Chamber Temperature Uniformity Analysis

Analysis of Chamber Temperature Uniformity of the Model CGS-240 Two-Temperature Two-Pressure Humidity Generator

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1 Introduction

Described here is the analysis of the Chamber Temperature Uniformity[2] for a Model CGS-240 humidity generator, manufactured by RH Systems, LLC. Chamber temperature uniformity has a direct influence on relative humidity gradients within the test chamber. In order to determine the chamber temperature uniformity, 12 type 100 Ω PRTs where calibrated together over the temperature range -10 to 85°C. The thermometers were then placed throughout the test chamber (as shown in *Figure 1. PRT Location Map)*, approximately 1 inch from each corner and center of each wall.

2 Defining equation

The maximum measurement deviation from the mean will be determined by noting the maximum and minimum readings from the set of probes at the same point in time, then taking half the difference of these values.

$$MaxDev = \pm 0.5(MaxTemp - MinTemp) \quad (1)$$

where *MaxTemp* = Maximum Temperature as measured from the 12 PRTs

MinTemp = Minimum Temperature as measured from the 12 PRTs

The uniformity will then be computed by RSS combination (root of the sum of the squares) of the maximum deviation, MaxDev, and the estimated thermometer uncertainty, u(T).

$$uniformity^2 = (MaxDev^2 - u^2(T)) \quad (2)$$

where *u(T)* = Measurement uncertainty of the 12 PRTs

3 Calibration of PRTs

The 12 PRTs were calibrated simultaneously, in the same calibration bath, against a SPRT temperature reference. As the PRTs were calibrated in a stirred liquid calibration bath, to be used in air, self heating is not considered a significant contributing factor as all probes are subject to the same environment. The assumption is that each probe will have similar, if not the same, self heating effect which thus nullifies each other when comparing the temperature measurement of each probe. The accuracy of the calibration standard can also be ignored as the focus is on the difference between each of the 12 PRTs, and not the individual PRT accuracy. As the only concern in calibration of the PRTs is the relative accuracy of each

PRT in respect to the others, the measurement uncertainty of the PRTs, *u(T)*, with a coverage factor of k=2 is computed to be

$$u(T) = \pm 0.00622°C$$

3.1 Chamber Temperature Measurements

The following data was recorded during testing periods between October 5, 2020 and November 15, 2020, using a Model CGS-240 within the controlled environment of RH Systems Calibration laboratory. The generator was run at a fixed humidity of 20 %RH, chamber temperatures from -7 to 70 °C, and flow rates from 10 to 40 L/m. As there is an optional heat sink block available for purchase with the CGS-240, the tests were run using the standard configuration (flat plate) as well as with the optional heat sink block (both sealed and un-sealed). As stated earlier, the thermometers were then placed throughout the test chamber (as shown in *Figure 1. PRT Location Map)*, approximately 1 inch from each corner and center of each wall.

The procedure used to collect the temperature measurements involved setting a nominal chamber temperature value and allowing the chamber temperature to stabilize at the desired setpoint prior to data analysis. Once the chamber temperature stabilized at the desired setpoint, a minimum of 30 minutes of data was collected at the current flow rate, the flow rate was then changed and the 30 minute clock was reset. This was repeated until data was collected for all flow rates of interest.

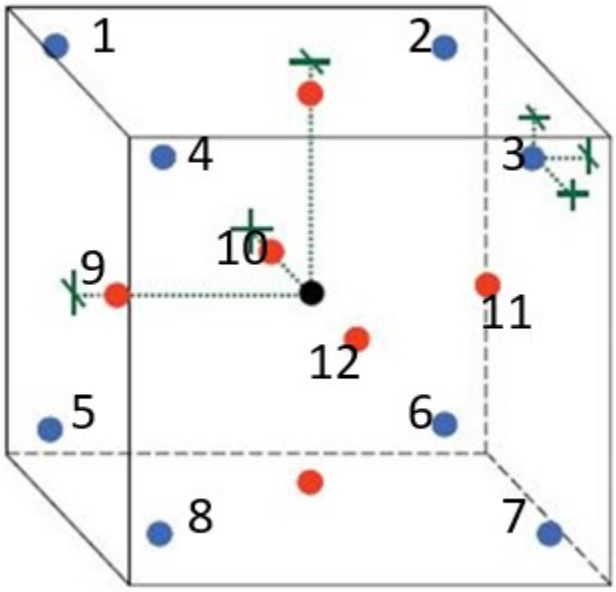

Figure 1Temperature probe location map

Table 1 Chamber Temperatures with Standard Plate

Chamber Temperatures with Standard Plate					
Flow Rate	**Chamber Temperature**	**PRT Average**	**Maximum Deviation**	**Maximum location**	**Minimum Location**
10	-7	-6.8168	0.0377	9	8
20	-7	-6.8480	0.0335	12	8
30	-7	-6.8579	0.0329	12	8
40	-7	-6.8600	0.0318	12	8
10	0	0.1175	0.0247	9	3
20	0	0.1156	0.0149	9	3
30	0	0.1159	0.0099	9	3
40	0	0.1182	0.0104	6	3
10	50	50.0173	0.0138	5	12
20	50	50.0532	0.0145	8	12
30	50	50.0521	0.0149	8	12
40	50	50.0526	0.0141	1	12
10	70	70.0527	0.0298	8	12
20	70	70.0629	0.0300	8	12
30	70	70.0488	0.0201	1	12
40	70	70.0412	0.0183	3	12

Shown above (*Table 2 Chamber Uniformity with Standard Plate)* are the temperature measurements taken with the standard flat plate installed. The location(s) with the highest recorded temperature as well as the lowest recorded temperature are indicated in columns on the right side of the table.

Table 3 Chamber Temperatures with Heat Sink Block

Chamber Temperatures with Heat Sink Block					
Flow Rate	**Chamber Temperature**	**PRT Average**	**Maximum Deviation**	**Maximum location**	**Minimum Location**
10	-7	-6.8649	0.0344	9	3
20	-7	-6.8619	0.0222	9	3
30	-7	-6.8683	0.0155	9	3
40	-7	-6.8586	0.0179	6	3
10	0	0.1175	0.0247	9	3
20	0	0.1156	0.0149	9	3
30	0	0.1159	0.0099	9	3
40	0	0.1182	0.0104	6	3
10	50	50.0557	0.0151	1	9
20	50	50.0533	0.0129	1	12
30	50	50.0514	0.0132	1	12
40	50	50.0516	0.0128	1	12
10	70	70.0527	0.0265	3	12
20	70	70.0629	0.0265	3	12
30	70	70.0488	0.0256	3	12
40	70	70.0412	0.0230	3	12

Shown above (*Table 4 Chamber Uniformity with Heat Sink Block*) are the temperature measurements taken with the optional heat sink installed. The location(s) with the highest recorded temperature as well as the lowest recorded temperature are indicated in columns on the right side of the table.

Table 5 Chamber Temperatures with Sealed Heat Sink Block

Chamber Temperatures with Sealed Heat Sink Block					
Flow Rate	**Chamber Temperature**	**PRT Average**	**Maximum Deviation**	**Maximum location**	**Minimum Location**
10	-7	-6.8333	0.0449	9	3
20	-7	-6.8590	0.0314	9	3
30	-7	-6.8652	0.0238	9	3
40	-7	-6.8630	0.0223	9	3
10	0	0.1173	0.0321	9	3
20	0	0.1161	0.0217	9	3
30	0	0.1183	0.0159	9	3
40	0	0.1184	0.0149	6	3
10	50	50.0429	0.0107	1	12
20	50	50.0527	0.0136	1	12
30	50	50.0578	0.0136	1	12
40	50	50.0524	0.0125	1	12
10	70	70.0799	0.0283	3	12
20	70	70.0579	0.0277	3	12
30	70	70.0446	0.0271	3	12
40	70	70.0546	0.0249	3	12

Shown above (*Table 6 Chamber Uniformity with Sealed Heat Sink Block*) are the temperature measurements taken with the optional heat sink installed and sealed to the chamber jacketing. The location(s) with the highest recorded temperature as well as the lowest recorded temperature are indicated in columns on the right side of the table.

3.2 Chamber Temperature Uniformity

As per equation 2, the uniformity at each condition is listed in the table below.

Table 7 Computed Chamber Uniformity

Chamber Uniformity				
Flow Rate	**Chamber Temperature**	**Flat Plate**	**Heat Sink Block**	**Sealed Heat Sink Block**
10	-7	0.0395	0.0365	0.0464
20	-7	0.0356	0.0253	0.0336
30	-7	0.0350	0.0196	0.0266
40	-7	0.0340	0.0216	0.0254
10	0	0.0274	0.0274	0.0343
20	0	0.0191	0.0191	0.0248
30	0	0.0156	0.0156	0.0199
40	0	0.0159	0.0159	0.0191
10	50	0.0183	0.0193	0.0161
20	50	0.0188	0.0176	0.0182
30	50	0.0192	0.0178	0.0181
40	50	0.0185	0.0176	0.0173
10	70	0.0322	0.0291	0.0308
20	70	0.0323	0.0291	0.0302
30	70	0.0234	0.0283	0.0296
40	70	0.0219	0.0259	0.0276

The values shaded in green are found to be within the stated uniformity specification of < 0.035 °C.