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UNCERTAINTY AND ERROR EVALUATION OF A FLOW DIVERTER VALVE ACTUATED BY A PNEUMATIC PISTON

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Abstract: The purpose of this study is to estimate the uncertainty contribution due to the diverter valve in the total uncertainty, concerning the calibration of flow meters in the water laboratory of the Center for Fluid Metrology.

Key words: uncertainty, timing error, diverter valve

1. INTRODUCTION

The calibration bench for water flow meters of the IPT Center for Fluid Metrology uses a gravimetric system with a diverter valve. It operates in flow rates from 10 m³/h to 250 m³/h.

During its operation, the diverter valve may cause a difference between the amount of water that is diverted into the weighing tank and the amount of water that is diverted into the return pipe.

Consequently, the diverter valve is an important source of uncertainty for the bench. Thus, it is essential that the timing error it may cause is accounted for as the systematic error it is, and not as part of the uncertainty of the system.

2. METHODS

Two different kinds of test were made in order to evaluate the systematic error and the uncertainty caused by the diverter valve.

2.1 Piston timing error

The first test performed intended to measure the time interval necessary for the piston to actuate in each direction.

For these measurements, two optic sensors were used. The sensors were installed on a base near the piston and connected to an oscilloscope. One sensor was used to signalize when the piston arm was in the upper position and the other was used to signalize when the piston arm was in the inferior position. These data were plotted on the screen of the oscilloscope. This way, it was possible to measure the referred time interval, since the time the piston began its course and also the time it finished it were marked on the screen of the oscilloscope.

The piston was actuated by compressed air coming from a cylinder, with a constant pressure of 6,2 bar. It is important that the pressure remained constant; otherwise the piston actuation time interval could have changed.

The valve (and thus the piston) was actuated at least 13 times to each side, so that a significant sample could be taken.

2.2 Deviation timing error

The other test was performed according to Annex A of the International Standard ISO 4185-1980 [1]. The test consisted in running a standard calibration of a flow meter and then repeating the calibration, diverting the valve n times, which means that n bursts of flow were deflected into the weighing tank, without resetting the timer or the scales. The timing error ($\delta_{diversion}$) might then be estimated by equation (1) :

$$\delta_{diversion} = \frac{t}{n-1}\left\{\frac{q}{q'}\times\frac{\sum_1^n \Delta m_i \Big/ \sum_1^n t_i}{(m_1 - m_0)/t} - 1\right\} \qquad (1)$$

Where:

t = time interval of standard calibration;

n = number of bursts of flow;

q and q' = flow rates during the standard run and the n bursts, respectively, as measured by the electromagnetic flow meter;

$\sum_1^n \Delta m_i \Big/ \sum_1^n t_i$ = flow rate determined from the totalized mass and totalized time for n bursts;

$(m_1 - m_0)/t$ = flow rate determined by the standard procedure.

3. RESULTS

3.1 Piston timing error

A difference between the time of diverting the valve to the tank and from the tank was found. The mean time of diverting the valve from the weighing tank to the return pipe was found to be (60,4 ± 2,2) ms, while the mean time of diverting the valve from the return pipe to the weighing tank was found to be (67,5 ± 0,5) ms. That results in a mean time difference of (7,1 ± 2,3) ms.

3.2 Deviation timing error

The tests were made in six different flow rates, 20 m³/h, 30 m³/h, 40 m³/h, 60 m³/h, 80 m³/h and 100 m³/h. Ten bursts of flow were deflected into the weighing tank in each test, and each flow rate was tested at least three times. The flow meter used in the tests is an 8-inch electromagnetic flow meter. Figure 1 shows the results of this test.

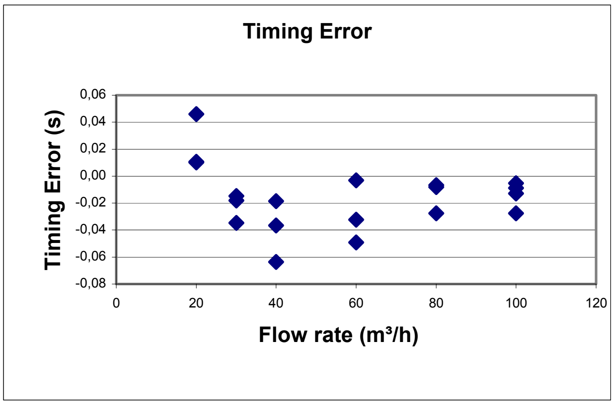

Figure 1 – Timing error x Flow rate

It may be assumed that the timing error is a constant, and that the dispersion of the data is its uncertainty. Thus, it is possible to use the mean value of the timing error as the constant, and to assume that the dispersion has a rectangular distribution. In this way:

$\delta_{diversion}$ = -0,015 s

Considering that the time meter has a resolution of 0,01 s, the standard uncertainty $u(\delta_{diversion})$ can be estimated by equation (2):

$$u(\delta_{diversion}) = \sqrt{\left(\frac{a(\delta_{diversion})}{\sqrt{3}}\right)^2 + (0{,}01)^2} \qquad (2),$$

where $a(\delta_{diversion})$ is the semi-amplitude of the dispersion of the timing error, and is equal to 0,055 s.

Thus, $u(\delta_{diversion})$ = 0,033 s

The expanded uncertainty $U(\delta_{diversion})$, assuming that the coverage factor k is 2, is:

$U(\delta_{diversion}) = u(\delta_{diversion}) \cdot k$

$U(\delta_{diversion})$ = 0,066 s

4. DISCUSSION

4.1 Piston timing error

The study of the piston timing error is only significant for the uncertainty calculation, if the nozzle, which leads to the diverter valve, is totally filled with water and if the flow profile is uniform at the moment the diverter valve cuts the water. This means that, for low flow rates, the uncertainty has to be estimated by other tests.

4.2 Deviation timing error

These data are very important to calculate the uncertainty of the calibration bench. They also show how much it is possible to correct, when the deviation is concerned.

The fact that, for the 20 m³/h flow rate, the timing error is positive, while it is negative for the other flow rates tested, means that the nozzle was not totally filled with water during the experiment. This means that more water fell into the weighing tank, when the ten bursts were deflected into it, than in normal calibration. This shows that the water tends to flow near one of the walls, when the nozzle is not completely fulfilled.

5. CONCLUSIONS

The overall value of the piston timing error was very small, when compared to the deviation timing error. Thus, when calculating the uncertainty contribution due to the diverter valve in the total calibration bench uncertainty, the piston timing error may be neglected, and the uncertainty of the deviation timing error may be considered the total uncertainty contribution of the diverter valve.

REFERENCES

[1] International Organization for Standardization, *ISO4185-1980 – Measurement of liquid flow in closed conduits – Weighing method*, 1st edition, December 1980.

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