

Digitalization of a calibration laboratory: Batch calibration

ARTICLE INFO

Keywords:
Digitalization
Traceability
Calibration
Simultaneous calibration

ABSTRACT

The Metrology and Calibration Centre (CMC) at the National Institute of Aerospace Technology (INTA) has introduced an innovative tool designed to enhance the efficiency and effectiveness of calibration processes within its facilities. This cutting-edge software enables technicians to conduct multiple calibrations simultaneously, provided the requisite experimental setup is in place. Developed with a focus on streamlining the entire calibration workflow, from data acquisition to certificate issuance, the software ensures compliance with the ISO/IEC 17025 standard. Through rigorous testing, the CMC verified the software's performance using devices employed for monitoring ambient conditions (temperature and humidity) across various INTA test laboratories. Notably, these devices underwent batch calibration in groups of six, resulting in a sixfold reduction in experimentation time. Although the associated paperwork was reduced, the necessity to maintain traceability and issue individual calibration certificates for each device offsets the time savings.

1. Introduction

The Metrology and Calibration Centre (CMC) at the National Institute of Aerospace Technology (INTA) is responsible for providing traceability to all relevant measurements involved in tests and research activities. Furthermore, the CMC also provides calibration services to customers from both the private and public sectors outside INTA's corporate organization. This results in a large number of calibrations performed at the CMC, totalling over 5000 per year.

A new software has been developed to assist in this task [1], serving as a comprehensive solution for the quality system implemented at the CMC. This software meets all the requirements of the ISO/IEC 17025 [2] and ISO/IEC 17043 [3] standards. Additionally, it streamlines the entire calibration process, from data acquisition to certificate issuance.

This tool offers the flexibility to perform multiple calibrations simultaneously, once the necessary experimental is provided. Its use not only reduces the time required for calibration due to the inherent efficiency improvement of simultaneous calibrations but also significantly simplifies the associated paperwork of a calibration which meets the accreditation requirements. Moreover, it enhances the ease of data analysis for calibration purposes. Thus, the time required in performing several calibrations is slightly larger than the time required for a single calibration. This results in a considerable increment on the time-efficiency of technicians and calibration systems [4].

In essence, the batch calibration process optimizes both tangible and intangible resources involved in calibration without any adverse effects on the results.

INTA has 11 test laboratories and 2 calibration laboratories accredited by the Spanish national accreditation body (ENAC). The test laboratories are accredited for over 200 different tests, while the calibration laboratories conduct calibrations in more than 10 areas with over 70 calibration procedures. The majority of these calibration and

tests require control and/or monitoring of ambient conditions. This presents a unique opportunity for the CMC, which is responsible for calibrating the equipment used to monitor and record ambient conditions.

Since the metrological requirements for most test and calibration laboratories are similar, the CMC can select equipment with similar metrological specifications and features. This allows the CMC to test the benefits of batch calibration.

The CMC has acquired over 120 devices dedicated to monitoring ambient conditions, specifically temperature and humidity, in laboratories and clean rooms. The selection of these devices was meticulous, considering the metrological requirements of the laboratories, as well as their connectivity and compatibility with existing software.

The majority of these devices underwent simultaneous calibration for temperature and humidity in batches ranging from 2 up to 6 devices. The results obtained from some of these calibrations are presented in the current work.

2. Methods and procedures

2.1. Equipment

The devices selected to monitor the ambient conditions of the various test or calibration laboratories were chosen to meet the requirements established in their respective accredited scopes. Typically, these requirements include a humidity range from 25 %RH up to 75 %RH, with a humidity uncertainty of $U(RH) = 2,0$ %RH and a temperature range from $t = 15$ °C up to $t = 30$ °C, with a temperature uncertainty of $U(t) = 0.1$ °C. Additionally, to facilitate installation and monitoring of measurements, it was established as a requirement that the equipment must connect wirelessly.

Two different model devices were selected and tested. Rotronic RMS-

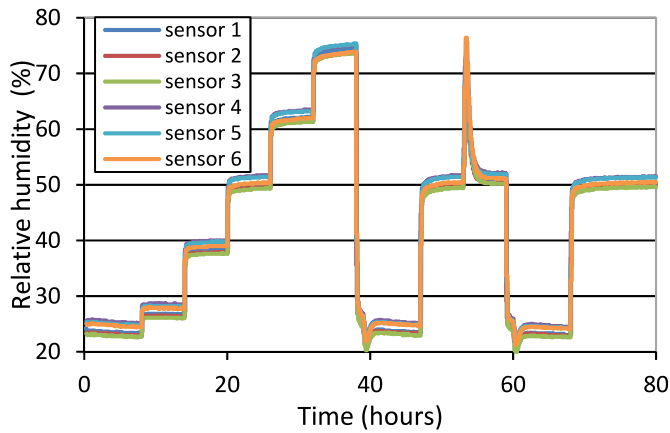


Fig. 1. Registered measurements of relative humidity obtained in a batch calibration of 6 Wisensys thermo-hygrometers.

HCD-S probes connected through Data Logger - Wireless Interface - 868 MHz - Rotronic RMS-LOG-868. And wisensys WSE-DLTc connected through WS-BU-ethernet-01.

The batch calibration was performed using the humidity laboratory calibration system, which consists of:

- Two ISOTECH Platinum resistance thermometers Isotech calibrated in the temperature range, from $t = 0\text{ }^{\circ}\text{C}$ up to $t = 80\text{ }^{\circ}\text{C}$ and traceable to national standards.
- MBW chilled mirror dewpoint hygrometer model 573, calibrated in dewpoint temperature range from $t_d = -20\text{ }^{\circ}\text{C}$ up to $t_d = 90\text{ }^{\circ}\text{C}$ using the INTA national humidity standards.
- Thunder scientific model 2500 2-Pressure humidity generator, to provide the required climatic conditions.

The relative humidity was calculated from the dewpoint temperature t_d and ambient temperature t data according to the standard BS 1339-1:2002 [5].

2.2. Procedure

The calibration was conducted following the internal procedure TH-PRC-5020-102-INTA v1 [6] of the humidity laboratory for the calibration of thermo-hygrometers. This procedure is included in the accredited scope for humidity calibrations.

The methodology employed to ensure the equivalence between batch calibration (simultaneous calibration of multiple devices) and single device calibration is straightforward. Six thermo-hygrometers are calibrated simultaneously, following which, a single device from the batch is recalibrated individually. The temperature and humidity corrections obtained from both batch and single calibration are then compared to ascertain their compatibility within the uncertainty limits.

The uncertainty contributions to the overall measurement uncertainty are described, calculated, and validated in accordance with the internal calibration procedure. The uncertainty was determined following the guidelines outlined in the Guide to the Expression of Uncertainty in Measurement [7].

The results obtained from single and batch calibration are deemed compatible within uncertainty limits if Equation (1) is satisfied.

$$\frac{|C_b - C_s|}{2} \leq U_b + U_s \quad (1)$$

Where C_b and C_s are the corrections obtained in the batch and single calibrations respectively, and U_b and U_s are the expanded uncertainty ($k = 2$) associated with the batch and single calibration respectively.

The devices were positioned inside the humidity generator Thunder

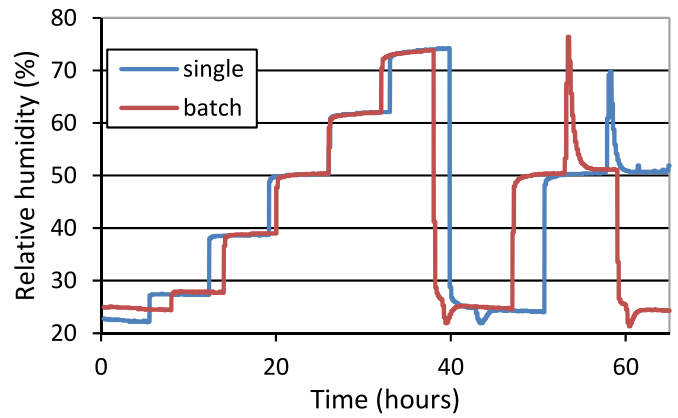


Fig. 2. Registered measurements of relative humidity obtained by device 6 in batch calibration (red) and in single calibration (blue).

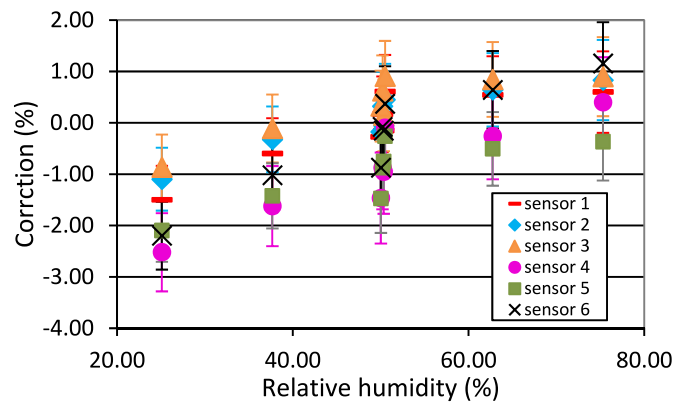


Fig. 3. Correction and uncertainty in a batch calibration of 6 Wisensys thermo-hygrometers.

Scientific Model 2500. For the Rotronic sensors, they are aligned axially with a separation of approximately 6 mm between sensors and sampling the dewpoint from the centre, together with the chamber temperature sensor. The Wisensys loggers are placed in two rows of three in such a way that the inlet holes of the sensor are upstream of the airflow. In both cases, the platinum resistance thermometers are placed in such way as to encompass all the devices at their sensor locations. This procedure is valid when the devices dissipate insignificant heat to the surrounding air and is not suitable for heated sensors.

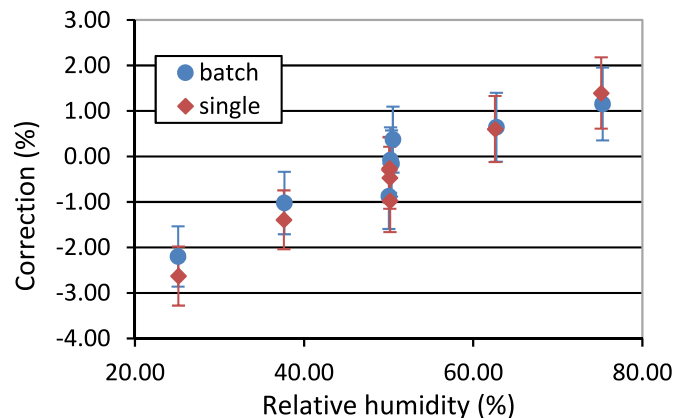


Fig. 4. Correction and uncertainty in a batch calibration of device 6 in batch calibration (red) and in single calibration (blue).

Table 1

Comparison between the batch and single calibration of device 6 in terms of correction and uncertainty at different nominal relative humidities.

RH/%	t/°C	Cb/RH%	U(Cb)/RH%	Cs/RH%	U(Cs)/RH%
25.0	23	-2.20	0.66	-2.63	0.71
37.5	23	-1.02	0.69	-1.39	0.65
50.0	23	-0.08	0.72	-0.26	0.69
67.5	23	0.64	0.76	0.60	0.73
75.0	23	1.15	0.80	1.39	0.78
50.0	15	-0.16	0.73	-0.30	0.71
50.0	30	-0.88	0.72	-0.97	0.69
50.0	23	0.37	0.73	-0.47	0.68

3. Results and discussion

3.1. Results

The most significant data and results obtained in this study are presented in this section.

Fig. 1 illustrates the data collected during the batch calibration of 6 Wisensys devices.

Fig. 2 displays a graphical comparison between the data obtained from device 6 in a batch calibration and in a single calibration.

From the data presented in Figs. 1 and 2, a dataset comprising at least 15 minutes was selected at each calibration point for all devices. These data were selected to have the same starting and finishing times for all devices, starting after sufficient time for stabilization. The correction and associated uncertainty of these points were calculated and presented for all devices in Fig. 3.

Fig. 4 provides a graphical comparison between the obtained results of the same device in batch and single calibration. Table 1 displays the data already presented in Fig. 4 for a numerical comparison, adhering to equation (1).

3.2. Discussion

From the data presented in Table 1, it can be concluded that batch and single calibration are compatible in terms of uncertainty.

Since batch and single calibration are compatible, the implications of this compatibility, such as resource savings and efficiency improvement, can be discussed.

Batch calibration facilitates resource savings for calibration laboratories. Humidity calibration necessitates a continuous supply of dry air throughout the experiment, which can span several hours. By calibrating multiple devices simultaneously, the reduction in dry air requirements is directly proportional to the number of devices being calibrated. This principle extends to the equipment within the calibration system, including the humidity generator, and temperature and dewpoint standards. The operational hours of the equipment during batch calibration are reduced in proportion to the number of devices calibrated, thereby extending their lifespan.

The man-hours required for each calibration are also reduced. While the setup for experimentation in batch calibration is larger than for a single calibration, it is not as time-consuming as the cumulative equivalent of single calibrations. Additionally, the time a technician needs to complete associated paperwork is slightly reduced. Although some paperwork may be similar for each device, since each one requires its own certificate, this process cannot be significantly reduced.

Batch calibration enhances the overall efficiency of calibration laboratories. It increases the number of calibrations conducted over the lifetime of the calibration system and reduces both direct and indirect costs associated with each calibration.

Although this study focused on calibrations in humidity, its findings and methodologies could be extended to other quantities in different laboratories.

The improvement in effectiveness can be quantified as the reduction

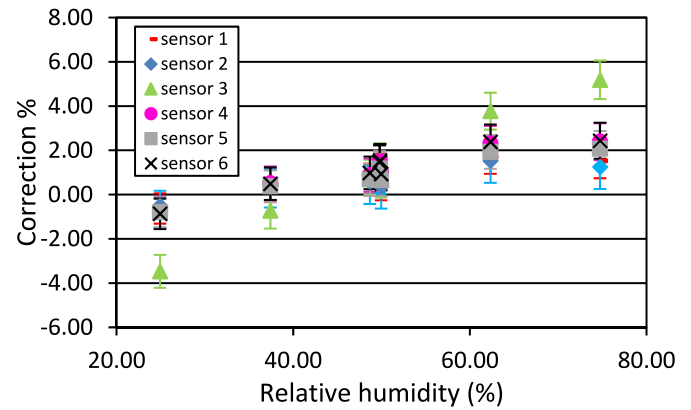


Fig. 5. Correction and uncertainty in a batch calibration of 6 Wisensys thermo-hygrometers when abnormal behaviour of one the devices (sensor 3) is observed for.

of calibration-associated costs. Equation (2) provides a rough approximation of how these costs can be calculated for batch calibration.

$$C_c = \frac{Pr}{n} + n \cdot p_{1mh} \quad (2)$$

Where C_c represents the calibration cost per device, p_r is the price for material resources such as the volume of dry air and machine hours, p_{1mh} is the price of one man-hour, and n is the number of devices calibrated simultaneously.

3.2.1. Abnormal behaviour detection

During the batch calibration of some of the devices acquired for monitoring the ambient conditions of the different test and calibration laboratories, abnormal behaviour was detected in some of these devices. Fig. 5 illustrates the results of a calibration when this abnormal behaviour was observed.

When events like this are observed in single calibrations, technicians often rely on the metrological superiority of the laboratory standards to endorse the trustworthiness of the results. While this approach is valid in most cases, the truth is nobody can be absolutely certain. On the other hand, when this issue is observed in only one of the devices calibrated simultaneously, it is likely that the equipment showing the odd behaviour is the one that needs to be double-checked.

4. Conclusion and future work

The procedure developed at the CMC facilities of INTA for batch calibration can accommodate up to 6 thermo-hygrometers simultaneously. The efficiency of both tangible and intangible resources is increased almost proportionally to the number of devices calibrated simultaneously. Batch calibration offers the possibility of unambiguously identifying odd behaviour of single devices when calibrated together with devices of the same brand and model.

This study is limited to humidity calibration with up to 6 thermo-hygrometers calibrated simultaneously. Future research will involve increasing the number of devices calibrated and extending the batch calibration procedure to other quantities and fields.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgments

We thank CDTI for funding the CDTI IDI-20170265 project

“Development of a software application for the automation of the analysis of the calculations of the tests and measurements with metrological traceability” and the team at Whitestone Technology and INTA, whose dedication and effort made it possible to develop the software tool used in this work. CDTI is a Business Public Entity under the Ministry of Science, Innovation and Universities that promotes innovation and technological development of Spanish companies.

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Fernando J. Pérez-Sanz^{*}, Rebeca Larroca Sanz, Inmaculada Mohino Herranz, Jaime García Gallegos, Tomás Vicente Mussons, Robert Benyon Puig
Instituto Nacional de Técnica Aeroespacial (INTA), Carretera Ajalvir, km 4, Torrejón de Ardoz, 28850, Madrid, Spain

^{*} Corresponding author.
 E-mail address: fpersan@inta.es (F.J. Pérez-Sanz).