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CALIBRATION OF DIGITAL HYGROMETERS

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Abstract
This paper reports information about calibration of digital hygrometers in the range of 10 %rh to 95 %rh. A procedure has been developed in the NPP "Temperature measurements" Laboratory. The hygrometers has been calibrated against the standard digital hygrometer with metrological traceability to SI units. The process of obtain the reading of standard hygrometer is automated. The measurement model relating the input quantities with output quantity has been developed. Paper also describes the details of estimation and expression the expanded uncertainty of measurement.
The laboratory demonstrates its measurement competence in relative humidity area by participation in the proficiency testing scheme by interlaboratory comparison BIM-T-RH-2023-01. The results are presented and analyzed. The aims of this comparison are to evaluate the performance of laboratories and to confirm their technically competence in the field of relative humidity measurements.
Keywords: metrology, digital hygrometer, calibration, uncertainty, interlaboratory comparison

1. Introduction

The measurement and control of relative humidity plays a significant role in the industry, pharmaceutical, textile, food including various sectors such as electrical plays a significant role in and aerospace. Its need is increasing day by day with the modernization of industries and awareness of quality system.

The main activities of laboratory are: ensuring traceability of measurements in the NPP by calibration to SI units, performance of metrological control of measuring instruments.

The need to calibrate a large number of hygrometers used for environmental monitoring in an industrial plant such as Kozloduy NPP requires developing the procedure of calibration, according to ISO/IEC 17025 [1].

The detailed study of the uncertainty associated with the measurement has been evaluated and discussed.

2. Calibration procedure

Calibration of Hygrometers is carried out by a comparison method with a Standard Hygrometers by measuring the relative humidity in a chamber (Humidity Generator).

The measuring probe of the calibrated hygrometer and the probe of the reference hygrometer are placed in the generator chamber, so that their sensitive elements are as close as possible to each other to reduce the influence of the chamber gradient. When the set relative humidity is stabilized the readings of the calibrated and reference hygrometers are compared and the values of relative humidity and its associated uncertainty, expressed in the unit %rh, are determined for the corresponding reading of the calibrated hygrometer.

The mathematical model of the reference relative humidity value has been developed with following form:

$$W_{std} = \bar{W}_{std} + \delta W_{std} + \delta W_{drift} + \delta W_{linr} + \delta W_{grad} + \delta W_{inst}, \quad (1)$$

where $\bar{W}_{std}$ is the humidity measured by a reference hygrometer; δW_{std} is the correction of reference hygrometer taken from its calibration certificate; δW_{drift} is correction due to the drift of the reference hygrometer, δW_{linr} is correction due to nonlinearity; δW_{grad} is correction due to gradient in the humidity generator chamber; δW_{inst} is correction due to instability the humidity generator chamber.

The mathematical model of the measured relative humidity value with calibrated hygrometer has the following form:

$$W_c = \bar{W}_c + \delta W_{res} + \Delta W, \quad (2)$$

where: $\bar{W}_c$ is the humidity measured by calibrated hygrometer; δW_{res} is correction due to resolution of the calibrated hygrometer; ΔW is correction for the difference between the actual and measured relative humidity.

The input quantities for the reference and measured relative humidity are evaluated. Correction δW_{std} is taken or calculated from the calibration certificate of the reference hygrometer. The estimated values of the remaining inputs have a zero mathematical expectation.

The standard uncertainty of measurement of the input quantities for the reference and measured relative humidity value are determined.

When evaluating the value of the reference and measure relative humidity the impact of the input quantities, the functional dependence is linear and the sensitivity coefficients are equal to unity.

The expanded uncertainty of a digital hygrometer measurement defines the interval around the measurement result. This interval is assumed to cover a large part of the distribution of values that could be attributed to the humidity measurement at a given point with coverage factor k=2, corresponding to a confidence interval of approximately 95%.

3. METCAL automated calibration procedure

Automated calibration web base software METTEAM has been implemented in the NPP Metrological Assurance Department. METCAL automated calibration procedure for Digital Hygrometers has been created based on the developed methodology 82.MO.00.MT.1868/00 [2].

METCAL automated calibration procedure is created for digital hygrometer, type Testo 645.

The measuring instrument is used as proficiency testing (PT) item in PT scheme, in which the NPP lab was participated. The user screen in the METCAL Editor is shown in Fig. 1.

The results of digital hygrometer calibration using METCAL automated calibration procedure (Fig. 2) confirm the results reported in interlaboratory comparison describe below. This allows METCAL automated calibration procedure to be used for calibration of digital hygrometers.

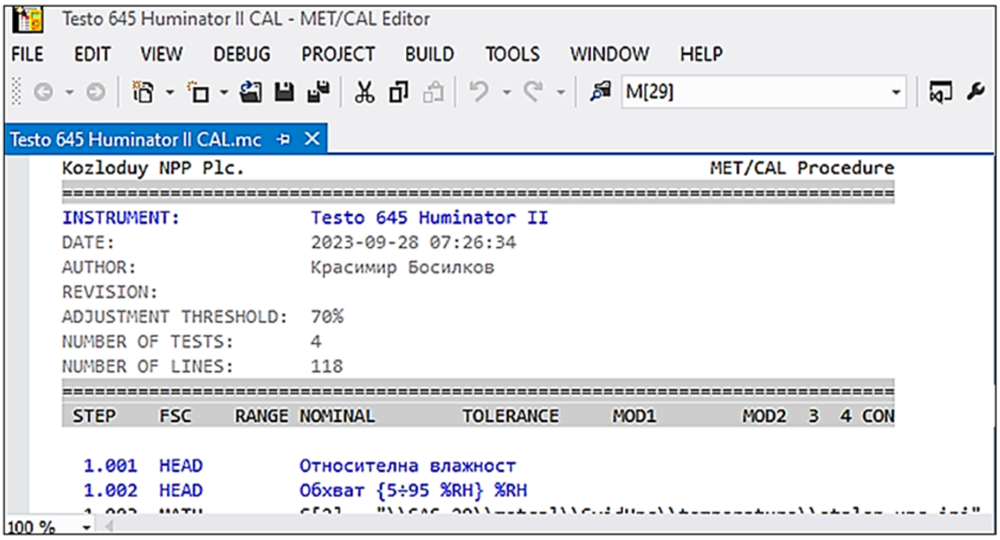

Fig. 1. User screen in METCAL Editor

РЕЗУЛТАТИ ОТ КАЛИБРИРАНЕ:

Met/Cal процедура: Testo 645 CAL Huminator II

MET/CAL Results **In Tolerance** **0-WLT-1054237**

Точка на калибриране	Зададена стойност	Измерена стойност	Отклонение	Оценена стойност	Неопределеност
5÷95 %RH					
30.00 %RH		**30,0 %RH**	0,55 %RH	29,5 %RH	2,9 %RH
50.00 %RH		**50,0 %RH**	-0,10 %RH	50,1 %RH	2,9 %RH
70.00 %RH		**70,0 %RH**	-0,40 %RH	70,4 %RH	2,9 %RH

Fig. 2. Calibration results from METCAl procedure

4. Interlaboratory comparison

The NPP laboratory has been participated in proficiency testing (PT) scheme by interlaboratory comparison BIM-T-RH-2023-01 with individual code 23RH-2.

The specific task of this comparison was to calibrate digital hygrometer. The points of the measurements were agreed to be 30 %rh, 50 %rh and 70 %rh.

Four laboratories took part in the comparison. The Bulgarian Institute of Metrology (BIM), which is accredited PT provider, according to EN ISO/IEC 17043/2023 [3] was the reference laboratory. The comparison was organized and conducted by BIM.

The reported results and associated uncertainties were used for the calculation of criteria E_n.

A. PT Item

The PT item (subject of comparison) was a standard digital hygrometer, Testo 645 with measurement sensor and range from 0 %rh to 100 %rh.

The PT item was chosen to provide sufficiently small uncertainty of the reference value with the calibration and measurement capabilities of the participants.

The PT item was demonstrated to be sufficiently stable to ensure that they will not undergo any significant change throughout the conduct of the PT round, including storage and transportation. A method of comparison measurement was used.

B. Reference value

The assigned values (X_{REF}) are determined by standard dew point hygrometer S4000 with metrological traceability to PTB Germany. The assigned values and their associated uncertainties are determined in line with procedure of PT provider.

The X_{REF} is calculated using the formula:

$$X_{\mathrm{REF}} = \frac{\Delta RH_1 + \Delta RH_2}{2}, \qquad (3)$$

where: ΔRH_1 is the difference between measured by PT item value and reference relative humidity value, determined before participants; ΔRH_2 is the difference between measured by PT item value and reference relative humidity value, determined after participants;

The uncertainty of the X_{REF} was determined using the following formula:

$$u_{\mathrm{REF}} = \sqrt{u^2(X_{\mathrm{REF}}) + u^2(X_{\mathrm{STAB}})}, \ \%\mathrm{rh}. \qquad (4)$$

where: $u(X_{\mathrm{REF}})$ is the standard uncertainty of the reference laboratory; $u(X_{\mathrm{STAB}})$ is the additional component of the stability of the PT item for the period of the performance of the comparison.

The expanded uncertainty of X_{REF}:

$$U_{\mathrm{REF}} = 2u_{\mathrm{REF}}, \qquad (5)$$

where: k=2 is coverage multiplier corresponding to a confidence interval of approximately 95%.

C. Performance of the labs

The purpose is to present the deviation from the assigned value. The performance was evaluated by using E_{n} criteria.

The criteria are calculated using the formula:

$$E_n = \frac{X_{\mathrm{LAB}} - X_{\mathrm{REF}}}{\sqrt{U_{\mathrm{LAB}}^2 + U_{REF}^2}}, \qquad (6)$$

where: X_{LAB} is the result from participant; X_{REF} is the assigned value; U_{LAB} is the expanded measurement uncertainty of a participant's result; U_{REF} is the expanded uncertainty of the assigned value.

Performance is usually evaluated relative to conventional performance criteria as follows:

- the result is acceptable and generates no signal when $|E_n| < 1{,}0$;
- the result is not acceptable and generates an action signal when $|E_n| \geq 1{,}0$.

D. Analysis of the results

The results were published in the Final report dated 07 November 2023 [7]. The differences between the results of the participating laboratories were presented graphically in groups in comparison to the reference laboratory X_{LAB}-X_{REF} for each measurement point together with associated expanded uncertainty, Fig. 3,4 and 5.

For each measured value of each laboratory, the obtained results of the criteria $|E_n|$ were presented graphically.

The results of NPP lab are acceptable, $|E_n|$<1,0 for all points of calibration, Fig. 6,7 and 8. The desire outcome is for the $|E_n|$ value to be as close to zero as possible.

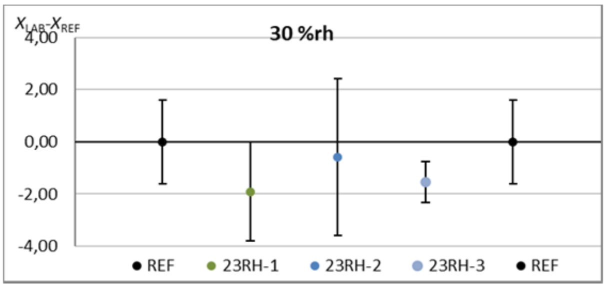

Fig. 3. The differences between the results of the participating laboratories in point 30 %rh

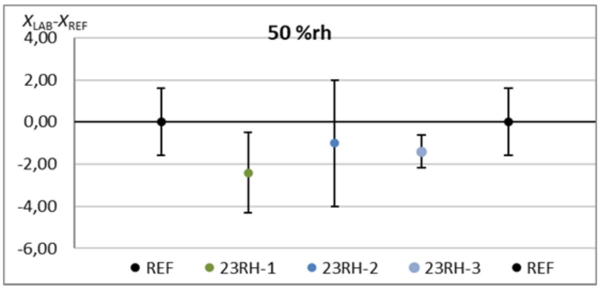

Fig. 4. The differences between the results of the participating laboratories in point 50 %rh

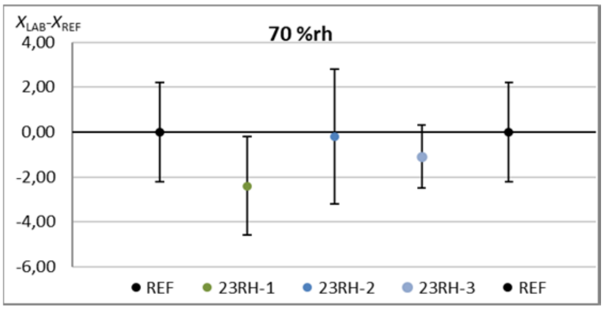

Fig. 5. The differences between the results of the participating laboratories in point 70 %rh

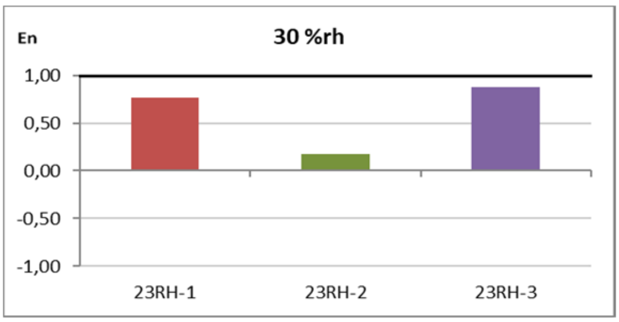

Fig. 6. Criteria E_n in point 30 %rh

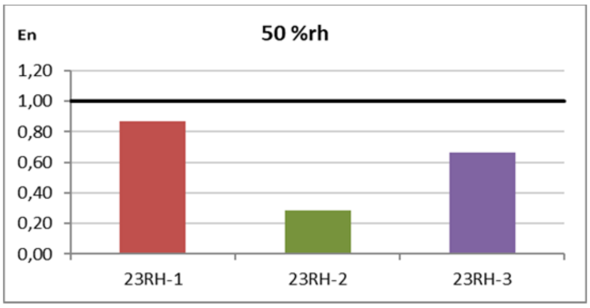

Fig. 7. Criteria E_n in point 50 %rh

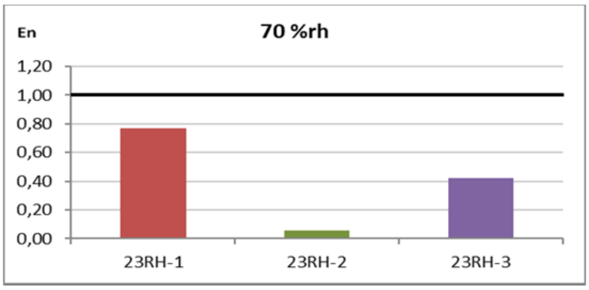

Fig. 8. Criteria E_n in point 70 %rh

5. Conclusion

The participation of NPP Temperature Measurements Laboratory in the BIM-T-RH-2023 shows that:

- the laboratory demonstrates that it is technically competent and can produce technically valid results in calibration it performs for its clients;
- the laboratory met the general requirements defined in ISO/IEC 17025 and confirmed the efficiency of the procedures, instructions and other technical documentation needed to ensure the results of the digital hygrometer calibration;
- the laboratory improved its claimed calibration and measurement capabilities (CMC) and may reduce it.

References

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2. 82.MO.00.MT.1868/00 – Procedure for Calibration of Digital Calibration.
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4. JCGM100:2008 Evaluation of Measurement Data. Guide to the Expression of Uncertainty in Measurement. BIPM, Sèvres, France;
5. ISO IEC Guide 2014, International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM 3);
6. Technical protocol BIM-T-RH-2023-01- Calibration of a Digital Hygrometer;
7. Final report dated 17 November 2023 on the proficiency testing scheme by inter-laboratory comparison BIM-T-RH-2023-01.

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Калібрування цифрових гігрометрів

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Анотація

У цьому документі міститься інформація про калібрування цифрових гігрометрів у діапазоні від 10% відносної вологості до 95% відносної вологості. В лабораторії «Вимірювання температури» АЕС розроблено методику. Гігрометри були відкалібровані за стандартним цифровим гігрометром з метрологічною простежуваністю до одиниць SI. Процес отримання показань стандартного гігрометра автоматизований. Розроблено модель вимірювання, яка зв'язує вхідні величини з вихідними. Стаття також описує деталі оцінки та вираження розширеної невизначеності вимірювання. Лабораторія демонструє свою компетентність у вимірюванні відносної вологості шляхом участі в схемі перевірки кваліфікації шляхом міжлабораторного порівняння BIM-T-RH-2023-01. Результати представлені та проаналізовані. Метою цього порівняння є оцінка продуктивності лабораторій і підтвердження їхньої технічної компетентності у сфері вимірювання відносної вологості.

Ключові слова: метрологія, цифровий гігрометр, калібрування, невизначеність, міжлабораторні порівняння.