Research on different test methods based on heat meter flow sensor

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Abstract

Heat meters as an important measurement instrument and the basis for heatingbilling purpose, must ensure the accuracy and long-term reliability of measurement.After the heat meters from domestic brands are installed in the field, quality issues are frequently happening. Due to this reason some of the market is replaced by the heat meters from imported brands. Reflected to the test method, there is a big difference and one of the biggest differences between European and Chinese product standard on the durability requirement. This researchaims to establish a study based on a testing of 4,000 times temperature alternation, to make comparison to the 2,400 hours testing and to have a continuous perfection on durability requirement from standard perspective.It's the first time in China to have an overall assessment towards the durability of heat meter in the condition of laboratory. This would provide theoretical support to the transformation and upgrading of the heat meter industry,and empower the development of heating billing.

1. Introduction

In the national standard "GB/T32224-2020Heat Meters", it requires that that the heat meter flow sensor shall have a service lifetime of ten years.Two method of durability test are mentioned in the standard. One is the basic durability test and the additional durability test - the flow cycle test for2400 hours and the constant temperature /flow test for500 hours. Another one is the accelerated durability test and the additional durability test - the 4000 times of temperature cycle tests and the constant temperature/flow test for 500 hours.

Among the two durability testmethods, the additional test for 500 hours is the same. The basic durability test for 2400 hours (hereinafter referred to as 2400h) and the accelerated durability test for 4000 times cycle (hereinafter referred to as 4000 times) is different on the perspective of the test method and test time. The 2400h test has been included in "GB/T32224-2015 Heat Meters"in 2015. The operating methods, technical conditions, equipment, personnel, etc. are comprehensively defined. And there are already plenty of experimental data from long term testing. However the 4000 times test is a new test that is recently included into"GB/T32224-2020 Heat Meters". This research established these two tests separately according the latest standard for the heat meters from same batch of products. The tested meters are ultrasonic heat meters DN20 with no movable mechanical parts on the flow part. The test results of the two test methods are compared to provide support for product development and to enhance the evaluation of the long-term use and stability of the product.

2. Experimental format

2.1 Basic durability test (2400h)

The temperature of the test medium should be the upper limit of the temperature of the heat meter. When the upper temperature limit of the heat meter is higherthan 95 ℃the test temperature should be95 ℃, and the test temperature toleranceis$_{-5}^{\ 0}$°C.

The tolerancesof the flow rate:
$(1.5\times q_i)$ ±5%
q_p ±5%
$q_{s}{}_{-5}^{\ 0}$%

The test procedure is based on a continuous series of 100 cycles at three different flow rates,each cycle lasting 24 h. The high load phase lasts 18 h; the flow rate shall be 16 h equal to q_p, plus onehour in which the flow rate is raised up to q_s. The high load phase shall be followed by a low load phaseat 1.5 $\times q_i$ lasting 6 h. The four transition intervals between the different loads shall be approx. 15 minutes each. The flow versus time is shown in Figure 1.

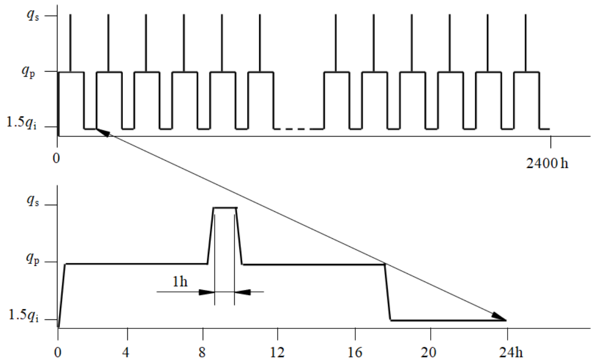
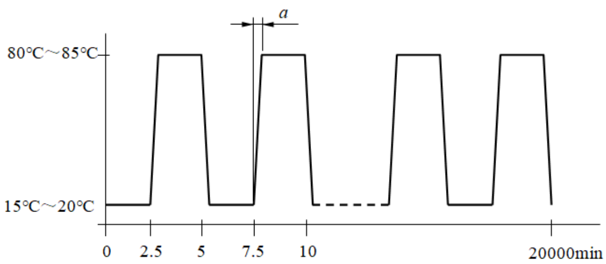


Figure 1:Basic wear test cycles with magnification of the first cycle.

2.2 Accelerated durability test (4000 times)

The samples with no moving mechanical part should be tested at 4,000 continuous load change cycles of medium temperature with 5 minutes of each cycles. The medium temperature changes shall be raised up from (20 to 15) ℃ to (80 to 85) ℃and reversed at the constant flow rate q_p(tolerance ±5%). Each low load phase and each high load phase shall last2.5 min. The transition intervals between the different temperature loads shall be within 1 min.

The temperature versus time is shown in Figure 2.



Thereinto: *a*- Changing time period of medium temperature

Figure 2:Accelerated test cyclesfor the meters with no movable mechanical parts.

3. Experimental process design

1) The test samples are ultrasonic heat meters from a domestic brand with own development and production ability
   a) DN 20
   b) Accuracy class II
   c) q_p=2.5 m^3/h
   d) 32 pieces out from 1537 pieces
   e) Repeatability error and measurement error are within ±0.5 ×MPE
   f) 32 pcs samples are divided into two groups (16 units for each test) for the 4000 times + 500h and 2400h + 500h

2) Test plan, test preparation, test implementation, etc. according to "GB/T32224-2020 Heat Meters".

3) The tests are carried out in the heat meter durability laboratory of the Dezhou Park, Shandong Institute of Metrology.

4) Before and after the test, the accuracy of thesamples are tested under the flow rate of: 0.05m^3/h,0.16m^3/h,0.5m ^{3}/h,1.58m^3/h,5m^3/h.

5) During the whole test, not only the change of the accuracy was compared, but also the key parameter of the transducers like waveform, frequency, amplitude, bandwidth, and Q_m(Q_m:mechanical quality factor parameter of the transducer) were also monitored. Additionally, the condition of the direct contact part between flow sensor and medium is monitored as well.

4. Technical parameters of the test equipment

Testable Diameter: DN15~DN25
Flow range: 0.045m^3/h~7m^3/h
Power of the pump: 3kW×2
Volume of the water tank: 0.8~ 1.2m^3
Heating power: 12kW
Cooling power: 4kW
Test capacity: 16 units

The equipmenthas an electromagnetic flowmeter covering the flow range required by the test and two electric valves of different diameterfor flow detection and adjustment. The flow channel is controlled by the pneumatic ball valve. And a three-way pneumatic ball valve is used to control the heating and cooling medium are running in the correct flow circle.

Test condition for the accelerated durability test (4000 times):

- High temperature range is controlled between 82 ~ 85 ℃
- Low temperature range is controlled between 17 ~ 19 ℃
- Test flow rate is q_p of the samples (2.5 m^3/h)
- Changing time is 40s from low temperature to high temperature and the same for reverse changing
- One cycle lasts 5 min including the changing period

Test condition for the basic durability test (2400h):

- Medium temperature is 90~95℃
- Test flow rates are 1.5q_i (minimum flow),q_p (nominal flow), q_s (maximum flow)

Test condition of the 500h additional durability test:

- Medium temperature is 90 ~ 93 ℃
- Test flow rate is 4.95m^3/h.

5. Test evaluation criteria

According to the requirements of GB/T32224-2020（article 7.9.2.6): After 2400h+500h and 4000+500h durability tests if the following error occurs, the meterisjudged to be unqualified:

1) At medium temperature 50℃±5℃, under 5 flow points: the volume indication error exceeds ±1.0 times MPE; the difference of the volume indication error before and after the test exceeds ±1.0 times the MPE .

2) Significant error occur during the test: the display is not clear, not complete or even no display anymore; flow sensor has leakage or even being damaged.

6. Test results

6.1 Verification on accuracy after durability test

6.1.1 Basic durability test (2400h)+500h:

After the basic durability test (2400h) and the additional durability test (500h), 16 samples were qualified for the indication value error. Among the 16 samples, 9 units has the accuracy within ±0.5*MPE， as shown in Figure 3.

6.1.2 Accelerated durability test (4000 times) +500h:

After the test, the indication value error of sample 9167# exceeded the limited at the flow rate of 0.05m^3/h. The rest 15 units have accuracy performance within ±1.0*MPE. 7 units out from these 15 units have accuracy performance within ±0.5*MPE, as shown in Figure 4.

By observing the waveform of the ultrasonic transducer of the sample 9167# and further testing on the transducer such as amplitude, frequency, bandwidth, Q_m value, etc., it is found that the signal of thetransducer is suddenly attenuated in the temperature shock experiment.The transducer is determined to be damaged due to temperature shock.

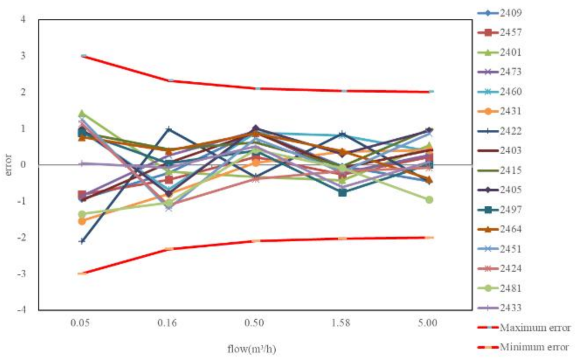


Figure3:Indication error after 2400h + 500h.

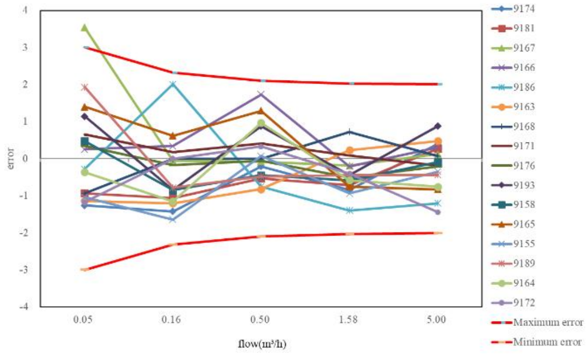


Figure4:Indication error after 4000 time + 500h

6.2 The difference of error before and after the test for each sample

6.2.1 Basic durability test (2400h) + 500h:

The difference of error of all the 16 units is within ±1.0*MPE. Among these 16 units, 10 units has the difference within ±0.5*MPE, as shown in Figure 5.

6.2.2 Accelerated durability test (4000 times) + 500h

The sample 9186# was unqualified because the difference of error exceed ±1.0*MPE. The rest 15 units can pass the test with the difference of error within ±1.0*MPE. Among these 15 units, 6 units have the difference of error within ± 0.5*MPE, as shown in Figure 6.

Before and after the test, the ultrasonic transducers of the sample #9186 areinspectedthree time on the waveform, amplitude, frequency, bandwidth, Q_m value and other parameters.It turns out that all the parameters are within the normal range, and there isno obvious change. After the durability test, the calculator unit of the sample 9186# was disassembled andthe signal line was drawn out. Afterwards the signal statusduring the test was monitored with the oscilloscope. And no abnormalities were found. In summary, the variation of the sample 9186# is caused by sudden temperature changes during the experiment.

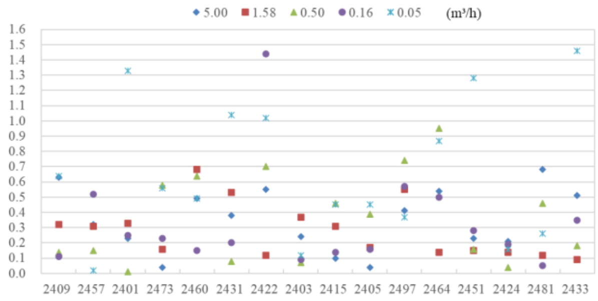


Figure5 :Difference oferror after 2400 hours + 500h.

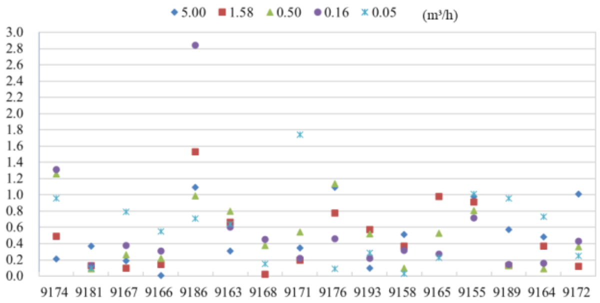


Figure6 :Difference oferror after 4000 times + 500h.

6.3Statistics of test results

1)Test pass rate comparison

Table 1: Test pass rate statistics.

Test items	Qty	Rate(%)
2400h+500h passed, 4000 times+500h passed	30	93.8
2400h+500h passed, 4000 times+500h failed	2	6.2
2400h+500h failed,4000 times +500h passed	0	0
2400h+500h failed,4000 times +500h passed	0	0

2)Indication error and Difference of error before and after test

Table 2:Indication error and Difference of error before and after test.

Test items	2400h+500h	4000 times + 500h
Indication error within ± 0.5*MPE	9	7
Difference of error before and after test within ±0.5*MPE	10	6

7. Conclusions

Table 1 shows:The pass rate of the flow sensor accelerated durability test (4000 times) and the additional durability test (500h) is 93.8%, and the pass rate of the basic durability test (2400h) and the additional durability test (500h) is 100%. Both samples that were failed in the test were found outin accelerated durability tests (4000 times).

Table 2 shows: The percentage of the meters that have a performance within ± 0.5*MPE on the aspect of the indication error and difference of error in the test of the accelerated durability test (4000 times)is significantly less than the results of another test method (2400h).

According to the test, the results of the 4000 +500h test cover the results of 2400h+500h. And it can be preliminarily determined that 4000 +500h tests can be used as an option to replace the 2400h+500h test, which is in line with GB/T32224-2020 standard requirements.

From the aspect of the service life evaluation of the heat meter flow sensor, the 4000 times +500htest results are better than the 2400h+500h test results.

The accelerated durability test (4000 times) takes about 14 days, and the basic durability test (2400h) takes about100 days. Accelerated durability test (4000 times) has the advantages of low test cost and short test cycle.

In the next step, we will actively explore the development of accelerated durability (4000 times) test devices, make the test device to be more robust, to be more energy-saving, to have shorter on temperature transition time, to have smaller flow fluctuations when the pipeline is switched, etc. And try tospeed upthe process of test exploration, get more test data, and be well prepared in supporting towards product technical standards.

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