Chamber Temperature Uncertainty Analysis
of the
Thunder Scientific Model 2500 Two-Pressure Humidity Generator

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1 Introduction

Described here is the Chamber Temperature Uncertainty Analysis, following NIST Guideline 1297[1], for a Model 2500 Humidity Generator. The chamber temperature is measured with a 10k ohm thermistor, calibrated in-circuit against a reference thermometer in a well stirred fluid bath.

2 Defining Equation

The actual equation used to convert resistance of the thermistor to temperature is considered insignificant to this analysis since the thermistor is calibrated in the system, as a system to align the thermistor's indicated temperature readings with the reference thermometer. The exact equations and mathematics used to achieve this alignment are not considered in this analysis.

3 Uncertainty Components

In the mathematical analysis of chamber temperature, there are several factors to consider. Those factors include measurement uncertainty, measurement resolution, self heating, and uncertainty of the reference standard.

3.1 Measurement Uncertainty

For computation of chamber temperature uncertainty due to measurement uncertainty, analysis was performed on ***as found*** data of 10 separate Model 2500 humidity generators during their annual recalibrations. This data is from customer owned units, returned to Thunder Scientific for calibration, each with one year or more of service since the previous calibration***. This analysis typifies expected uncertainty after one year of in field use***.

Each chamber temperature was tested against a reference thermometer at 3 points over the range of 0 to 70°C, resulting in 30 points from which to compute statistical standard deviation. The standard deviation of the difference between the reference standard and chamber temperatures over the stated temperature range is

$$\text{Std dev} = 0.018°\text{C}$$

The uncertainty in chamber temperature due to measurement, u(M), is then the standard deviation of the repeated measurements just stated.

$$u(M) = 0.018°\text{C}$$

3.2 Uncertainty in Temperature Measurement Resolution

The analog to digital conversion process which transforms probe resistance into digital values resolves to 0.01°C. Based on a rectangular distribution of the half-interval, the uncertainty component of temperature resolution is then

$$u(R) = 0.01 * 0.5/\sqrt{3}$$
$$= 0.0029$$

3.3 Uncertainty due to Self Heating of Chamber Temperature Probe

The chamber temperature probe is generally calibrated and checked in a well stirred fluid bath, but used in air. There is the possibility of some self heating associated with this measurement then that must be considered. The self heating, with temperature measurements in °C, is estimated to be +0.05% of reading. Based on rectangular distribution of the interval, the equation for the temperature uncertainty of self heating, u(SH), is then

$$u(SH) = 0.05\% * T_c / \sqrt{3}$$
$$= 0.00029 * T_c$$

3.4 Uncertainty of the Temperature Reference Standard

The reference thermometer has a manufacturer stated accuracy of ±0.01°C. Assuming rectangular distribution of the half interval, the uncertainty of the temperature reference standard, $u(T_{ref})$, is then

$$u(T_{ref}) = 0.01/\sqrt{3}$$
$$= 0.006°C$$

4 Combined Standard Uncertainty of Chamber Temperature

The standard uncertainty components and the resulting combined standard uncertainty of chamber temperature, $u_c(T_c)$, are listed in the following table. The combined uncertainty was computed as the square root of the sum of the variances with the equation

$$u_c^2(T_c) = u^2(M) + u^2(R) + u^2(SH) + u^2(T_{ref})$$

Standard Uncertainty Components of Chamber Temperature

Source	**Type**	**Term**	**Temperature**		
			0	**35**	**70**
Measurement	A	u(M)	0.018		
Resolution	B	u(R)	0.003		
Self Heating	B	u(SH)	0.000	0.010	0.020
Reference	B	$u(T_{ref})$	0.006		
combined		$u_c(T_c)$	.019	.022	.028

5. Expanded Uncertainty

Utilizing a coverage factor k=2, the expanded uncertainty, U, is listed in the following table at various temperatures using the following formula.

$$U = k * u_c(T_c)$$

Expanded Uncertainty of Chamber Temperature with Coverage Factor k=2					
Source	**Term**	**Time Interval**	**Temperature**		
			0	**35**	**70**
Chamber Temperature	U	One Year	±0.038°C	±0.044°C	±0.056°C

Note that the expanded uncertainties shown represent expected uncertainties after one year of use.

References:

1. Taylor, Barry N. and Kuyatt, Chris E., *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, NIST Technical Note 1297, 1994 Edition

2. Kuyatt, Chris, et al., *Determining and Reporting Measurement Uncertainties*, Recommended Practice RP-12, National Conference of Standards Laboratories, April 1995