XX IMEKO World Congress
Metrology for Green Growth
September 9−14, 2012, Busan, Republic of Korea

UNCERTAINTIES IN CALIBRATION OF AIR TEMPERATURE SENSORS

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Abstract: This paper describes sources of uncertainties in the calibration of air temperature sensors. Air temperature sensors are calibrated within different calibration environments. Depending on the environment, typical sources of uncertainties are analyzed and evaluated. In total, three different air temperature sensors, two platinum resistance thermometers in combination with resistance bridge and one digital thermometer are calibrated from -7 °C to 70 °C and from -40 °C up to 100 °C, in two different calibration environments. The reference temperature was determined using thermistors and calibrated platinum resistance thermometers.

Keywords: air temperature sensors, calibration, traceability, uncertainty sources

1. INTRODUCTION

This paper describes sources of uncertainties in the calibration of air temperature sensors. Air temperature sensors are calibrated within different calibration environments. There are different sources of uncertainty that have to be taken into account, depending on the environment. Sometimes air temperature sensors are calibrated within liquid baths. In this case, we have to be very careful not to damage sensor with bath liquid. Also, there is significant difference in self-heating due to different thermal characteristic of surrounding media (air and liquid).

Relative humidity varies strongly with air temperature. Failure to take this into account can sometimes lead to errors so large that the measurement is meaningless. As a consequence one of the main sources of uncertainty in measurement and calibration of relative humidity sensors is uncertainty of air temperature measurement, [1]. Roughly speaking, at room temperature, a change in air temperature of 1 °C corresponds to a change in relative humidity of 6 % r.h. A thermometer indicates its own temperature. It is important to note this because a thermometer may not always be at the same temperature as its surroundings. Thermometers can be influenced by the temperature of other objects nearby. Thermometers can also suffer from time lags, and self-heating may affect electrical resistance thermometers. All these effects are at their worst when a measurement is undertaken in air, as opposed to in liquid. Errors from these sources can easily amount to several tenths of a degree.

2. MEASUREMENT EQUIPMENT USED

In our measurement experiment we have used two different calibration environments. The thermometer under test is cleaned and put into the either ThunderScientific 2500 or Voetsch 7100 calibration environments. Using different holders, we assure that thermometer under calibration is not touching bottom or any side of calibration environments and inserts. Also, around thermometer under calibration we place at least 5 calibrated PRTs or thermistors. These thermometers are used for determination of reference temperature and homogeneity within insert. The inserts also behave as sort of equalizing block and radiation shield for calibration of air temperature sensors. These inserts are used for calibrations of highest accuracy. The response time of the system is increased as a result of the inserts. Furthermore, inside of the calibration environment is additionally insulated from outside. In such way better thermal stability and homogeneity is achieved.

Reference thermometers are connected via scanner to precise micro ohmmeter. Complete system is controlled with custom made modular software system.

We monitor the reference temperature and temperature of the unit under calibration. When system is in thermal equilibrium, we measure reference temperature and temperature of unit under calibration.

Typical stability over 10 minutes is in order of 0,02 K. Homogeneity of the system depends on the temperature and used calibration environment. It is from 0,03 K up to 0,07 K.

For this measurement we have used a set of reference thermistors, made by Betatherm, calibrated in liquid baths, in the range from -7,5 °C up to 70 °C. The expanded uncertainty of used thermistors, together with scanner and digital micro ohmmeter, is 5 mK, with drift better than 3 mK. The second set of reference thermometers used in the exercise, were industrial platinum resistance thermometers PRT, calibrated in the liquid bath in the range from -70 °C up to 140 °C, with expanded uncertainty of 0,03 K, with drift better than 0,01 K. For the resistance measurements we have used HP(Agilent) 34420A in combination with Keithley 7001 scanner and two 7067 10 channel PRT scanner cards.

Figure 1 Measuring equipment used (Hp 34420 A and Keithley 7001)

Units under calibration were calibrated in both of our air temperature sensor calibration environments. This enabled us to estimate different influences, from potential radiation, homogeneity, stability of the system to possible thermal leakage from inside of the environment to surrounding.

The first calibration environment consists of ThunderScientific 2500 humidity generator together with copper insert. The range of the ThunderScietific is from -10 °C to 70 °C, but due to limitation of reference thermistors used for determination of reference temperature, we have used it in the range from -7 °C to 70 °C.

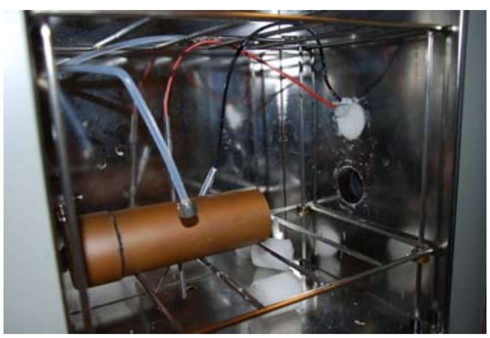


Figure 2 Measuring set up inside ThunderScientific 2500

The second calibration environment consists of Voetsch 7100 climatic chamber together with custom made wooden black box. The box was put inside the chamber. It was equipped with additional ventilation system, which enables better heat exchange with outside of the climatic chamber. The range of the Voetsch 7100 is from -70 °C up to 180 °C, but due to limitation of the EURAMET project 1061, it was used in the range from -40 °C up to 100 °C.

Figure 3 Measuring set up inside Voetsch 7100

The measurements in the liquid baths were made in our water bath, Kambič OB-35/2H in combination with ASL F700 resistance bridge and Rosemount 162 CE, serial number 4775 reference SPRT. Reference SPRT is calibrated in our laboratory at fixed points.

The calibrated equipment consisted of an ASL F250 thermometer bridge with two PT 100 probes and an HMT335 thermohygrometer as the transfer standards. For the purpose of the exercise small program for data acquisition via RS232 from ASL F250 was made. This software enabled us to make fully automated measurements and include them into our standard calibration system.

3. MEASUREMENT PROCEDURE AND RESULTS

The measurements were performed between 18.11.2010 and 10.12.2010. in accordance with "EURAMET project 1061 Instructions for the part 2 version 4".

First the measurements were made in water bath at temperatures 10 °C and 80 °C. The black cover of probe A, as prescribed by the protocol, was removed for the measurement inside water bath. The probe B was protected with quartz tube before measurement was performed in water bath.

The measurements in the ThunderScientific 2500 were made at -7 °C, 20 °C, 40 °C, 60 °C and 70 °C and then at 70 °C, 40 °C and -7 °C. As a reference Betatherm 11 was used in combination with above mentioned equipment.

The measurements in the Voetsch 7100 were made at -40 °C, -20 °C, 40 °C, 70 °C and 100 °C and then at 100 °C, 40 °C and -40 °C. As references Elpro 8419 and Elpro 8422 were used.

At the end measurements in water bath were repeated for probe A and probe B, which were connected to ASL F250 thermometer bridge.

The probe of the thermohygrometer HMT335 (s/n Z4610004) was calibrated only in ThunderScientific 2500 and Voetsch 7100 calibration environments.

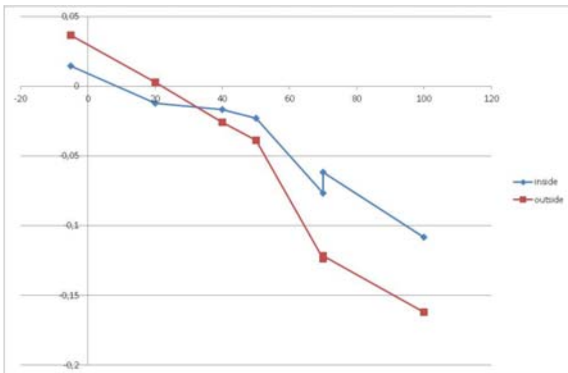
4. UNCERTAINTY SOURCES

The total uncertainty budget consist of number of components, which can be divided into reference temperature related, calibration environment related, unit under calibration related. The first two are identical for all three air temperature sensors calibrated in our laboratory in same environment.

The thermal radiation effect

In order to be able to estimate radiation effect, the black protective cover of probe A was removed and measurements repeated. However, no detectable influence was measured. Furthermore, additional experiments with our reference PRTs and thermistors were made.

The PRTs and thermistors were divided into three different groups in terms of emissivity. First group with very low emissivity, achieved by using aluminium foil around thermometers, second group with very high emissivity, achieved by high emissivity cover around thermometers and third group with original condition. In case of PRTs, original condition was stainless steel protective tube, while in the case of thermistors, the original condition was glass encapsulated thermistor.



The self-heating effect

The self-heating effect in case of probe A and probe B was determined. Since we have automated ASL F250, we were able to see difference if we would scan both channels within one measurement, and only one. This we could say that it is resulting from the fact that when we scan both channels within couple of seconds, current just starts to warm up sensor. In other case, when we measure only one channel the current is constantly going through the sensor and it is slightly warmer. This can also happen if the channels are manually switched with higher speed. Also, in order to be able to estimate self-heating, we have disconnected probes from ASL F250, started measurement and monitored response. From the curve we were able to determine effect of the self-heating.

The convective heat transfer

With using higher number of sensors, which were put around handle and cable of units under test, we have tried to determine potential convective heat transfer. However, no detectable influence was measured.

The hysteresis

The effect of hysteresis was determined from two different measurements in the middle of the calibration range. First the measurements in the increasing temperature order were made. Then, measurements in decreasing temperature order were taken. Difference at the middle temperature, corrected for any temperature change of reference temperature, was used for determination of hysteresis.

5. CONCLUSIONS

In this paper we have analysed typical uncertainty sources in the process of calibration of air temperature sensors. Special care was taken in analysis of self-heating, convective heat transfer and radiation effect. It can be concluded that each of these components is very important and depends on the temperature range, type of calibration environment, type of air temperature sensor under calibration and further usage of the sensors. Uncertainty of calibration of air temperature sensors is significantly larger than calibration of sensors in liquid baths.

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