Flow rate quality assessment through interlaboratories comparison

M Anghel¹, A Salceanu², F Iacobescu³ and M M Poenaru³

¹Romanian Bureau of Legal Metrology, Bucharest, Romania,
²Gheorghe Asachi Technical University of Iaşi, Iasi, Romania,
³University of Craiova, Craiova, Romania,

E-mail: asalcean@tuiasi.ro

Abstract. In order to establish the technical performance of laboratories, an assessment of these laboratories is necessary within every domain. This paper presents the results of 7 laboratories that have performed interlaboratory metrological verifications within flow rate domain. The main goal of this intercomparison was the assessment of laboratories capabilities performing verifications of flow (rate) meters based on 3 travelling measurement standards.

1. Introduction

Interlaboratory comparison (ILC) assessment has been performed by a Romanian PT Schemes Provider in compliance with ISO 17043:2010 [1], [2]. According to ILC protocol, measurements have been performed at 3 levels: Qₙ (normal), Qₜ (transitional) and Qₘᵢₙ (minimum).

The purpose of such interlaboratory comparisons is mainly to determine their performance, while complementary including: evaluating and monitoring the performance of laboratories for specific tests or measurements; identification of problems in laboratories and initiation of improvement actions; establishing the efficacy and comparability of test and measurement methods; providing additional confidence to their customers; identifying differences between laboratories; training of participating laboratories on the basis of the results of such comparisons.

2. Travel of measurement standard

The selected type of proficiency testing scheme was the quantitative sequential participation scheme, which had involved the proficiency test (PT) item being circulated as it is presented schematically in Figure 1. After using the proficiency test item for the first 4 laboratories, it has been sent back to the proficiency testing provider for rechecking, aiming to be appropriately used for the tests that would take place in the last three laboratories.

As proficiency test items have been chosen three flowmeters manufactured by Actaris Metering Systems, Aquadis type, having their serial numbers: 09LA181183, 09LA181185 and 09LA181186, respectively. Their main characteristics are the following: nominal diameter: 15 mm; permanent flow rate: 1.5 m³/h (symbolized qₙ); accuracy class: B; mounting position: horizontal (H); type of indication: analogical; pattern approval CEE: F04 G 297.

² To whom any correspondence should be addressed
3. Results and discussions

The provider’s reference laboratory has twice performed the characterization of travelling measurement standard. The assigned values taken into account there were the means of measured values by the reference laboratory for every established point/value. Each participating laboratory has determined the measurement errors of the three flowmeters, accuracy class B, having 15 mm diameter, symbolized by $Q_n$, $Q_t$ and $Q_{\text{min}}$ within the following flow rate ranges: $0.030 \text{ m}^3/\text{h} \leq Q_{\text{min}} \leq 0.033 \text{ m}^3/\text{h}$, $0.120 \text{ m}^3/\text{h} \leq Q_t \leq 1.320 \text{ m}^3/\text{h}$ and $1.350 \text{ m}^3/\text{h} \leq Q_n \leq 1.500 \text{ m}^3/\text{h}$, respectively.

The attributed values of proficiency test have been calculated as the mean of the values obtained by the reference laboratory, for every test flow rate. The relative measurement errors at each established point of flow rates have been calculated using the following formula [3]:

$$e_x(\%) = \frac{V_i - V_A}{V_A} \times 100,$$

where:

- $V_i$ - displayed flow rate of 'i' flow meter;
- $V_A$ - attributed flow rate determined by using a bell prover

The relative errors obtained by provider’s reference laboratory and the corresponding values registered for the seven participating laboratories (while using the three selected flowmeters) are synthesized in Table 1.

**Table 1 - Measurement results obtained by all the involved laboratories, while using the reference and the three selected flowmeters.**

| Laboratory code | relative errors for 09LA18118 | relative errors for 09LA181185 | relative errors for 09LA181186 |
|-----------------|-------------------------------|-------------------------------|-------------------------------|
|                 | $Q_n$ (%) | $Q_t$ (%) | $Q_{\text{min}}$ (%) | $Q_n$ (%) | $Q_t$ (%) | $Q_{\text{min}}$ (%) | $Q_n$ (%) | $Q_t$ (%) | $Q_{\text{min}}$ (%) |
| Reference Lab.  | 0.01      | 1.69      | 1.51               | -0.01     | 1.60      | 1.39               | 0.01      | 1.68      | 1.50               |
| 1st Lab.        | 0.20      | 1.81      | 1.43               | 0.18      | 1.62      | 1.26               | 0.21      | 1.68      | 1.33               |
| 2nd Lab.        | 0.22      | 1.60      | 1.23               | 0.33      | 1.51      | 1.59               | 0.12      | 1.51      | 1.26               |
| 3rd Lab.        | 0.11      | 1.77      | 1.37               | 0.16      | 1.60      | 1.37               | 0.11      | 1.69      | 1.63               |
| 4th Lab.        | 0.13      | 1.91      | 1.54               | 0.13      | 1.78      | 1.47               | 0.14      | 1.90      | 1.60               |
| 5th Lab         | 0.10      | 1.70      | 1.48               | 0.11      | 1.60      | 1.19               | 0.10      | 1.80      | 1.58               |
| 6th Lab         | 0.05      | 1.71      | 1.49               | 0.09      | 1.68      | 1.29               | 0.07      | 1.84      | 1.59               |
| 7th Lab         | 0.39      | 1.76      | 1.43               | 0.42      | 1.86      | 1.50               | 0.48      | 1.79      | 1.63               |
A graphical representation of the previously presented errors for the three selected flowmeters is provided in Figure 2, Figure 3 and Figure 4, respectively.

The evaluation of acceptance criteria [4] for each laboratory has been performed by using the following formula:

\[ z_{\text{score}} = \frac{x_i - X_i}{\sigma} \] (2)

where:
- \( x_i \) - measurement result of \( i \) laboratory, for each measurement point;
- \( X_i \) - assigned value of PT object;
- \( \sigma \) - assigned PT standard deviation.

Z score criteria are the following:
- \( |z| \leq 2 \); the score indicates “satisfactory” performance,
- \( 2 < |z| < 3 \); the score indicates “questionable” performance,
- \( |z| \geq 3 \); the score indicates “unsatisfactory” performance.

Z scores obtained by the seven participating laboratories are synthesized in Table 2.
Table 2 - Z score obtained by all the involved laboratories, while using the three selected flowmeters.

| Laboratory code | Z for 09LA181183 | Z for 09LA181185 | Z for 09LA181186 |
|-----------------|------------------|------------------|------------------|
|                 | Qn               | Qt               | Qmin             |
| 1st Lab.        | 0.29             | 0.18             | 0.05             |
| 2nd Lab.        | 0.31             | 0.14             | 0.17             |
| 3rd Lab.        | 0.18             | 0.32             | 0.02             |
| 4th Lab.        | 0.06             | 0.03             | 0.01             |
| 5th Lab.        | 0.08             | 0.11             | 0.05             |
| 6th Lab.        | 0.29             | 0.18             | 0.05             |
| 7th Lab.        | 0.31             | 0.14             | 0.12             |
| 8th Lab.        | 0.25             | 0.02             | 0.08             |
| 9th Lab.        | 0.15             | 0.12             | 0.08             |
| 10th Lab.       | 0.14             | 0.01             | 0.02             |
| 11th Lab.       | 0.17             | 0.00             | 0.12             |
| 12th Lab.       | 0.14             | 0.02             | 0.05             |
| 13th Lab.       | 0.20             | 0.27             | 0.05             |
| 14th Lab.       | 0.20             | 0.33             | 0.06             |
| 15th Lab.       | 0.15             | 0.01             | 0.12             |
| 16th Lab.       | 0.17             | 0.00             | 0.12             |
| 17th Lab.       | 0.14             | 0.00             | 0.06             |
| 18th Lab.       | 0.25             | 0.02             | 0.08             |
| 19th Lab.       | 0.70             | 0.17             | 0.08             |

The assigned PT value [5] of PT object was the mean of the measurement results obtained by the reference laboratory, for each measurement point, taken in the first stage, at the beginning and then, at the middle of PT scheme. The participating laboratories had the accuracy requested requirements.

4. Conclusions

All participants have achieved the acceptance criteria of competence. The measurement results of this interlaboratory comparison proved that $|z|$ scores were smaller than 1.0 for all registered situations.

For $Q_n$, $|z|$ scores were between:
- [0.0-0.2] for 11 values – 57.14 %;
- (0.2-0.5) for 5 values – 23.81 %;
- (0.5-0.7] for 4 values – 19.05 %.

For $Q_t$, $|z|$ scores were between:
- [0.0-0.2] for 15 values – 71.43 %;
- (0.2-0.5] for 6 values – 28.57 %.

For $Q_{min}$, $|z|$ scores were between:
- [0.0-0.2] for 21 values – 100 %.

5. References

[1] JCGM 200:2008, *International Vocabulary of Metrology. Basic and General Concepts and Associated Terms* (VIM), 3rd edition
[2] ISO/IEC 17043:2010, *Conformity assessment – General requirements for proficiency testing*
[3] Czichos & others, 2011, *Handbook of Metrology and Testing*, Springer
[4] Eurachem Guide 2014, *The fitness for purpose of analytical methods*, 2nd edition
[5] ISO 13528:2005, *Statistical Methods for Use in Proficiency Testing by Interlaboratory Comparisons*