility for water meters whose main standard is a tank or a weighing, the detailed testing methods are given in the JJG1113-2015 " Verification Facility for Water Meters " verification regulation; while for the piston cylinder, only the brief testing methods are given in the appendix. There are no specific requirements on the verification volume and flow rate of the piston cylinder, and the operation method is not clearly defined. In order to ensure the accuracy and reliability of the test results of the piston cylinder water meter test device, and to verify whether there is any influence of different verification volumes and flow rates on the test results of the piston cylinder during the test, this paper will be verified through experiments and the results will be analyzed and studied.

The basic theoretical basis for the design of verification facility for water meters of piston is that a piston with a regular and uniform shape is used as a moving part, and the piston is controlled to move at a uniform speed to displace an equal volume of fluid in the piston cylinder to achieve the metering function, and the volume of the piston movement is the corresponding volume of fluid. According to JJG1113-2015 "Verification Facility for Water Meters " calibration regulations, MPE of the main standard is ±0.1%, and its repeatability should be better than 1/3 of the absolute value of MPE; according to the requirements of the calibration regulations, the piston cylinder should have sufficient measurement resolution, and within its range of use, its resolution should be no greater than 0.05% of the measured value.

2. Experiment Parameter

Two verification facility for water meters of piston (device 1, device 2) with a volume of 30L were selected for the experiment, with a gooseneck pipe as the outlet to ensure a stable water discharge each time. An electronic balance (Ⅲ level, (0~32)kg), a temperature transmitter (MPE: ±0.1 ℃, (0~50) ℃), and a water container were prepared for the experiment. Firstly, the piston cylinder is filled with water and 2L of water is discharged to ensure that there is no air in the outlet pipe, then the verification volume V_0 is set to 2L in the device software and the flow rate Q is 25L/h. The liquid of the calibration volume is discharged through the outlet pipe to the container placed on the electronic balance, where a temperature transmitter that can measure the water temperature in real time is placed, and the volume V of water discharged from the piston for each experiment is recorded (according to the final display of the software). The temperature of water t in the container and the reading of the electronic balance m_i are also recorded at the same time. Drain continuously until the piston cylinder is empty, then fill the piston cylinder with water and repeat the above steps for the experiment. Using the water temperature t and the water density table, find the corresponding water density ρ and use equation 1 to obtain the actual (standard) volume of water discharged by the piston.

$$V_i = c\frac{m_i}{\rho} \quad (1)$$

where c is — the air buoyancy correction factor, which is 1.0011;

m_i — the mass of water discharged by the piston each time (g);

ρ — the density of the water at a temperature t (g/L).

Then calculate the indication error according to equation 2.

$$E_i = \frac{V - V_i}{V_i} \times 100\% \quad (2)$$

where V — the volume of piston movement shown on the software.

V_i — the actual (standard) volume of water discharged from the piston cylinder

In order to derive the repeatability of the experiment, the above experimental steps were repeated 3 times to obtain 3 times the indicated error of the corresponding experimental section of the piston cylinder, calculate the average error and repeatability. Using equation 3 to get repeatability. (where d_n = 1.69).

$$(E_r)_i = \frac{(E_i)_{max} - (E_i)_{min}}{d_n} \quad (3)$$

where: $(E_i)_{max}$ — the maximum value of the piston cylinder's i-th experimental section of the indicated error.

$(E_i)_{min}$ — the minimum value of the piston cylinder's i-th experimental section of the indicated value error.

According to the above experimental procedure, the flow rate Q and the verification volume V_0 are used as two variables to study the influence of these two variables on the volume detection of the piston cylinder, where Q is 200L/h, 150L/h, 100L/h, 50L/h, 25L/h and the verification volume V_0 is 2L, 4L and 6L respectively. According to the requirements of the calibration regulations, its resolution should be no greater than 0.05% of the measured value, the minimum volume of the piston cylinder is 0.001L, so the minimum verification volume in the test is set to 2L.

3. Experimental results

3.1 Verification volume of 2L

Due to the large number of test results in this section, a list of the test data will be given in other test sections in order not to take up space. The experimental data obtained were processed according to the test requirements and plotted accordingly (where the horizontal coordinates indicate the position of the experimental section of the piston cylinder and the vertical coordinates are the indication value error or repeatability respectively), the experimental results are as follows.

As can be seen from Figure 1(a), for device 1, most of the indication error is within ±0.1%, except for the individual experimental sections with flow rates of 200L/h and 100L/h, where the indication error is slightly greater than 0.1%. The trend of the curve of the indication error was basically similar for different flow rates, indicating that the setting of the test flow rate had some influence on the magnitude of the measured indication error, but did not change the trend of the curve of the overall error of the piston cylinder.

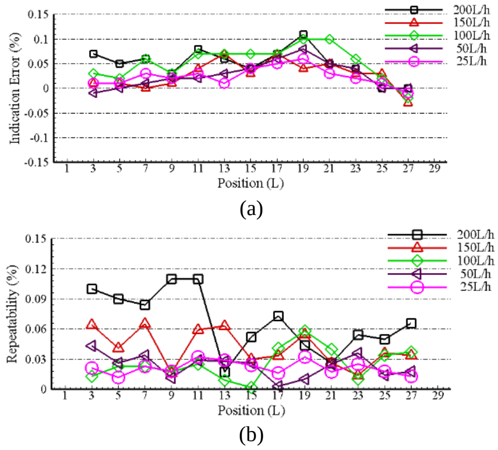


Figure 1: Device 1, the indication error (a) and repeatability (b) of different experimental sections of the piston cylinder at different flow rates with a verification volume of 2 L.

Figure 1(b) shows the repeatability of each test section of the piston cylinder. It can be found that the repeatability is the worst at a flow rate of 200 L/h, with a maximum value of 0.11%, and only two experimental sections have a repeatability of less than 0.033%, while the repeatability of the other experimental sections does not meet the requirements. As the flow rate decreases, the repeatability values become smaller. When the flow rate is as small as 50 L/h, only two test sections have a repeatability of 0.04%, while the other values are less than 0.033%. When the flow rate Q was reduced to 25L/h, the repeatability of each test section was relatively stable without much fluctuation, with a maximum value of 0.032%, a minimum value of 0.012% and others basically around 0.02%.

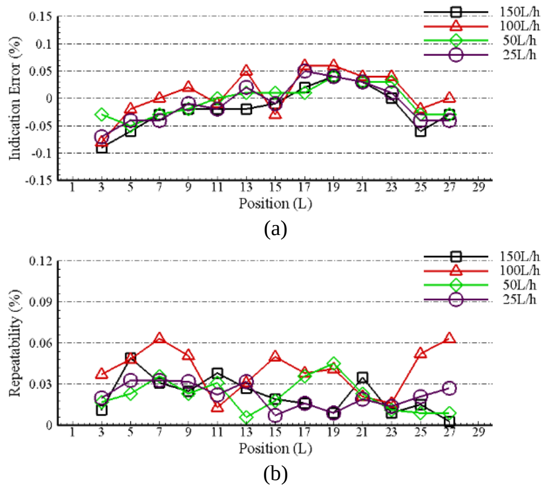


Figure 2: Device 2, the indication error (a) and repeatability (b) of different experimental sections of the piston cylinder at different flow rates with a verification volume of 2 L.

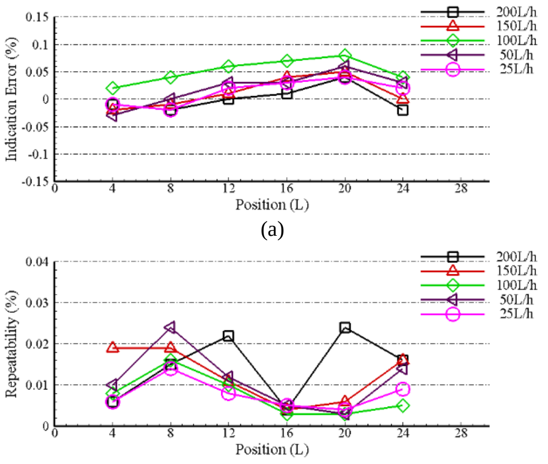
In order to verify the experimental results, the same test was carried out on another verification facility for water meters of piston (device 2). After data processing, according to the results were drawn in Figure 2.

Figure 2 (a) shows the average error of the indicated value of the piston cylinder in different test sections at different flow rates with a verification volume of 2L. The experimental results display that the indication error curves are similar under different flow rate conditions, the maximum difference of the indication error is 0.06% and 0.07% at position 3 and 13, and the other test sections do not exceed 0.05%.

As can be seen from Figure 2(b), the worst test repeatability was found at a flow rate of 100L/h, with a maximum value of 0.063%, much greater than the 0.033% required by the regulations. When the flow rate was 150L/h and 50L/h respectively, the repeatability of a few test sections exceeded 0.033% of the indicated value error, which also did not meet the requirements. When the flow rate was reduced to 25L/h, the maximum repeatability was 0.033%. The test results of device 2 were basically the same as those of device 1, with a test volume of 2L, the error of the indicated value was deviated under different flow conditions, but the trend of the error curve was not affected, and the repeatability of the test section of the piston cylinder had a great influence.

3.2 Verification volume of 4L

The test was carried out according to the requirements, and the test data for device 1 and device 2 with a verification volume of 4L and a flow rate of 50L/h were simply processed and listed in Table 1.



(a)

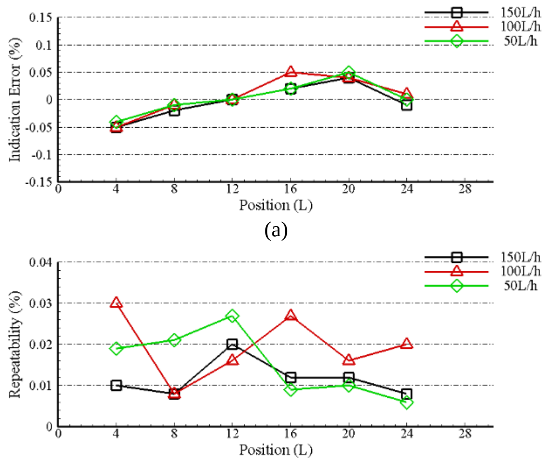
(b)

Figure 3: Device 1, the indication error (a) and repeatability (b) of different experimental sections of the piston cylinder at different flow rates with a verification volume of 4 L.

To see the test results more visually, they are plotted on the basis of the data. When the piston cylinder of device 1 was tested and the calibration volume was increased to 4L, it can be seen from Figure 3(a) that the indication error curve is roughly similar for each flow rate condition, with an upward shift in the indication error curve at a flow rate of 100L/h, and a downward shift at 200L/h. And when the flow rate is 50L/h and 25L/h, the indicated value error tends more towards the data center. Figure 3(b) shows the repeatability of the indicated value error for the corresponding experimental section, which varies but can be seen to be in compliance (≤0.033%).

Table 1: the test data for device 1 and device 2 with a verification volume of 4L and a flow rate of 50L/h.

Device No.	Piston cylinder test section position	Volume of piston movement V (L)	Standard volume V_i (L)	Indication error E_i (%)	Average indication error $\bar{E}_i$ (%)	Repeatability E_r (%)
Device 1	4	4.009	4.01053	-0.038	-0.03	0.010
		4.004	4.00534	-0.033		
		4.005	4.00588	-0.022		
	8	4.006	4.00692	-0.023	0.00	0.024
		4.007	4.00725	-0.006		
		4.009	4.00828	0.018		
	12	4.005	4.00424	0.019	0.03	0.012
		4.006	4.00447	0.038		
		4.006	4.00527	0.018		
	16	4.008	4.00644	0.039	0.03	0.005
		4.007	4.00567	0.033		
		4.009	4.00778	0.030		
	20	4.010	4.00755	0.061	0.06	0.003
		4.009	4.00658	0.060		
		4.008	4.00577	0.056		
	24	4.008	4.00725	0.019	0.03	0.014
		4.009	4.00768	0.033		
		4.008	4.00627	0.043		
Device 2	4	4.003	4.00531	-0.058	-0.04	0.019
		4.007	4.00802	-0.025		
		4.005	4.00682	-0.045		
	8	4.004	4.00531	-0.033	-0.01	0.021
		4.006	4.00622	-0.005		
		4.006	4.00591	0.002		
	12	4.006	4.00521	0.020	0.00	0.027
		4.006	4.00551	0.012		
		4.004	4.00501	-0.025		
	16	4.008	4.00772	0.007	0.02	0.009
		4.007	4.00622	0.019		
		4.007	4.00611	0.022		
	20	4.008	4.00591	0.052	0.05	0.010
		4.007	4.00521	0.045		
		4.009	4.00652	0.062		
	24	4.006	4.00591	0.002	0.00	0.006
		4.004	4.00431	-0.008		
		4.005	4.00530	-0.007		



(a)

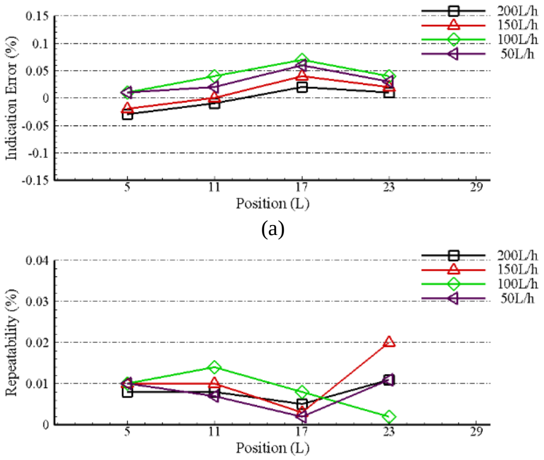
(b)

Figure 4: Device 2, the indication error (a) and repeatability (b) of different experimental sections of the piston cylinder at different flow rates with a verification volume of 4 L.

In order to verify the test results, a test with the same parameters was also carried out on device 2. From Figure 4 (a), it can be found that the indicated value error of the corresponding test section of the piston cylinder was basically the same for each flow rate condition at a verification volume of 4L, with a maximum difference of 0.03% at position 16. Figure 3 (b) shows that the repeatability of the indicated value error is also in accordance with the requirements (≤0.033%).

3.3 Verification volume of 6L

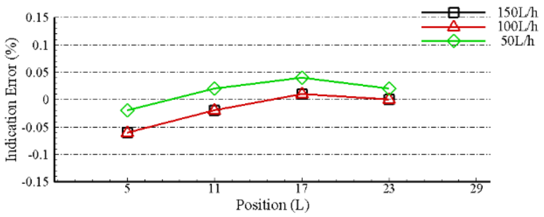
When the calibration volume of each experimental section was increased by 6L, the data in Figure 5 (a) and Figure 6 (a) showed that the curve of the indicated value error was basically similar. However, from Figure 3 (a) and Figure 5 (a), it can be found that regardless of whether the calibration volume is 4L or 6L, the error curve for a flow rate of 100L/h is shifted in a positive direction, while the error curve for a flow rate of 200L/h is shifted in a negative direction, and for other flow rates, it tends to be in the middle; this may be related to the characteristics of the piston cylinder itself.



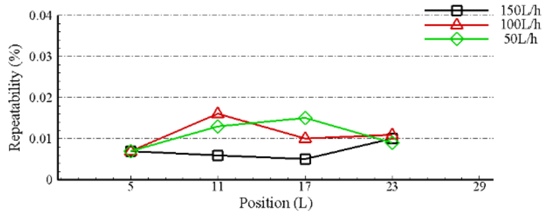
(b)

Figure 5: Device 1, the indication error (a) and repeatability (b) of different experimental sections of the piston cylinder at different flow rates with a verification volume of 6 L.

The repeatability values in Figure 5 (b) and Figure 6 (b) are also both less than 0.033%, which meets the requirements.



(a)



(b)

Figure 6: Device 2, the indication error (a) and repeatability (b) of different experimental sections of the piston cylinder at different flow rates with a verification volume of 6 L.

4. Conclusion

From the existing test results, when the piston cylinder is used as the main standard, the verification volume V and the flow rate Q still have a great influence on the test results; especially when the flow rate Q is large and the test volume V is small, the test data will cause misjudgment whether the piston cylinder is qualified or not. When the verification volume is 2L, at a flow rate of 25L/h, the test data shows that the piston cylinder test results meet the requirements; as the flow rate increases to 50L/h or even greater, the test data shows that the piston cylinder measurement performance does not meet the requirements. With the verification volume increasing to 4L or 6L and the flow rate from 50l/h to 200l/h, the test results show that the indication error and repeatability of the piston cylinder test section meet the requirements of the regulation. However, when the flow rate is greater than 200L/h, or even greater, the test results will continue to be investigated in subsequent tests. It was found that during each test section of the piston cylinder, the sudden start of the piston quickly reached the specified flow rate, and at the end of the test, the piston suddenly stopped from the specified flow rate, this start-stop effect of the piston had a great impact on the test results; specifically, when the verification volume is very small, the small flow rate conditions can reduce the impact of this start-stop effect, as the flow rate increases, the start-stop effect of the piston is manifested; and as the verification volume increases, the start-stop effect is then weakened. Based on the test results, it can be roughly concluded that when the test volume is 2L, it is recommended that the flow rate setting should preferably not exceed 25L/h in order to make the test results accurate and reliable. In short, the metering performance of the piston cylinder can be correctly reflected only by choosing the appropriate verification volume and flow rate, otherwise it will lead to misjudgment.

References

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[2] Zhao Jianliang, Du Weipeng "Design and Application of the Piston Type Standard Device for Continuous Liquid Flow Measurement", *Process Automation Instrumentation*, Vol.37 No.12, 32-36, 2016.