CALIBRATION OF RELATIVE HUMIDITY MEASURING INSTRUMENTS AT EARS

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1. Introduction

Periodical recalibration of relative humidity measuring instruments is important issue in Quality assurance system at EARS. Calibration Laboratory Service with its state-of-art equipment performs adjustments and calibration of humidity sensors in our meteorological network. Traceability scheme and an evaluation of measuring uncertainty assure traceability of calibrations to the international level. Uncertainty evaluation of the reference standard and uncertainty disemination to comparison calibration of widely used capacitive instruments is presented.

2. Traceability scheme

Traceability of relative humidity instrument calibrations is maintained in the range from 10% to 95% in temperature range from -20°C to 40°C. Dew point hygrometer Mitchell S4000 as a reference standard was primarily calibrated in WYKO Calibration Service in Great Britain as shown in figure 3. In future reference standard will be calibrated in CL using temperature standards and capabilities. Thunder Scientific 2500 two pressure humidity generator is recently bought to improve efficiency and metrological capabilities. Humidity generator is nowadays in a testing and implementing mode and it is expected to improve best measurement capabilities to 1% level.

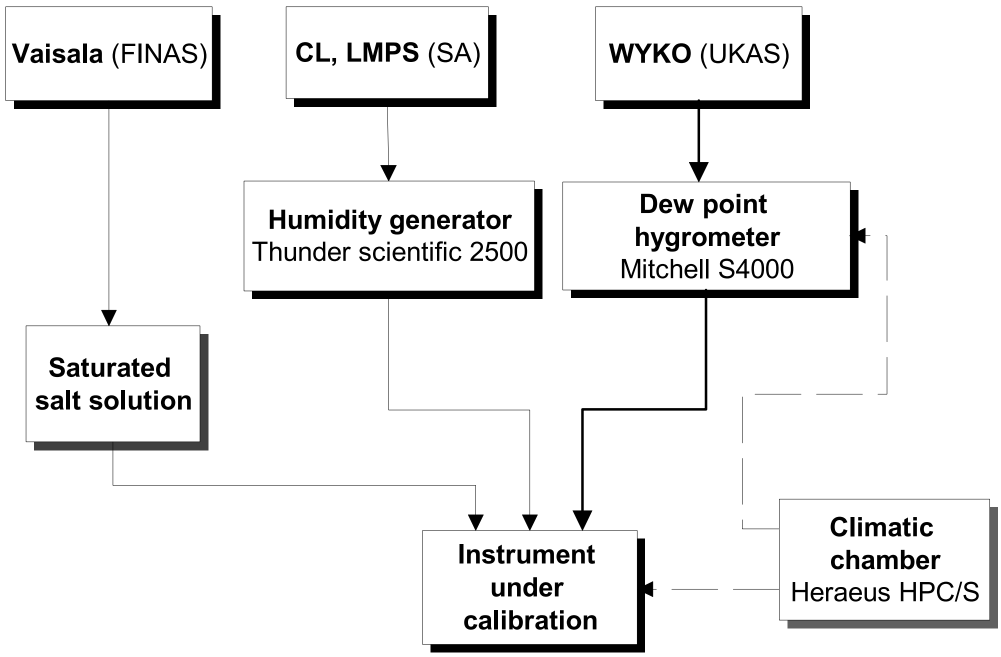

Figure 1: Traceability of calibrations of relative humidity instruments at EARS

Saturated salt solutions are used for adjustments of capacitive humidity instruments only. Climatic chamber is the main uncertainty source in comparison calibrations of field instruments (capacitive sensors, hygrographs). Reduction of time instability and spatial unhomogenity is possible if reduced volume of climatic chamber is used. Expanded calibration uncertainty of field instruments is at present time 4%.

3. Reference standard

Operating principle of dew point reference standard is based on a plated copper mirror and Peltier thermoelectric device as commonly known. At a temperature determined by the moisture content of sample air, dew forms on the mirror surface as Peltier device cools the mirror. This formation of dew causes reduction in reflected light intensity from red LED light source. The control loop maintains the mirror surface at the exact dew point temperature which is accurately measured by an embedded platinum resistance thermometer as shown in figure 1.

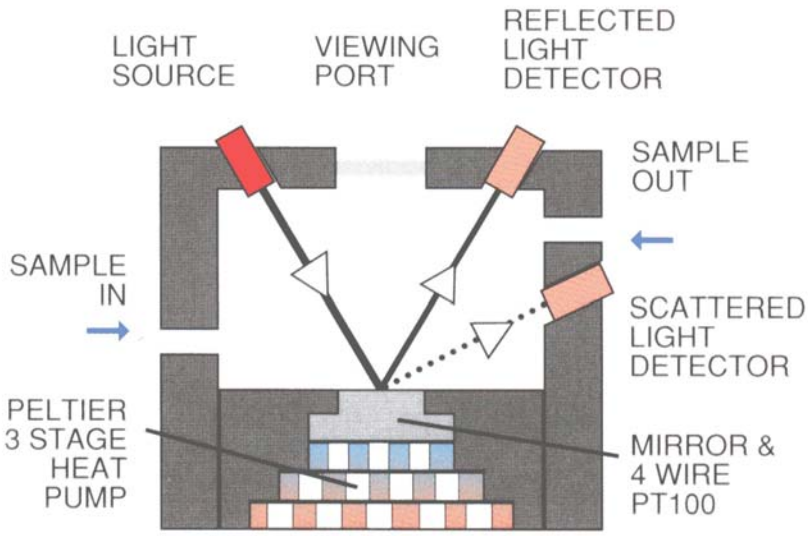

Figure 1: Dew-point sensor

Relative humidity can be calculated:

$$RH = 100 \cdot \frac{p_s(t_d) \cdot f(t_d, P)}{p_s(t_a) \cdot f(t_a, P)} \tag{1}$$

where:

$p_s(t_d)$ - calculated vapour pressure at dew/frost point temperature t_d [hPa],
$p_s(t_a)$ - calculated vapour pressure at ambient temperature t_a [hPa],
P – air pressure [hPa],
t_d – dew/frost point temperature t_d [°C],
t_a – ambient temperature t_a [°C],
$f(t_d, P)$, $f(t_a, P)$ - enhancement factors.

The measurement uncertainty arises from several effects on the mirror surface:

- Raout effect: soluble contaminants do not change the reflectivity of the mirror. There salts dissovle in the water layer on the surface of the mirror and couse the vapour pressure to be lowered. This result in an excess bildup of water on the mirror surface at the true dew-point. This Raoult effect can result in an error of several degrees.
- Kelvin effect: non-soluble contaminants affect the light reflective characteristics of the mirror and increase vapour pressure on the mirror and so compensation is required.
- Uncertainty of determining dew/frost point: undercooling effect of water on the mirror surface.
- Uncertainty of sampling system: dew asorption and desorption in the sample path.
- Uncertainty of dew-point temperature measurement: most important uncertainty sources are temperature gradients between mirror surface and platinum resistance thermometer and measurement uncertainty of PRT.

Some of these effects can be reduced by establishing a periodic cycle in which the hygrometer heats the mirror above dew/frost point until it is dry, looks at the reflectivity of the mirror compared to a clean, dry mirror and adjusts the bias of the optics to compensate for the contamination.
Uncertainty sources which are taken into account in analitical measurement uncertainty evaluation are:

- uncertainty of saturated vapour pressure calculation,
- ambient and dew/frost point temperature measurement uncertainty,
- uncertainty of enhancement factors calculation,
- uncertainty of air pressure measurement.

Quantity	Sensitivity coefficient	Standard uncertainty u_i	Probability law	Contribution u_i [%]*
$p_s(t_d)$	$\frac{f(t_d,P)}{p_s(t_a)\cdot f(t_a,P)}$	$0.0001\cdot p_s(t_d)$	normal	$2.5\cdot 10^{-3}$
$p_s(t_a)$	$\frac{-p_s(t_d)\cdot f(t_d,P)}{p_s^2(t_a)\cdot f(t_a,P)}$	$0.0001\cdot p_s(t_a)$	normal	$2.5\cdot 10^{-3}$
$f(t_a,P)$	$\frac{p_s(t_d)}{p_s(t_a)\cdot f(t_a,P)}$	0.1 ppm	normal	$2.5\cdot 10^{-6}$
$f(t_d,P)$	$\frac{-p_s(t_d)\cdot f(t_d,P)}{p_s(t_a)\cdot f^2(t_a,P)}$	0.1 ppm	normal	$2.5\cdot 10^{-6}$
t_d	$\frac{f(t_d,P)}{p_s(t_a)\cdot f(t_{a,P})}\cdot\frac{dp_s(t_d)}{dt_d}+\frac{p_s(t_d)}{p_s(t_a)\cdot f(t_{a,P})}\frac{df(t_d,P)}{dt_d}$	0.075 °C	normal	0.222
t_a	$\frac{-p_s(t_d)\cdot f(t_d,P)}{p_s^2(t_a)\cdot f(t_{a,P})}\cdot\frac{dp_s(t_a)}{dt_a}+\frac{p_s(t_d)\cdot f(t_d,P)}{p_s(t_a)\cdot f^2(t_{a,P})}\frac{df(t_a,P)}{dt_a}$	0.1 °C	normal	0.268
P	$\frac{p_s(t_d)}{p_s(t_a)\cdot f(t_{a,P})}\frac{df(t_a,P)}{dP}+\frac{p_s(t_d)\cdot f(t_d,P)}{p_s(t_a)\cdot f^2(t_{a,P})}\frac{df(t_a,P)}{dP}$	50 Pa	normal	$1.6\cdot 10^{-3}$
Resolution	*1*	0.1 %	normal	0.1
u_A	*1*	0.2 %	normal	0.2
Expanded measurement uncertainty U		$U = K\times\sqrt{\sum_{i=1}^{10}(u_i)^2}$		**U=0.69% K=2**

* Ta=20 °C and 50 % relative humidity

Table 1: Evaluation of uncertainty sources

The most important contribution to the overall uncertainty of dew point hygrometer is uncertainty of measurement of ambient air temperature and dew point temperature as shown in figure 2:

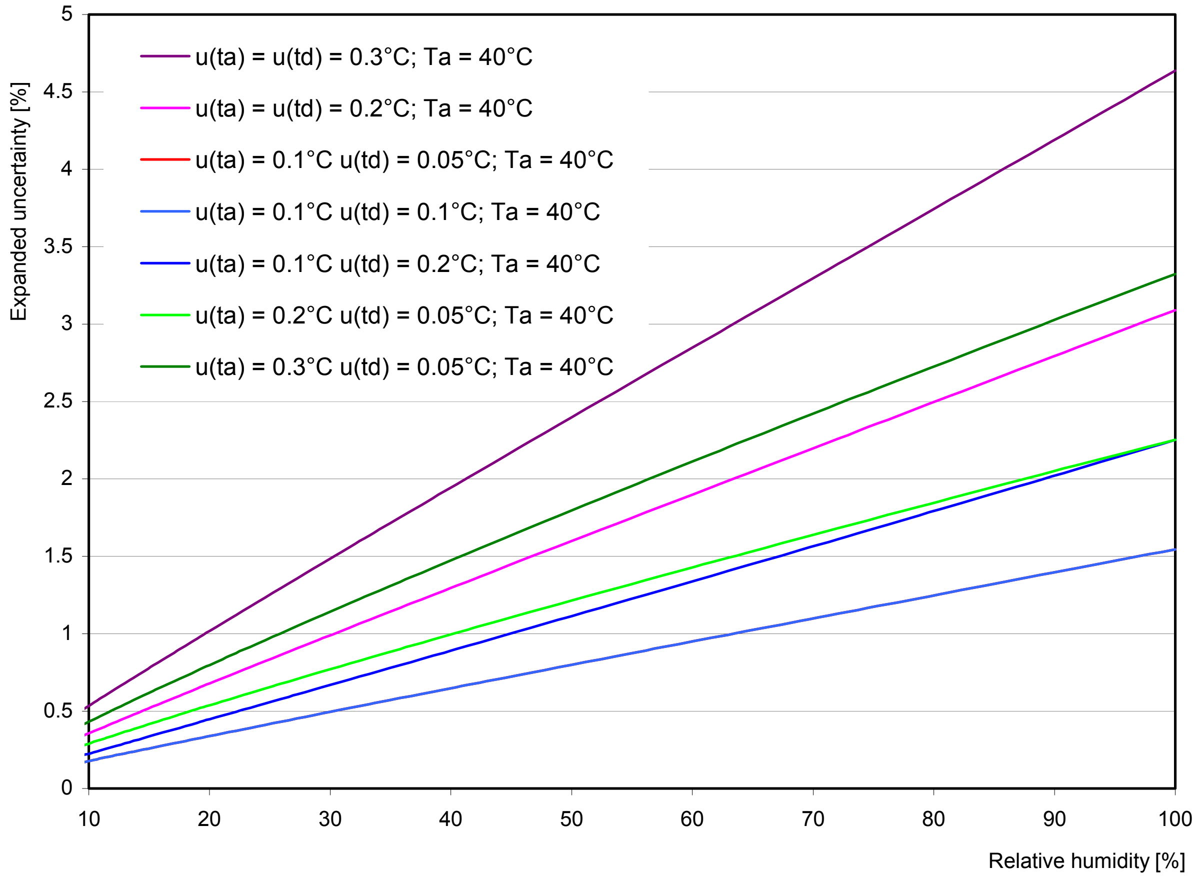

Figure 2: Temperature measurement uncertainty contribution to total uncertainty

Expanded measurement uncertainty of reference standard in the temperature range from -20 °C to 50 °C is shown in figure 3.

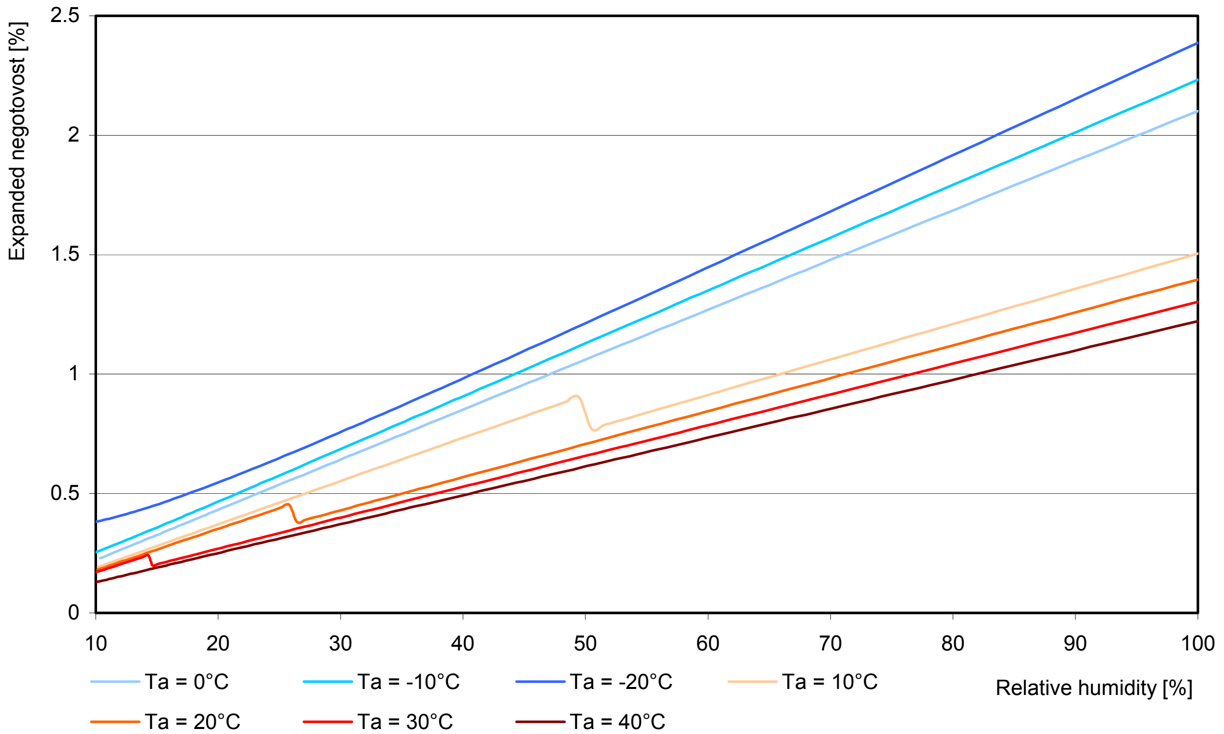

Figure 3: Expanded measurement uncertainty of reference standard in the temperature range from -20 °C to 50 °C

4. Summary

Expanded uncertainty 50% relative humidity and air temperature 40°C of Mitchell S4000 is 0.7%. Climatic chamber is the main uncertainty source in comparison calibrations of field instruments (capacitive sensors, hygrographs). Reduction of time instability and spatial unhomogenity is possible if reduced volume of climatic chamber is used. Expanded calibration uncertainty of field instruments is at present time 4%.
Future work of Calibration Laboratory in the filed of relative humidity measurements will be focused on implementation and metrological evaluation of two-pressure humidity generator to improve efficiency and metrological capabilities. Humidity generator is nowadays in a testing and implementing mode and it is expected to improve best measurement capabilities to 1% level.

References

1 World Meteorlogical Organisation, Guide to meterological instruments and methods of obervations, 6th edition, WMO No.8, 1996.
2 Quality Manual, Environmental Agency of the Republic of Slovenia, 3rd edition, Ljubljana, 2003.
3 Expression of the Uncertainty of Measurement in Calibration EA-4/02, European co-operation for Accreditation, December 1999.