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Calibration of dew point hygrometers with gas temperature measurement for relative humidity

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Deutscher Kalibrierdienst (DKD) – German Calibration Service

Since its foundation in 1977, the German Calibration Service has brought together calibration laboratories of industrial enterprises, research institutes, technical authorities, inspection and testing institutes. On 3rd May 2011, the German Calibration Service was reestablished as a *technical body* of PTB and accredited laboratories.

This body is known as *Deutscher Kalibrierdienst* (DKD for short) and is under the direction of PTB. The guidelines and guides developed by DKD represent the state of the art in the respective areas of technical expertise and can be used by the *Deutsche Akkreditierungsstelle GmbH* (the German accreditation body – DAkkS) for the accreditation of calibration laboratories.

The accredited calibration laboratories are now accredited and supervised by DAkkS as legal successor to the DKD. They carry out calibrations of measuring instruments and measuring standards for the measurands and measuring ranges defined during accreditation. The calibration certificates issued by these laboratories prove the traceability to national standards as required by the family of standards DIN EN ISO 9000 and DIN EN ISO/IEC 17025.

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Foreword

DKD expert reports aim to provide background information and references in connection with other DKD documents as, for example, the DKD guidelines. In some cases, they may even go far beyond these documents. They do not replace the original DKD documents but do provide a lot of supplementary information worth knowing. The expert reports do not necessarily reflect the views of the DKD's Management Board or Technical Committees in all details.

DKD expert reports are intended to present significant aspects from the field of calibration. Through publication by the DKD they are made available to the large community of calibration laboratories, both nationally and internationally.

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1 Introduction

The aim of this expert report is to outline the technical conditions for the calibration of dew point hygrometers with connected temperature sensors with regard to the measurand relative humidity and thus to create a uniform approach among calibration laboratories, technical assessors and users. All symbols and formula symbols are used in analogy to the definition in DKD-R 5-8:2019 [1]. This expert report addresses accredited calibration laboratories or calibration laboratories in the process of accreditation. It can also be used by other calibration laboratories.

2 Calibration of dew point hygrometers with connected temperature sensors with regard to the measurand relative humidity

The current version of the Guideline DKD-R 5-8 covers the calibration of hygrometers with direct measurement of the relative gas humidity by means of resistive, capacitive, resistive-electrolytic and mechanical sensor elements [1]. DKD-R 5-8 does not explicitly list dew point hygrometers as calibration items. However, some of these measuring devices also provide indications for relative humidity; their indicated value is usually determined from the measured frost-/dew-point temperature and a reference temperature. The reference temperature can be a predetermined value or its value can be determined by measurement using an external temperature sensor connected to the indicating unit of the dew point hygrometer. In both cases, these devices are not approved as calibration items in accordance with DKD-R 5-8:2019 [1] and therefore cannot be calibrated according to this guideline.
Under certain conditions, dew point hygrometers with a connected temperature sensor whose measured value is used to determine the relative humidity of the gas can be calibrated using a separate procedure.
An important aspect here is that the sensors for frost-/dew-point temperature and gas temperature in these devices are designed to work separately, i.e. the measuring location of both quantities can be determined separately by the user, but the indicated value is calculated from both quantities.

The following sections explain in more detail how such a procedure can be formally and technically implemented in accordance with current state-of-the-art technology.

2.1 Requirements regarding the CAB

In this report, conformity assessment body (CAB) refers to calibration laboratories. It is assumed that the CAB has been accredited for absolute humidity (frost-/dew-point temperature with dew point hygrometers as calibration item) and (gas) temperature (for the present type of temperature sensor).

2.2 Reference standards

As to the reference standards, the requirements specified in DKD-R 5-1 and DKD-R 5-8 apply.

2.3 Calibration procedure

Calibration of dew point hygrometers for relative humidity according to DKD-R 5-8:2019 [1] is not possible. A separate procedure, the so-called in-house procedure, must therefore be developed and validated by the laboratory (see DIN EN ISO/IEC 17025:2018 [2]). This procedure, in particular the positioning and evaluation including the determination of the measurement uncertainty, is to be described as part of the in-house procedure for the calibration of dew point hygrometers or as a separate in-house procedure. The procedure must fulfil the following requirements:

- With regard to the procedures used to determine the frost-/dew-point temperature and (gas) temperature, reference to the respective procedures (included in the scope of accreditation) is to be made; alternatively, these procedures are to be described accordingly in the in-house procedure.
- When calibrating dew point hygrometers with an external measuring head which is tempered inside a temperature chamber, the temperature chamber must be set to the gas temperature, even if, for example, the gas temperature sensor is simultaneously immersed in a calibration bath.
- When positioning an external dew-point measuring head and gas temperature sensor in a temperature chamber, it must be ensured that the dissipated heat from the measuring head does not affect the temperature calibration.
- The value of the relative humidity is to be determined from the primary measurands frost-/dew-point temperature and the (gas) temperature (see DKD-R 5-8:2019 [1]). The calculation of the relative humidity is to be described (reference state of the relative humidity as saturation over water and/or saturation over ice and/or hypothetical state (hypothetical system pressure), enhancement factor, saturation vapour pressure equation used, ...). Uncertainties in the equations are to be taken into account in the measurement uncertainty calculation.
- As very small measurement uncertainties can be achieved, the measurement uncertainties are to be determined over the entire humidity and temperature ranges and taken into account in the scope of accreditation. At temperatures and/or frost-/dew-point temperatures below 0 °C, the measurement uncertainties increase significantly. This is to be taken into account in the presentation of the scope.
- All relevant influence quantities (among others those of the reference standards, temperature, frost-/dew-point temperature, calibration equipment, calibration item, calculation equations, absolute pressure) are to be taken into account in the measurement uncertainty budget.

2.4 Calibration item

The calibration item must have a separate indication or signal output for relative humidity resulting from the two measured quantities gas temperature and frost-/dew-point temperature (no fixed reference value). It must also be clear which relative humidity is being calibrated. This means that the reference point must be specified, e.g. for gas temperatures below 0 °C saturation over ice U_i or saturation over water U_w or a hypothetical condition (hypothetical system pressure) above 100 °C.

2.5 Application of the calibration

The calibration applies only to the calibrated points. Direct interpolation of the calibrated relative humidity values is possible if interpolation is carried out between the relative humidity points at the applicable gas temperatures. Alternatively, an interpolation can be carried out taking into account the primary measuring quantities (gas temperature and frost-/dew-point temperature). At frost-/dew-point temperatures and/or gas temperatures below 0°C, particular attention must be paid as to which saturation states (ice/water) are assumed for the vapour pressure equations used to calculate the humidity.
In the measurement uncertainty budget, additional deviations that may be present due to interpolation between the calibration points are to be taken into account.
Metrological traceability of the calibration result is only given if the measuring point lies within the calibrated ranges of the gas temperature, frost-/dew-point temperature **and** relative humidity.

2.6 Calibration certificate

To provide a clear description of the procedure and the measurement results, the calibration certificate must fulfil the following requirements:

- The calibration certificate must state the (gas) temperature and frost-/dew-point temperature of the targeted calibration points for relative humidity including the measurement uncertainty.
- The relative humidity is stated as an additional quantity including the measurement uncertainty. It must be indicated that this value has been calculated. The basis for determining the reference value (e.g. calculation equation or literature reference as well as other quantities used to calculate the relative humidity) must be clearly stated.
- The calibration certificate must clearly describe the position of the temperature sensor and the measuring head for the frost-/dew-point temperature (especially ambient conditions, measuring head temperature, immersion depths, local separation of both sensors, if necessary) as well as the calibration device used in each case. If both sensors (gas temperature and frost-/dew-point temperature) are calibrated in close proximity in the same calibration device, the influence of both sensors on the measurement or, respectively, on the measurement uncertainty are to be taken into account.
- All components of the calibration item (for the measurands temperature and frost-/dew-point temperature) must be clearly identifiable and specified in the calibration certificate. The calibration is valid only for this combination.
- The calibration is valid only for the calibrated points; interpolation is only possible under the conditions described in Section 2.5. This is to be stated in the calibration certificate.

2.7 Assessment

In addition to the correct implementation of Sections 2.1 to 2.6, the assessment should focus on the competence of the CAB regarding the conversion of frost-/dew-point temperature and gas temperature (and absolute pressure) into relative humidity U_i or U_w and hypothetical condition as well as on the classification of the indicated measured value of the dew-point hygrometer (U_i ,

U_w , $U_{w,hyp}$ hypothetical condition, frost-/dew-point temperature T_f or T_d , absolute pressure p_{abs}).

2.8 Presentation in the appendix of the accreditation certificate

As the procedure is not covered by DKD-R 5-8:2019, it should be listed as a separate procedure in the appendix of the accreditation certificate. An example of how to do this is given in Table 1.

Measurand / calibration item	Measuring range / measuring span	Measuring conditions / procedure	Expanded measure-ment uncertainty	Remarks
Relative humidity Dew point hygrometer with gas temperature measurement	5 % to 80 %	Frost-/dew-point temperature: -25 °C to +55 °C Reference temperature of the relative humidity: +10 °C to <+20 °C +20 °C to +60 °C Procedure 1234, V1	 1,5 % 1,0 %	Comparison method with reference dewpoint hygrometer and reference thermometer Measurement uncertainty expressed as absolute value of relative humidity

Table 1: Example of how to design the appendix of the accreditation certificate for the calibration of dew point hygrometers with connected temperature sensors for the measurand relative humidity

2.9 Proof of verification

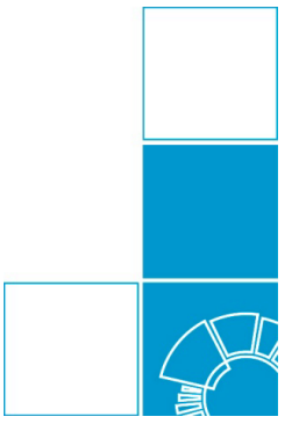
A separate comparison measurement is not required for verification. However, the calculation of the relative humidity value from the individual measurements of the frost-/dew-point temperature and the gas temperature as well as the associated measurement uncertainty calculation must be demonstrated on the basis of the documentation. For the two procedures used to determine the gas temperature and the frost-/dew-point temperature, the corresponding proof of verification and, if necessary, validation of the individual procedures from the accreditations as stipulated in Section 2.1 must be available.

As an example, the measurement uncertainty must be calculated for the entire scope of accreditation. The accredited measurement uncertainty must never be less than the calculated measurement uncertainty. This is particularly important at the limits of the measuring range, where, for example, the measurement uncertainty of the frost-/dew-point temperature increases or the sensitivity coefficients rise (frost point temperature and temperature below 0 °C).

3 Bibliography

[1] Richtlinie DKD-R 5-8, Ausgabe 02/2019, Revision 0, Kalibrierung von Hygrometern zur direkten Erfassung der relativen Feuchte, Physikalisch-Technische Bundesanstalt, Braunschweig und Berlin. DOI: 10.7795/550.20190214
(English translation available: DKD-R 5-8, Calibration of hygrometers for the direct measurement of relative humidity. DOI: 10.7795/550.20190214EN)

[2] DIN EN ISO/IEC 17025:2018-03: Allgemeine Anforderungen an die Kompetenz von Prüf- und Kalibrierlaboratorien (ISO/IEC 17025:2017); German and English version EN ISO/IEC 17025:2017
(English title: General requirements for the competence of testing and calibration laboratories)



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