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RESEARCH ARTICLE

DETERMINATION OF CALIBRATION MEASUREMENT UNCERTAINTY EFFECT FOR DIFFERENT AMBIENT TEMPERATURES UPON DIGITAL THERMOMETER READOUTS

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Abstract

Calibration of digital thermometer is usually performed in laboratory environmental conditions, mostly at 23 °C ± 3 °C. However, after calibration, there may be circumstances where the device is used at different temperatures. Generally for on-site processes, it is not much possible to provide laboratory environmental conditions. In that situation, it is necessary to determine how the device responds to different temperatures. In this study, calibration measurement uncertainty effect for different ambient temperatures upon digital thermometer readout is investigated by exposing digital thermometer readout to temperature values of 10 °C and 40 °C.

Introduction:-

Measurement on different ambient temperatures is one of the challenge that end users should be aware of. If devices are used at temperatures equal to calibration environmental conditions, there shouldn't be a problem (1). However, outside the laboratory, it is not most likely possible to work at laboratory environmental conditions. If a device is calibrated at 23 °C ± 3 °C and if it is used at 10 °C, end user should think that if the device has same error if it was used at 23 °C. When the end user checks calibration certificate, it is clear that the measurement results are usually valid for 23 °C ± 3 °C. Therefore, its effect has to be investigated if it is used at 10 °C.

Although this issue is usually stated in manual or datasheet of devices, end users should know how their devices respond on different ambient temperatures and gather information. In this study, determination of calibration measurement uncertainty effect for different ambient temperatures upon digital thermometer readouts is investigated.

Material and Method:-

The reference devices used in this study have provided their metrological traceability by an accredited laboratory according to the ISO/IEC 17025 standard (2) (3).

Devices used in measurements

- Digital thermometer with 10 channel thermocouple sensors
- Climate chamber
- Alcohol bath
- Water bath
- Reference platinum resistance thermometers (Pt100)

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- Reference thermometer readout
- Reference temperature-relative humidity meter
- Ambient temperature-relative humidity meter

Thermocouples, Pt100s, readout and temperature-relative humidity meter have their calibration traceability by standard methods (4) (5) (6) (7) and temperature sources (climate chamber and baths) have been tested by determining homogenity and stability (8).

Digital thermometer readout was inside the climate chamber and the thermocouples were outside the chamber. 5 thermocouples were placed in alcohol bath and 5 thermocouples were placed in water bath. In order to determine the actual temperature in the baths, two reference thermometers with Pt100 sensors were placed in the baths. While a reference temperature-relative humidity meter was used to monitor the temperature of the chamber, an ambient temperature-relative humidity meter was used to monitor the environmental conditions.

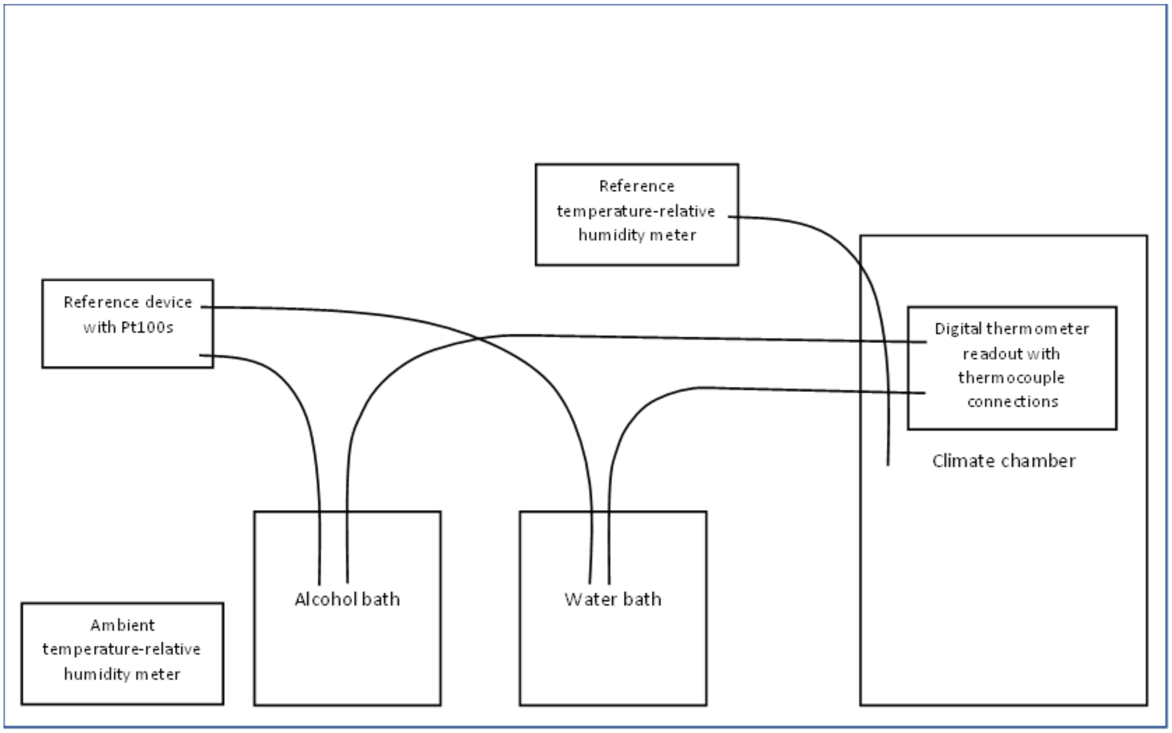

Figure 1:- Measurement setup.

First of all, it is necessary to examine the calibration certificate of the resistance thermometers to make sure that the temperature measured from the reference thermometer readout with the reference Pt100 sensor is reliable.

Reference Temperature (T)	***Resistance of PRT (R_T)***	***Measurement Uncertainty***
°C	***Ω***	***°C***
419,527	253,8647	0,006
231,928	187,5820	0,005
156,599	159,8259	0,005
29,7646	111,5954	0,004
-38,8344	84,7125	0,004
-80,0817	68,2113	0,020
0,0100	100,0096	0,004

Table 1:- Sample for Pt100 calibration certificate.

The coefficients are entered into the reference thermometer readout by calculating the coefficient according to the resistance values corresponding to the reference temperature. Thus, it is ensured that the temperature values on the readout is equal to the actual temperature. To obtain these coefficients, the Callendar-Van Dusen equation coefficients are used (9) (10).

$R = R_0 \cdot (1 + At + Bt^2 + C(t - 100°C)t^3)|$ C=0 for $t > 0$ °C

	Callendar-Van Dusen	unit
R_0	100,002441845	Ω
A	3,9108314864E-03	$°C^{-1}$
B	-5,8025110277E-07	$°C^{-2}$
C	-1,0828871275E-11	$°C^{-4}$

Table 2:- Sample for CVD coefficients.

Measurements:-

The humidity part of the climate chamber was off mode and the chamber was firstly adjusted to 10 °C. At the same time, the alcohol bath was set at 0 °C and the water bath at 50 °C. After the system stabilized, instead of taking measurements from all thermocouple channels, measurements were taken from the 1st thermocouple and 10th thermocouple channels by sampling method.

Measurement results are stated below (degree Celsius) when the climate chamber is at 10 °C.

Alcohol Bath Reference Value (average)	Channel-10	Alcohol Bath Reference Value (average)
0,01	0,4	0,01
	0,4	
	0,4	
	0,4	
	0,5	
	0,5	
	0,5	
	0,5	
	0,4	
	0,5	

Table 3:- Channel-10 measurement results when the climate chamber is at 10 °C.

Water Bath Reference Value (average)	Channel-1	Water Bath Reference Value (average)
49,83	49,4	49,85
	49,4	
	49,4	
	49,4	
	49,5	
	49,5	
	49,5	
	49,5	
	49,5	
	49,5	

Table 4:-Channel-1 measurement results when the climate chamber is at 10 °C.

Ambient temperature of the the climate chamber was 10.3 °C during the measurements taken from the baths. Reference temperature-relative humidity meter was used for determining the ambient temperature of the climate chamber.
Afterwards, the temperature of the climate chamber was increased from 10 °C to 40 °C without changing the position of the thermocouples and provided that the temperatures of the baths remained exactly same. After the system became stable, instead of taking measurements from all thermocouple channels, measurements were again taken from the 1st thermocouple and 10th thermocouple channels by sampling method.

Measurement results are stated below (degree Celsius) when the climate chamber is at 40 °C.

Alcohol Bath Reference Value (average)	Channel-10	Alcohol Bath Reference Value (average)
0,00	0,3	0,02
	0,3	
	0,3	
	0,3	
	0,3	
	0,3	
	0,3	
	0,3	
	0,2	
	0,3	

Table 5:- Channel-10 measurement results when the climate chamber is at 40 °C.

Water Bath Reference Value (average)	Channel-1	Water Bath Reference Value (average)
49,84	49,5	49,86
	49,5	
	49,5	
	49,6	
	49,5	
	49,5	
	49,5	
	49,5	
	49,4	
	49,5	

Table 6:- Channel-1 measurement results when the climate chamber is at 40 °C

Ambient temperature of the the climate chamber was 40,8 °C during the measurements taken from the baths. Reference temperature-relative humidity meter was used for determining the ambient temperature of the climate chamber.

Discussion and Conclusion:-

When the alcohol bath is constant at 0 °C;

The difference between ‘the measurement deviation detected when the climate chamber is set to 10 °C’ and ‘the measurement deviation detected when the climate chamber is set to 40 °C’ is calculated as the uncertainty effect due to the ambient temperature and that value was calculated as 0,16 °C. The summary table is below:

Laboratory Environmental Conditions	Climate Chamber Temperature	Reference Value in Alcohol Bath	10th Thermocouple Average Value (while digital thermometer readout in climate chamber)	Measurement Error (measured value minus reference value)	Ambient Temperature Effect (difference between measurement errors)
22 °C ± 1 °C // 50 %rh ± 10 %rh	10,3 °C	0,01 °C	0,45 °C	0,44 °C	0,16 °C
	40,8 °C	0,01 °C	0,29 °C	0,28 °C	

Table 7:- Measurement results when the alcohol bath is constant at 0 °C

When the water bath is constant at 50 °C;

The difference between ‘the measurement deviation detected when the climate chamber is set to 10 °C’ and ‘the measurement deviation detected when the climate chamber is set to 40 °C’ is calculated as the uncertainty effect due to the ambient temperature and that value was calculated as 0,03 °C. The summary table is below:

Laboratory Environmental Conditions	Climate Chamber Temperature	Reference Value in Water Bath	1st Thermocouple Average Value (while digital thermometer readout in climate chamber)	Measurement Error (measured value minus reference value)	Ambient Temperature Effect (difference between measurement errors)
22 °C ± 1 °C // 50 %rh ± 10 %rh	10,3 °C	49,84 °C	49,46 °C	-0,38 °C	0,03 °C
	40,8 °C	49,85 °C	49,50 °C	-0,35 °C	

Table 8:- Measurement results when the water bath is constant at 50 °C.

Digital thermometer readout (therefore connection points of thermocouples) were exposed to temperature values of 10 °C and 40 °C. Calibration points may vary according to expectation of customers. In this study, the effect of uncertainty was investigated when thermocouples were at 0 °C and 50 °C. Therefore, when the digital thermometer readout is desired to be used between 10 °C and 40 °C,considering that calibration uncertainties for reference system and measurement itself, the uncertainty effect caused by ambient temperature can be taken as 0,2 °C. Afterwards, that uncertainty value can be used by adding to measurement uncertainty budgets (11) (12).

Uncertainty Source	**Uncertainty (°C)**	**Probability Distribution**	**Divider**	**Standard Uncertainty (°C)**	**Sensitivity Coefficient**	**Uncertainty Contribution (°C)**
Ambient Temperature Effect	0,2	rectangular	1,732	0,1155	1	0,12

Table 9:-Ambient temperature effect as uncertainty contribution.

Source:-

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