Consideration regarding the quality of the results of the measurement

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Abstract- The estimation of measurement uncertainty is a compulsive task of each metrological laboratory which has implemented the quality system. This paper presents the main factors that influence the quality of the measurement and the importance of the inter-laboratory comparison.

I. Introduction

Today it is taken for granted that a measurement represents the same quantity everywhere. The national measurement system ensures that measurements performed in different places, at the same or different times, will be compatible one another regarding as well as the uncertainty levels for each instrument. The various national measurement systems of the different countries in the world have a common physical basis by virtue of the International System of Units (SI).
The implementation of a quality system represents one of the main requirement which must be satisfied if the recognition in conformity with SR EN ISO 17025 [1] of metrological laboratory is desired. The recognition of the quality system by an accreditation organization demonstrates that the laboratory meets the standards of quality and technical competency imposed by SR EN ISO 17025. The accreditation is based upon this agreed standard with specified measurement parameters and uncertainties. The estimation of the measurement uncertainties and the assurance of the traceability to SI of all the standards used are compulsive requirements for the laboratory mentioned above.

II. How to ensure the quality of the measurement

The quality of the measuring process involves:

- To use the authorized staff to make calibrations. The laboratory management shall ensure the competence of all who operate specific equipment, perform calibration [2], evaluate results, and sign calibration certificates. Personnel performing specific tasks shall be qualified on the basis of appropriate education, training, experience and/or demonstrated skills, as required.
- To ensure environmental conditions. Laboratory facilities for calibration, including but not limited to energy sources, lighting and environmental conditions, shall be such as to facilitate correct performance of the calibrations.
- To choose an available measuring method correctly. The laboratory shall use appropriate methods and procedures for calibrations within its scope. These include handling, storage and preparation of items to be calibrated, and where appropriate, an estimation of the measurement uncertainty [2] as well as statistical techniques for analysis of calibration data. The laboratory shell use calibration methods which meet the needs of the client and which are appropriate for the calibrations it undertakes. Methods published in international, regional or national standards shall preferably be used.
- To choose a measuring method which is validated. The laboratory shall ensure that it uses the latest valid edition of a standard.
- To use a correct procedure for calculating the true value of the measurement and also the uncertainty. A calibration laboratory performing its own calibrations, shall have and apply a procedure to estimate the uncertainty of measurement for all calibrations and types of calibrations. When estimating the uncertainty of measurement, all uncertainty components which are of importance in the given situation shell be taken into account using appropriate methods of analysis. Sources contributing to the uncertainty include, but are not necessarily limited to, the reference standards, methods and equipment used, environmental conditions, properties and condition of the item being calibrated, and the operator. The predicted long-term behavior of the calibrated item is not normally taken into account when estimating the measurement uncertainty.

- To choose the measurement standard correctly. The laboratory shell be furnished with all items of measurement required for the correct performance of calibrations. All equipment used for calibrations, including equipment for subsidiary measurements having a significant effect on the accuracy or validity of the result of the calibration, shall be calibrated before being put into service.
- To provide the traceability of the measurement by using a traceable measurement standard according to the International System of Units (SI). A calibration laboratory establishes traceability of its own measurement standards and measuring instruments to the SI by an unbroken chain of calibrations or comparisons linking them to relevant primary standards of the SI units of measurement. The link to SI units may be achieved by reference to national measurement standards.
- To make intermediary checks to increase the trust in the measurements made with the used measuring instrument. Intermediate checks are needed to maintain confidence in the calibration status of reference, primary, transfer or working standards.

III. How to check if the results of the measurement are correct

The results of the measurement can be checked by:
- participation in inter-laboratory comparison,
- replicate calibrations using the same or different methods,
- re-calibration of retained items.

The most important modality to check if the results of the measurement are correct is considered to be inter-laboratory comparison. In this direction National Institute of Metrology Bucharest (INM) participated to a comparison where the participating institutes were: Ulusal Metroloji Enstitüsü UME – Turkey, Bundesamt für Eich- und Vermessungswesen BEV- Austria and Institutul National de Metrologie INM –Romania.
The objective of this comparison was to link the National Institute of Metrology Bucharest (INM) to the key comparisons BIPM.EM-K11.a and BIPM.EM-K11.b.
The primary standard for DC voltage is formed by the Josephson Array Voltage Standard (JAVS). This type of standard is used by UME and BEV. The national standard of INM is a Zener standard, calibrated at BIPM.
The main targets of this comparison are:

- to demonstrate equivalence of metrological practice
- to contribute to acceptance of INM in EUROMET
- to confirm the proposed CMC values of INM in the field of DC voltage
- to check the correctness of the calibration results
- to check the correct traceability of the standards

The participants were asked to follow their usual measurement procedure to achieve their best measurement capabilities.
The standard used was a Fluke 732 B electronic DC reference standard. The quantities to be measured were 1.018 V and 10 V outputs.
Each of the laboratories gave one value for the output voltage at 1.018 V and 10 V, the corresponding measurement uncertainty for a confidence level of 95 % and the mean measurement date, respectively. The uncertainty budget of each laboratory was presented in the form of a table according to chapter 4 of the EA-4/02 document "Expression of the Uncertainty of Measurement in Calibration"[3].

Participant	U_{meas} [V]	$u(U_{meas})$ [µV]	U_{meas} [V]	$u(U_{meas})$ [µV]
UME	9.999 994 96	0.44	1.018 075 76	0.22
INM	9.999 998 30	5.04	1.018 075 83	0.56
BEV	9.999 994 82	0.70	1.018 075 48	0.10

Table 1: Measurement results and uncertainties (k = 2) of the participating laboratories

It is well known, that the output voltage of Zener standards shows some drift effects as a function of time. The JAVS measurements at UME and BEV were used to calculate this drift by assuming a linear time dependence $U = a\,t + b$, with t as the time and the coefficients a, b.
With this linear interpolation the reference value U_{ref} of the standard at the mean measurement date at INM was calculated. This fictitious reference value was also used to calculate the degree of equivalence for INM. For the uncertainty of this reference value the maximum uncertainty of the measurements from UME and BEV were taken.

The degree of equivalence D_{INM} with the reference value was calculated by subtracting the reference value from the INM result according to $D_{INM} = U_{INM} - U_{ref}$

with an associated uncertainty given by $u(D_{INM}) = \sqrt{u^2(U_{INM}) + u^2(U_{ref})}$. No correlations between the different measurements were taken into account.

The degree of equivalence for the measurements performed at INM are stated in the following table.

U_{nom} [V]	U_{ref} [V]	$u(U_{ref})$ [µV]	D_{INM} [µV]	$u(D_{INM})$ [µV]
10	9.999 994 89	0.70	3.41	5.09
1.018	1.018 075 62	0.22	0.21	0.60

Table 2: Calculated reference value at the mean measurement date at INM and degree of equivalence with the associated uncertainties (k = 2) for the INM results with respect to the reference value

The measurement results and estimation of the reference values are also shown in figure 1 and 2.

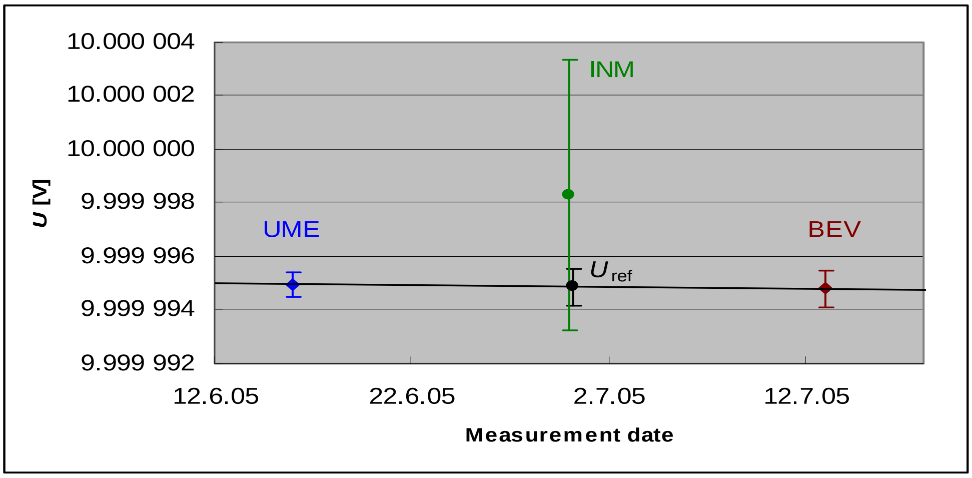

Figure 1: Measurement results and estimation of reference value for 10 V (uncertainty bars for k = 2)

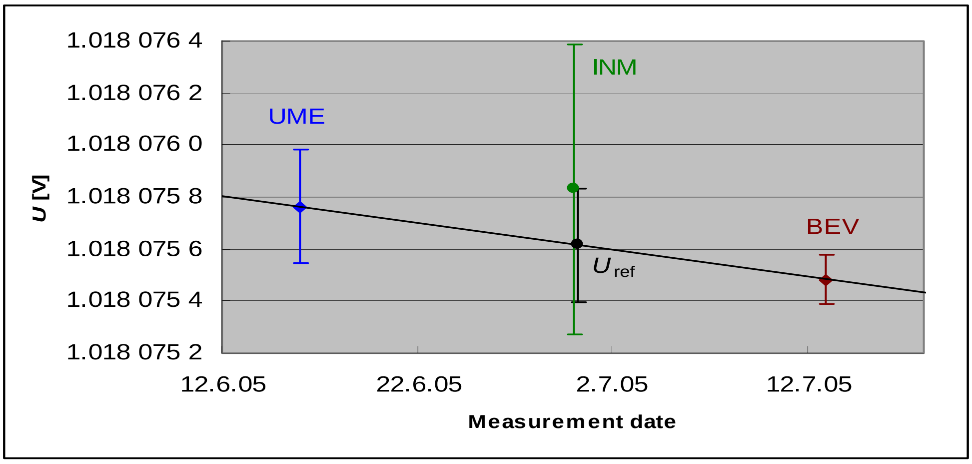

Figure 2: Measurement results and estimation of reference value for 1.018 V (uncertainty bars for k = 2)

For the INM measurement of DC voltage a link is given to the comparisons BIPM.EM-K11.a "DC voltage: 1.018 V, Zener diode" and BIPM.EM-K11.b: "DC voltage: 10 V, Zener diode". BEV took part in these comparisons and therefore the BEV degrees of equivalence and the corresponding uncertainties were used for the link.

In the Rapport BIPM-2001/03 [4] the final results of the comparison are presented as the differences between the values assigned to a 1.018 V and a 10 V standard by each laboratory and stated together with the combined standard uncertainty u_c (for $k = 1$). According to the results stated in the "BIPM key comparison database" these differences are used as the degree of equivalence $D_{K11,BEV}$ and the expanded uncertainty $U_{K11,BEV} = 2 \times u_c$ (for $k = 2$) of BEV as follows:

$D_{K11,BEV(10\ V)} = -0.04\ \mu V$ $\qquad$ $U_{K11,BEV(10\ V)} = 0.20\ \mu V$

$D_{K11,BEV(1.018\ V)} = -0.01\ \mu V$ $\qquad$ $U_{K11,BEV(1.018\ V)} = 0.03\ \mu V$

The same values are used now in this comparison for the evaluation of degrees of equivalence linked to BIPM.EM-K11.a and BIPM.EM-K11.b comparisons for the following reasons:

- as BEV used in the BIPM.EM-K11.a and BIPM.EM-K11.b comparisons and in this comparison the same Josephson system for measuring the Zener standards used as travelling standards, the same reproducibility of these measurements can be assumed.
- no drift of the Josephson measurements has to be taken into account as the Josephson system is a primary standard.

Therefore the degree of equivalence $D_{K11.6,INM}$ and the expanded uncertainty $U_{K11.6,INM}$ of INM with respect to the BIPM Reference Value given in the Rapport BIPM-2001/03 can be calculated as follows:

$$D_{K11.6,INM(10\ V)} = D_{K11,BEV(10\ V)} + D_{INM(10\ V)} = -0.04\ \mu V + 3.41\ \mu V = 3.37\ \mu V \qquad (1)$$

$$U_{K11.6,INM\ (10\ V)} = \sqrt{U^2_{K11,BEV\ (10\ V)} + U^2_{D,INM\ (10\ V)}} = \sqrt{(0.20\ \mu V)^2 + (5.09\ \mu V)^2} = 5.09\ \mu V \qquad (2)$$

$$D_{K11.6,INM(1.018\ V)} = D_{K11,BEV(1.018\ V)} + D_{INM(1.018\ V)} = -0.01\ \mu V + 0.21\ \mu V = 0.20\ \mu V \qquad (3)$$

$$U_{K11.6,INM(1.018V)} = \sqrt{U^2_{K11,BEV(1.018V)} + U^2_{D,INM(1.018V)}} = \sqrt{(0.03\mu V)^2 + (0.60\mu V)^2} = 0.60\mu V \qquad (4)$$

The results of the measurements show good agreement between the participating laboratories both for the nominal voltage of 1.018 V and 10 V.

IV. The factors involved in DC calibration

The uncertainty [3] of the result of a measurement reflects the lack of complete knowledge of the value of the measurand. Complete knowledge requires an infinite amount of information. In practice, there are many possible sources of uncertainty in a measurement, including:

- incomplete definition of measurand,
- imperfect realisation of the definition of the measurand,
- inadequately known effects of environmental conditions or imperfect measurements of these,
- personal bias in reading analogue instruments,
- finite instrument resolution or discrimination threshold,
- inexact values of measurement standards,
- inexact values of constants and other parameters obtained from external sources,
- approximations and assumptions incorporated in the measurement method and procedure,
- drift of the standard,
- variation in repeated observations of the measurand under apparently identical conditions.

V. Conclusions

Because the implementation of the quality system is a task of the modern economy, the study of the quality of the measurements is absolutely necessary. To report the result of a measurement of a physical quantity means to give a quantitative indication of the quality of this result so as the users can evaluate its credibility.

References

[1] SR EN ISO/CEI 17025 „*Cerințe generale pentru competența laboratoarelor de încercări şi etalonări*",

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[4] W. Waldmann, D. Reymann and T. J. Witt, "Rapport BIPM-2001/03: Bilateral Comparison of 1.018 V and 10 V Standards between the BEV, Austria and the BIPM", BIPM Publications, April 2001.