Flow meter calibration by volumetric method and by weighing method using an innovative system

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Abstract. A flow meter can be calibrated by different methods. To obtain minors measurements uncertainties, the laboratories use the weighing method; however, this method does not provide a simple operation, a specific apparatus has been developed for this calibration. Another approach is the calibration by volumetric method, using a tank prover as standard. This paper show the results obtained by this two different methods for the same flow meter. Key words: flow meter, weighing method, volumetric method, measurement uncertainty, innovation.

1. Introduction

The flow meter calibration occurs by different methods. A calibration by gravimetric method delivers the lowest measurement uncertainty, however the complexity of the method is greater. In a metrology laboratory the volumetric method is frequently used, however this method does not deliver the best measurement uncertainty.

The approach of this paper aims to compare the calibration of a same flow meter by the weighing method and volumetric method, in different layouts.

For this job, an oval gear flow meter was used, with range of 50 L/min to 500 L/min. Water cistern was used as calibration fluid.

2. Calibration method

The meter was calibrated in first moment by weighing method. For this method were used two equal balances with capacity of 300 kg and 2 g resolution [Fig. 1]. The balances were calibrated before and after of meter calibration. One 350 L capacity container was positioned on each balance. The totalized volume by flow meter was calculated as the difference between full mass and empty mass on the containers. A new device was developed for the totalized volume on the flow meter be maintained constant.

For volumetric method a tank prover was used as standard [Fig. 2] to calibrate the flow meter. The tank prover was calibrated using weighing method previously by Liquid flow laboratory (Laliq) of Inmetro internal standard. The equation 1 gives the mathematic model to determine the meter factor.

\[ F_m = \frac{V_i}{V_m} \left(1 - \alpha_m \cdot \left(T_{L_m} - T_c\right)\right) + \delta F_m \]  

(1)
Where:
Fm – Meter factor for totalized volume in flow meter (dimensionless)
Vr – Calculated volume by weighing method or volumetric method, in dm3.
Vm – Totalized Volume by flow meter (pulse number/K-factor), in dm3.
αtm – Flow meter volumetric thermal expansion coefficient, in °C⁻¹.
TLm – Water average temperature in flow meter, in °C.
TC – Calibration temperature on flow meter, in °C.
δFm – Random variation on determination of Fm

Figure 1. Weighing method calibration layout

Figure 2. Volumetric method calibration layout
3. Results

The difference between the two methods was approximately 0.013%. The measurement uncertainty obtained in the weighing method was 0.019% while the uncertainty obtained by the volumetric method was 0.052%. In table 1 and 2, the contributions to the measurement uncertainty are shown individually, so observe the largest contributions to the uncertainty.

| Influence quantities                          | Relative contribution |
|-----------------------------------------------|-----------------------|
| Flow meter indication                         | 43%                   |
| Repeatability                                 | 23%                   |
| Water mass                                    | 14%                   |
| Non adjustment polynomial                    | 12%                   |
| Temperature variation during calibration      | 4%                    |
| Others                                        | 3%                    |
| **Total**                                     | **100%**              |

**Table 2. Volumetric method uncertainty budget**

| Influence quantities                          | Relative contribution |
|-----------------------------------------------|-----------------------|
| Tank indication correction                    | 47%                   |
| Meter factor repeatability                    | 17%                   |
| Temperature gradient in tank                  | 7%                    |
| Flow meter                                    | 7%                    |
| Temperature variation in tank                 | 5%                    |
| Temperature variation in flow meter           | 5%                    |
| Tank temperature                              | 4%                    |
| Temperature variation during calibration      | 3%                    |
Tank temperature 3%
Tank resolution 2%
Others 1%
Total 100%

The calibration by the volumetric method was performed after the flow meter undergoing a course of about 100 m³, in a different rig which was used in the weighing method.

4. Conclusions

The final calibration results were compatible. The normalized error was 0.23 showing that a flow meter can be calibrated in the field for a tank prover without compromising the final result. The weighing method system presented a good performance calibration even in the field, proving the effectiveness of the developed device.

The expanded uncertainty is directly related to the conditions of the flow meter installation. Proper installation, environment and liquid temperature and flow conditions directly influences in the final result of the calibration.

5. References

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