Int J Thermophys (2008) 29:1678–1684
DOI 10.1007/s10765-008-0453-6

Bilateral Comparison of Humidity Standards Between UME and MIKES

M. Heinonen · S. Oğuz Aytekin · A. Uytun

Published online: 5 June 2008

Abstract In order to assure the quality of dew-point measurements, a bilateral comparison between the National Metrology Institute of Turkey (UME) and the Centre for Metrology and Accreditation (MIKES), Finland, was carried out in 2006. This comparison is registered as EUROMET Project No. 906. Two chilled-mirror hygrometers (MBW 373 and MBW 373H) were used to compare the UME two-pressure humidity generator with the MIKES dew/frost-point generator. An MBW 373 was used in the range from a frost point of −20 °C to a dew point of +20 °C and an MBW 373H in the range from a frost point of −20 °C to a dew point of +60 °C. Dew-point temperature measurements were performed at six dew-point temperatures in the range from a frost point of −20 °C to a dew point of +60 °C at UME and MIKES. According to the results, the mean difference between the laboratories varies from (−0.11 to +0.07) °C over the range. The estimated expanded uncertainty ($k = 2$) varies from (0.13 to 0.28) °C. A detailed description of the equipment, results and uncertainty analysis is presented in this paper.

Keywords Humidity generator · Dew-point temperature · Comparison

1 Introduction

UME and MIKES have organized and carried out a bilateral comparison of dew-point temperature standards as the aim of EUROMET Project No. 906, in order to establish

M. Heinonen (✉)
MIKES, Centre for Metrology and Accreditation, Helsinki, Finland
e-mail: Martti.Heinonen@mikes.fi

S. O. Aytekin · A. Uytun
UME, National Metrology Institute of Turkey, Kocaeli 41470, Turkey

international equivalence. Primary dew-point generators of the two-pressure type at UME and the two-temperature type at MIKES were used. The humidity generators are described in detail elsewhere [1,2]. The generators were compared to each other using two dew-point hygrometers as transfer standards. Both the analogue output and the digital display readings of dew-point temperatures and mirror temperatures were recorded during the measurements carried out using the UME transfer standards. Analogue output readings were recorded to increase the reliability of the mirror temperature measurements and the data recording.

2 Humidity Standards at UME and MIKES

2.1 UME Humidity Generator

UME uses a two-pressure humidity generator (Model 2500ST-LT) manufactured by Thunder Scientific Corporation. In the generator, compressed air passes through regulators. After adjustment by a flow-control valve, the air passes through immersed tubing into a pre-saturator whose temperature is maintained at a temperature of (15–20) °C warmer than the saturation temperature. Then, the air flows to the saturator, i.e. a "shell and tube"-type heat exchanger. As air having nearly 100% relative humidity is circulated through the saturator, it is cooled to ensure complete saturation, i.e. 100% relative humidity. Before entering the measurement chamber, the saturated air flows through a thermally isolated and heated expansion valve. With this valve, the air pressure is reduced and the final value for relative humidity is attained. The humidity generator was used by UME in the international comparison EUROMET 511 in 1999. The expanded uncertainty of the dew-point temperature realized by the UME generator was 0.3 °C in the exercise reported in this paper.

2.2 MIKES Humidity Generator

The MIKES dew/frost-point generator (MDFG) with three saturator systems operates in the range from (−80 to +84) °C. The expanded uncertainty of the dew-point temperature is between (0.05 and 0.06) °C in the range from (−60 to +84) °C.

In the MDFG saturators, air passes through a heat exchanger coil before entering a small horizontal cylinder containing water or ice. The dew-point temperature of the air supplied to the saturator is maintained slightly higher than the saturator temperature. Complete saturation is achieved in the cylinder. In this comparison, the output dew-point temperature was controlled through the regulation of the saturator temperature. The saturator temperature is measured with two Pt-100 thermometers (in each saturator system) connected to an ASL F700B resistance bridge with a switchbox (ASL SB148).

2.3 Transfer Standards

Two chilled-mirror hygrometers manufactured by MBW were used as the transfer standards in this comparison. The measurement ranges are (−60 to +60) °C and

(−20 to +100) °C for Models 373 and 373H, respectively. The resolution of the dew-point temperature reading is 0.01 °C. In addition to the digital output, they both provided direct access to a secondary PRT embedded in the mirror and to an analogue voltage output during the comparison. A digital multimeter transported with the instruments was used for the resistance and voltage measurements. The instruments are equipped with internal flow meters that were used to adjust the sampling flow rate.

3 Comparison Measurements and Results

The flow rate through the dew-point meters was adjusted to $0.5\,\mathrm{L \cdot min^{-1}}$. The reference dew-point temperature values were calculated from the saturator temperature and the pressures in the saturator and the dew-point meter. Internally electropolished stainless steel tubing was used to connect the dew-point meters to the generators. In the range above ambient temperature, heated hoses were used to maintain the tube temperatures 30 °C above the measured dew-point temperature. The mirrors were cleaned before the measurements by injecting water and pumping the excess water away from the mirror. The same nominal dew-point temperatures in the range from (−20 to +60) °C were measured at UME and MIKES.

At UME, measurements were taken using a resistance bridge, a standard platinum resistance thermometer (SPRT), the humidity generator and dew-point temperature meters. A Fluke Scientific Super Thermometer Model 1575 with a scanner (Model 2575) was used to measure the Pt-100 sensors embedded in the dew-point meters. The saturator temperature was also monitored with an SPRT to check the stability of the saturator.

At the two institutes, measurements were carried out under normal ambient conditions. Ambient temperature and relative humidity values were recorded continuously. No effect of ambient conditions on the instruments was found in this exercise.

The measurement results of the bilateral comparison are given in Tables 1–4.

The measurement results are shown in Figs. 1 and 2 where $t_{\mathrm{d}}^{\mathrm{REF}}$ is the dew-point temperature according to the UME and MIKES national standards and t_{d}^{373} and $t_{\mathrm{d}}^{373\mathrm{H}}$ are the dew-point temperature values indicated by the transfer standards.

The comparison results were evaluated in terms of the difference (R) between the generated dew-point temperatures $\left(t_{\mathrm{d}}^{A}, t_{\mathrm{d}}^{B}\right)$ and the corresponding measurement values

Table 1 Measurement results of the transfer standard MBW 373H at UME

UME Humidity generator dew-point tmperature (°C)	Dew-point meter (MBW 373H) readings (°C)	Difference (°C)	Expanded uncertainty, $k = 2$ (°C)
−20.00	−19.91	−0.09	0.27
1.04	1.06	−0.02	0.27
20.03	20.04	−0.01	0.17
40.50	40.50	0.00	0.19
50.08	50.03	0.05	0.27
59.99	60.00	−0.01	0.26

Table 2 Measurement results of the transfer standard MBW 373H at MIKES

MIKES humidity generator dew-point temperature (°C)	Dew-point meter (MBW 373H) readings (°C)	Difference (°C)	Expanded uncertainty, $k = 2$ (°C)
−19.54	−19.57	0.03	0.06
0.87	0.80	0.07	0.06
19.81	19.80	0.01	0.06
39.77	39.77	0.00	0.06
49.75	49.77	−0.02	0.06
59.74	59.76	−0.02	0.06

Table 3 Measurement results of the transfer standard MBW 373 at UME

UME Humidity generator dew-point temperature (°C)	Dew-point meter (MBW 373) readings (°C)	Difference (°C)	Expanded uncertainty, $k = 2$ (°C)
−20.00	−19.92	−0.08	0.27
1.04	0.98	0.06	0.27
20.03	20.00	0.03	0.17

Table 4 Measurement results of the transfer standard MBW 373 at MIKES

MIKES humidity generator dew-point temperature (°C)	Dew-point meter (MBW 373) readings (°C)	Difference (°C)	Expandeduncertainty, uncertainty, $k = 2$ (°C)
−19.92	−19.93	0.01	0.06
0.87	0.85	0.02	0.07
19.81	19.75	0.06	0.06

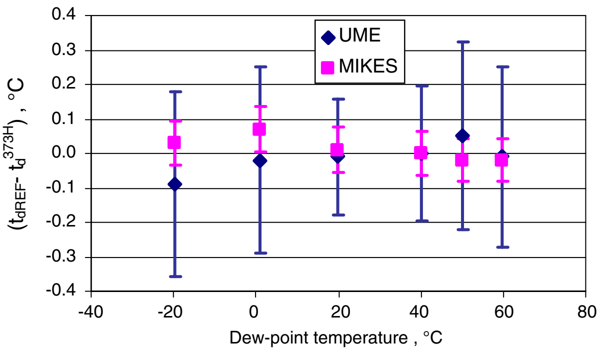

Fig. 1 Difference between the reference dew-point temperature and the transfer standard indication determined at UME and MIKES in the range from a frost point of −20 °C to a dew point of 60 °C

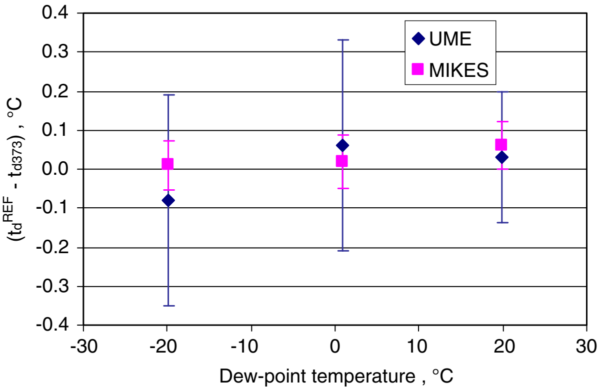

Fig. 2 Difference between the reference dew-point temperature and the transfer standard indication determined at UME and MIKES in the range from a frost point of −20 °C to a dew point of 20 °C

obtained by the transfer standards $I(t_d^A)$ and $I(t_d^B)$. Because the characteristic curves of the instruments are neither perfectly linear nor completely time-independent, an instrument-related correction term (ΔI) is also included in the analysis:

$$R = \left[t_d^A - I\left(t_d^A\right)\right] - \left[t_d^B - I\left(t_d^B\right)\right] + \Delta I. \quad (1)$$

The estimate for the correction term is zero because no change over the long term was found for the transfer standards, and the actual measurement points were close to the corresponding nominal points measured in both laboratories.

The uncertainty of the reference values, the uncertainty of the measured values and the uncertainty due to the nonlinearity and long-term instability of the transfer standards contribute to the uncertainty of the results. The last two terms were found to be negligible when compared with the calibration uncertainties stated by the participating laboratories.

The final results are given in Fig. 3. The error bars in the figures show the expanded uncertainties at ∼ 95 % confidence level ($k = 2$). The mean differences for the transfer standards 373H and 373 range from (−0.12 to +0.07) °C, with an average value of +0.025 °C, and from (−0.09 to +0.04) °C, with an average value of +0.027 °C, respectively. At all points, the mean differences were within the estimated uncertainties for both transfer standards. To calculate the bilateral equivalence, the results obtained in the range from (−20 to +20) °C were combined in the following way:

$$R_{\text{final}} = \frac{(R_{373} + R_{373\text{H}})}{2},$$
$$U(R_{\text{final}}) = \sqrt{u^2(R_{373}) + u^2(R_{373\text{H}})}. \quad (2)$$

Here, U and u are the expanded uncertainty ($k = 2$) and the standard uncertainty, respectively. In the range above +20 °C, the final results are just the results obtained

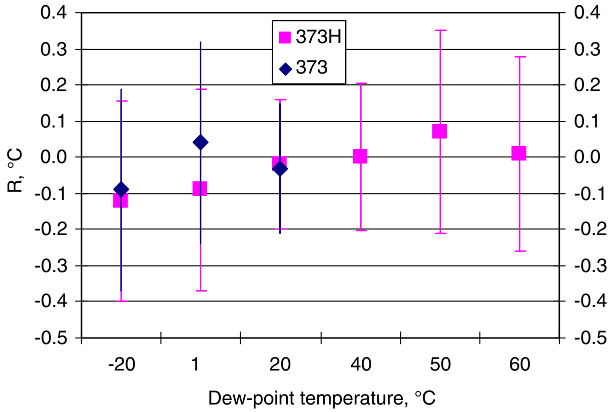

Fig. 3 Result of comparisons between UME and MIKES humidity generators measured by the transfer standard dew-point mirror MBW 373 and 373H in the range from a frost point of −20 °C to a dew point of 60 °C

Table 5 Final results of the comparison: bilateral degree of equivalence between UME and MIKES

Dew-point temperature (°C)	Bilateral degree of equivalence (°C)
−20	−0.11 ± 0.20
1	−0.03 ± 0.20
20	−0.02 ± 0.13
40	0.00 ± 0.20
50	0.07 ± 0.28
60	0.01 ± 0.27

with the transfer standard 373H. The final results in terms of degree of equivalence (i.e. $R_{\text{final}} \pm U(R_{\text{final}})$) are in Table 5.

4 Conclusion

Using transfer standard dew-point hygrometers, a comparison of the humidity generators at UME and MIKES was carried out in the dew-point temperature range from (−20 to 60) °C.

The differences between the laboratories (R) range from (−0.11 ± 0.20) °C to (+0.07 ± 0.28) °C in the whole range. At +20 °C, the difference is (−0.02 ± 0.13) °C. The comparison results show good equivalence between the dew-point temperature realizations and the calibrations at UME and MIKES.

The results indicate a small linear dew-point temperature dependence of the difference 0.0016 °C · $°\text{C}^{-1}$. However, reliable conclusions cannot be drawn because the effect of the dependence throughout the entire range is smaller than the estimated uncertainties.

References

1. M. Heinonen, *ISHM 2002 Taiwan, Papers from the 4th International Symposium on Humidity and Moisture* (ITRI, Taipei, 2002), pp. 485–492
2. M. Heinonen, S. Bell, K. Flakiewicz, G. Mamontov, P. K. Birch, A. Steiner, S. Ugur, "EUROMET 511: MIKES - VNIIM - GUM - DELTA - NPL -METAS - UME, Intercomparison of Humidity Standards" *MIKES Publication* J6 (2001)