Chamber Temperature Uniformity Analysis of the Thunder Scientific Model 2900 Two-Pressure Humidity Generator

By Michael Hamilton

1 Introduction

Described here is the Chamber Temperature Uniformity for a Model 2900 Humidity Generator equipped with a fluid jacket door, window door or fluid jacket on window door option. The generator was operated at three different chamber fan speeds of 25%, 50% and 100%. Chamber temperature uniformity has a direct influence on relative humidity gradients within the test chamber. In order to determine the chamber temperature uniformity, ten 100 Ohm RTD probes of equivalent type where calibrated together over the temperature range of -10 °C to 72 °C. The probes were then strategically placed at various locations within one inch of the chamber wall and within 2.5 inches of the chamber door as shown in Figure 1.

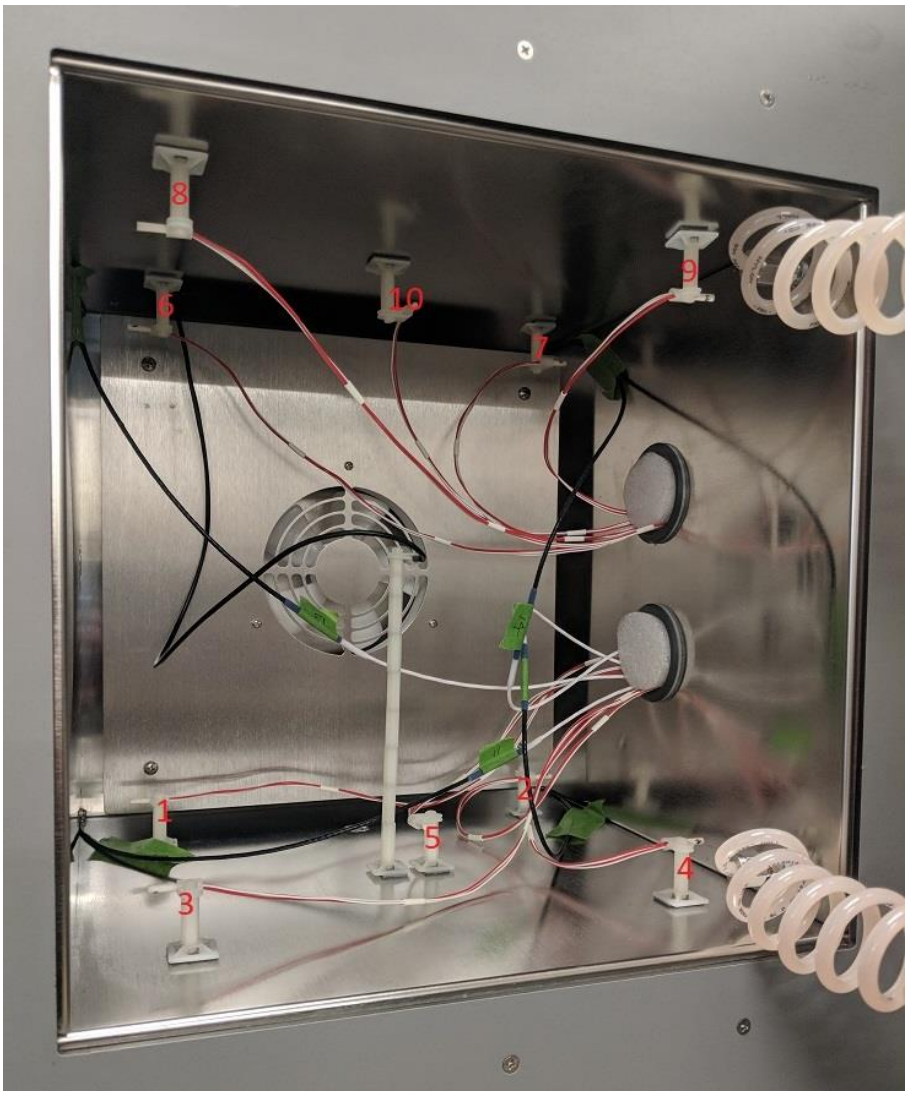

Figure 1

Document: Model_2900_Temperature_Uniformity_Analysis (Rev3)
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2 Calibration of Thermometers

The ten RTD probes were calibrated at the same time, in the same bath, against the same reference thermometer. Although they were calibrated in a well stirred fluid bath, yet used in air, self-heating is not considered a significant contributor since all probes are used in the same type of environment. All probes were subjected to similar self-heating effects which tend to cancel one another when viewing differences between probes. Each probe's combined uncertainty consists of repeatability, reproducibility and the reference thermometer uncertainty (Fluke 1595A). The uncertainty for any probe (u(T)) is then determined as the average uncertainty due to probe error using each probe's combined uncertainty.

$$u(T) = \pm 0.015°C$$

3 Defining Equations

The maximum measurement deviation from the mean will be determined by noting the average maximum and minimum readings from the set of probes over a ten-minute sample and then taking half the difference of these values.

$$MaxDev = \pm 0.5 * (MaxReading - MinReading) \quad [1]$$

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

$$uniformity^2 = MaxDev^2 + u^2(T) \quad [2]$$

3.1 Measurement of Chamber Temperatures

The following data was gathered during the uniformity analysis conducted in 2018, using a Model 2900 serial number 17110001. The generator was run at a fixed humidity of 50% RH using an automated profile to assure stability at each point. Ten minutes of data was collected for each probe at each temperature point and chamber fan speed. The uniformity was then calculated using equations 1 and 2. The test was repeated for each door combination and the results are given in Table 1, 2, 3 and figure 2, 3, 4.

3.1.1 Fluid Jacket Door

The fluid jacket door option uses a fluid jacket attached to the inside of the chamber door (without window). This allows the chamber to have six sides of controlled fluid circulating throughout.

Fluid Jacket Door				
°C	100% Fan Speed	50% Fan Speed	25% Fan Speed	Uniformity Specification
72	0.029	0.026	0.028	0.030
50	0.029	0.025	0.024	0.030
35	0.029	0.023	0.022	0.030
25	0.029	0.021	0.021	0.030
15	0.028	0.022	0.021	0.030
0	0.027	0.020	0.019	0.030
-10	0.028	0.020	0.020	0.030

Table 1

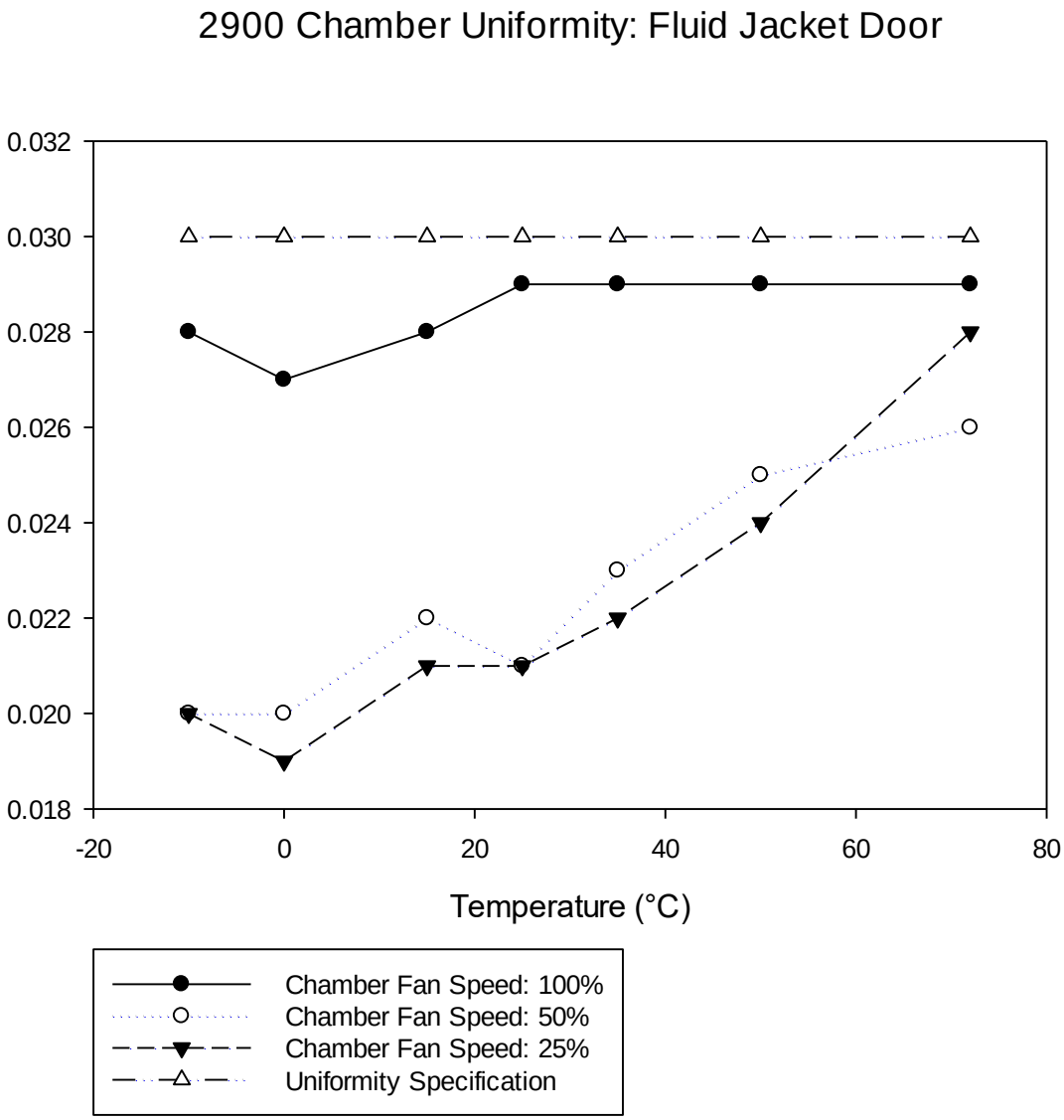

Figure 2

3.1.2 Window Door

The window door option allows the user to visually see the device under test in the chamber during operation. The window door option is only designed for limited chamber temperature ranges (±10 °C of ambient) due to the glass window's poor thermal insulator properties. When not using the fluid jacket door option the chamber uniformity is limited to ±10 °C of ambient.

Window Door				
°C	100% Fan Speed	50% Fan Speed	25% Fan Speed	Uniformity/Non-Uniformity Specification
72				
50				
35	0.031	0.025	0.023	0.032
25	0.026	0.021	0.021	0.031
15	0.024	0.022	0.021	0.030
0				
-10				

Table 2

NOTE: Special consideration is required when using the window door to prevent condensation from forming on the inside of the window glass. It is recommended to limit high humidity at temperatures above 10 °C from ambient to assure no condensation forms on the window glass.

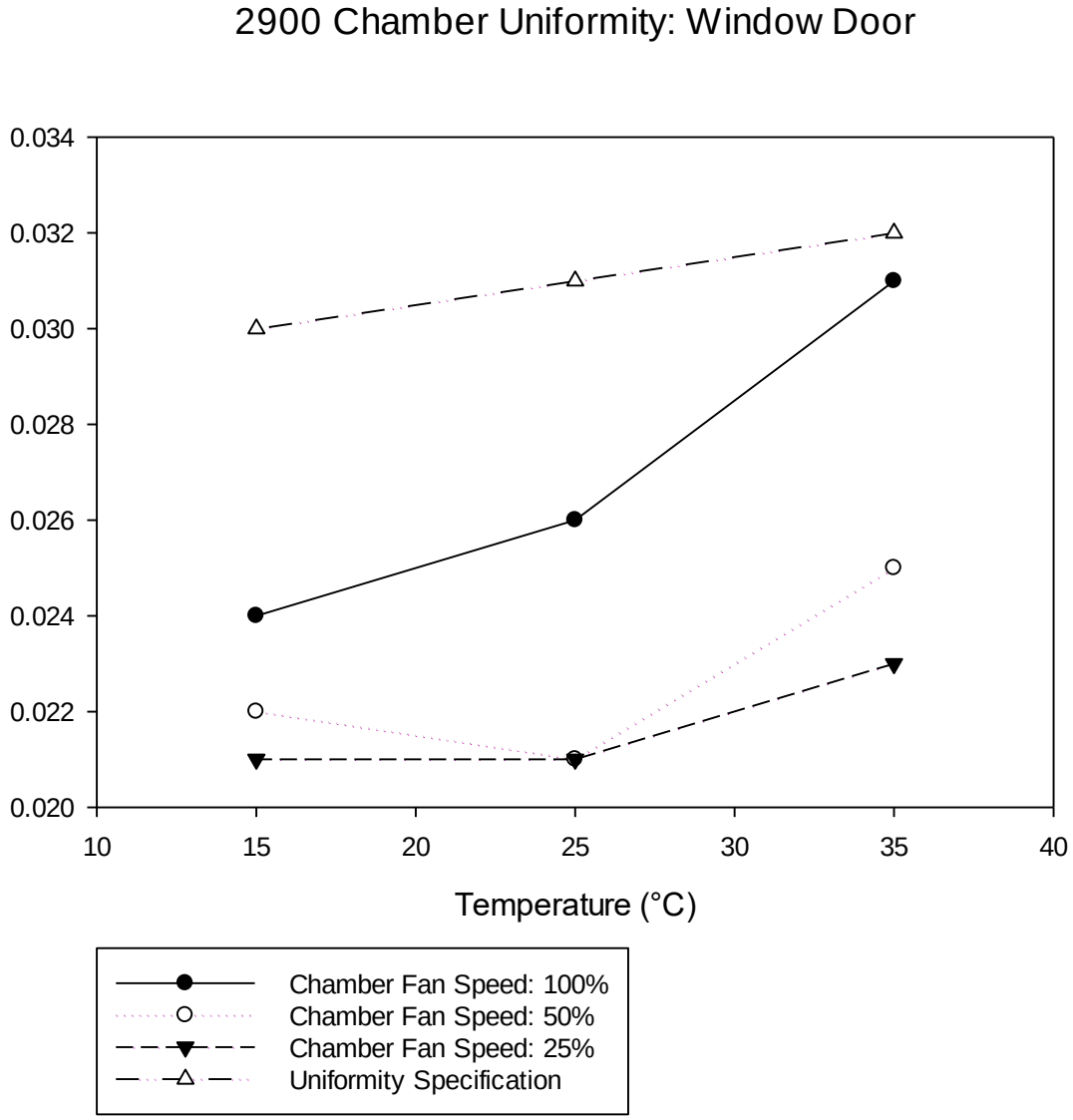

Figure 3

3.1.1 Fluid Jacket on Window Door

The fluid jacket attached to the window allows for improved uniformity without requiring the door to be changed for one without a window. The same dew point and fan limitations of the window door still apply even when using the fluid jacket on the window door.

Fluid Jacket on Window Door				
°C	100% Fan Speed	50% Fan Speed	25% Fan Speed	Uniformity/Non-Uniformity Specification
72	0.038	0.029	0.029	0.039
50	0.033	0.027	0.026	0.034
35	0.031	0.024	0.022	0.032
25	0.029	0.021	0.021	0.031
15	0.027	0.020	0.020	0.030
0	0.026	0.020	0.019	0.030
-10	0.027	0.020	0.020	0.030

Table 3

NOTE: Special consideration is required when using the window door to prevent condensation from forming on the inside of the window glass. It is recommended to limit high humidity at temperatures above 10 °C from ambient to assure no condensation forms on the window glass.

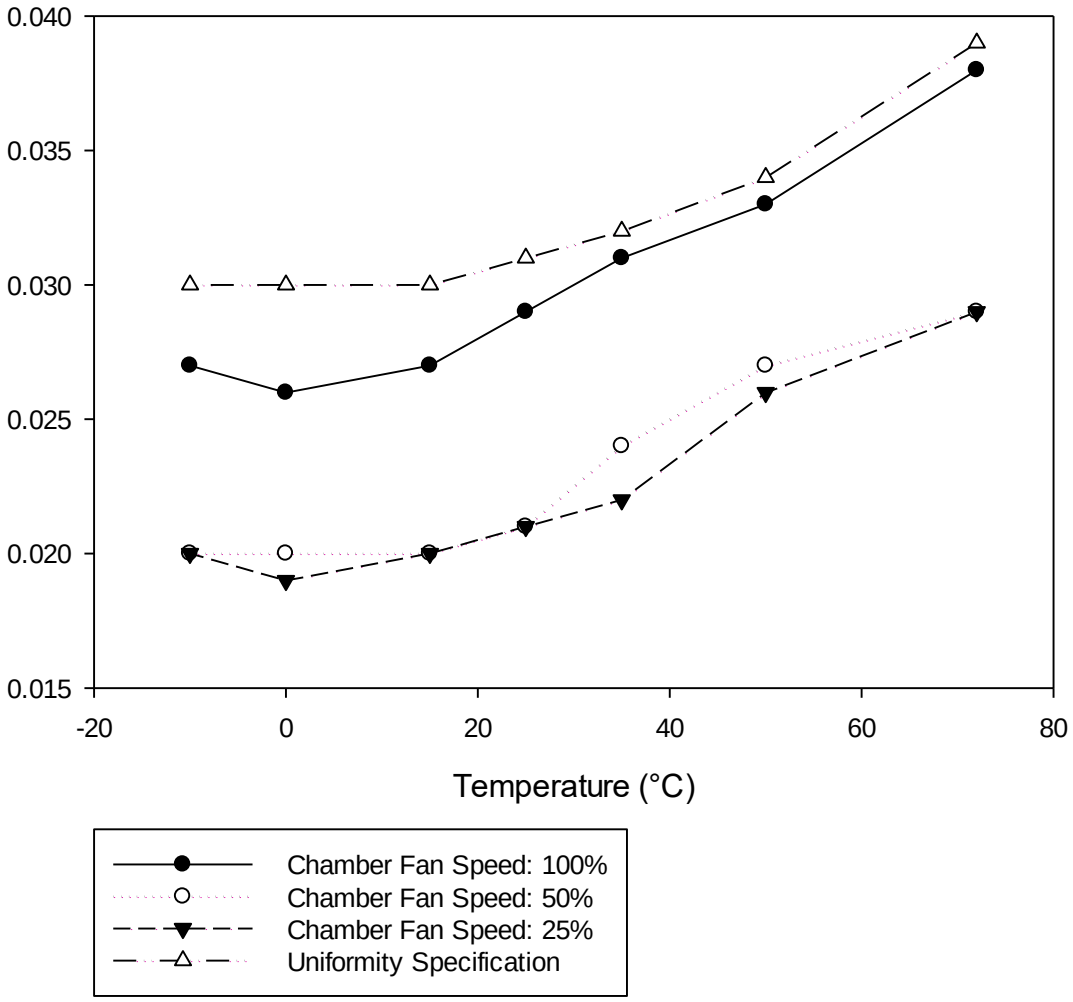

Figure 4

4. Chamber Temperature Uniformity and Non-Uniformity correction

The maximum value was selected from Table 1 and rounded up to determine the Uniformity Specification for the Model 2900 Two-Pressure Humidity Generator.

uniformity specification = 0.03 °C [1]

The window door adds a non-uniformity contributor due to the glass window's poor thermal insulator properties. The data in Table 2 and 3 was used to determine a chamber temperature-based correction factor defined by equation 3 to describe the Non-Uniformity Specification for the Model 2900 Two-Pressure Humidity Generator.

$$\text{non-uniformity specification} = (0.00034 * |Tc|)\ °C \quad [2] \qquad [3]$$

where Tc is the chamber temperature in °C.

[1] Using a minimum chamber fan speed of 25%. Between the temperature range of -10 °C to 72 ° when using the fluid jacket door option (without window).

[2] Using a minimum chamber fan speed of 25%. Between the temperature range of -10 °C to 72 ° when using a window door with the fluid jacket door option and ±10 °C from ambient when not using the fluid jacket door option.