Uncertainty Analysis
of the
Thunder Scientific Model 1200 Two-Pressure Humidity Generator

1.0 Introduction

Described here is the generated humidity uncertainty analysis, following the Guidelines of NIST and NCSL International [1, 6, 7], for a Model 1200 Humidity Generator that utilizes the NIST developed and proven two-pressure humidity generation principle [2, 3]. Generation of humidity in a system of this type does not require direct measurements of the water vapor content of the gas. Rather, the generated humidity is derived from the measurements of saturation and chamber pressures, and saturation and chamber temperatures.

The measurement instrumentation used in both our in-house working standards and our manufactured devices are obtained from companies which have demonstrated either NIST traceability or traceability to other acceptable standards. In most cases we therefore use the specifications supplied by these manufacturers as the starting point for our uncertainty statements. Over time, check calibrations against a NIST traceable pressure gauge and NIST traceable standard resistance thermometer, as well as the results of an on-going intercomparison program of both the individual components and of the outputs of operating generators, have allowed the determination of the ranges of disagreement among the various temperatures and pressures that enter into the final determination of the output uncertainties. The average values of these disagreements represent the uncertainties from our in-house processes and things like instrument drift over time, and these are coupled with the uncertainties given by the various instrument manufacturers to give overall uncertainty statements.

This document lists the various uncertainty sources, their magnitudes, and their origins over the operating range of the Model 1200 generator.

2.0 Defining Equations

NIST Technical Note 1297[1] states that the uncertainty in a dependent variable, which depends only on uncorrelated input variables, is

$$u^2(y) = \sum_i u^2(x_i)\left(\frac{\partial y}{\partial x_i}\right)^2 \qquad (1)$$

Relative Humidity is defined as the amount of water vapor in a sample compared to the maximum amount possible at the given sample's temperature and pressure.

This can be expressed by the following formula

$$\%RH = \frac{e(T_D)\, f(T_D, P_C)}{e(T_C)\, f(T_C, P_C)} \cdot \eta_S \qquad (2)$$

Where the *f* functions are enhancement factors, *e* is the saturation vapor pressure, η_S is the % efficiency of saturation, T_C, T_D are the chamber and Dew/Frost point temperatures, and Pc is the chamber pressure.

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The Dew/Frost point temperatures can be expressed by the following formulas

$$e_W(T_D)\cdot f(T_D,P_C) = f(T_S,P_S)\cdot e(T_S)\cdot \frac{P_C}{P_S} \tag{3}$$

$$e_I(T_F)\cdot f(T_F,P_C) = f(T_S,P_S)\cdot e(T_S)\cdot \frac{P_C}{P_S} \tag{4}$$

Where the *f* functions are enhancement factors, e_w is the saturation vapor pressure over water, e_I is the saturation vapor pressure over ice, T_D, T_F, T_S are the Dew point, Frost point and saturation temperatures, and Pc and Ps are the chamber and saturation pressures. Note that the actual Dew/Frost point temperature is defined implicitly and must be obtained through iterative solving.

Combining equation 1 with equations 3 and 4 we can express Relative Humidity in the terms of saturation and chamber temperatures and saturation and chamber pressure only by the following formula

$$\%RH = \frac{e(T_S)\,f(T_S,P_S)}{e(T_C)\,f(T_C,P_C)}\cdot\frac{P_C}{P_S}\cdot\eta_S \tag{5}$$

By incorporating the relationship in equation 2 into an uncertainty equation of the form of equation 5, it can be shown that the total uncertainty in relative humidity is given by the expression

$$u^2(RH) = u^2(T_C)\left(\frac{\partial RH}{\partial T_C}\right)^2 + u^2(T_S)\left(\frac{\partial RH}{\partial T_S}\right)^2 + u^2(P_C)\left(\frac{\partial RH}{\partial P_C}\right)^2 + u^2(P_S)\left(\frac{\partial RH}{\partial P_S}\right)^2 + u^2(\eta_S)\left(\frac{\partial RH}{\partial \eta_S}\right)^2 \tag{6}$$

Similarly incorporating the relationship in equation 2 into an uncertainty equation of the form of equation 3 and 4, the uncertainties in dew point and frost point measurement are

$$u^2(T_D) = u^2(T_S)\left(\frac{\partial T_D}{\partial T_S}\right)^2 + u^2(P_C)\left(\frac{\partial T_D}{\partial P_C}\right)^2 + u^2(P_S)\left(\frac{\partial T_D}{\partial P_S}\right)^2 + u^2(\eta_S)\left(\frac{\partial T_D}{\partial \eta_S}\right)^2 \tag{7}$$

and

$$u^2(T_F) = u^2(T_S)\left(\frac{\partial T_F}{\partial T_S}\right)^2 + u^2(P_C)\left(\frac{\partial T_F}{\partial P_C}\right)^2 + u^2(P_S)\left(\frac{\partial T_F}{\partial P_S}\right)^2 + u^2(\eta_S)\left(\frac{\partial T_F}{\partial \eta_S}\right)^2 \tag{8}$$

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3 Uncertainty Components

In the mathematical analysis of equation 6, 7 and 8, we'll analyze the uncertainties due to each of the above components separately and then combine the uncertainties to obtain the total expanded uncertainty. We are therefore concerned with four basic categories of uncertainty, pressure, temperature, saturator efficiency and the equations themselves. Each of these categories may also have associated uncertainty components. In determining components of uncertainty, there are several things to consider, such as measurement uncertainty, measurement hysteresis, and measurement resolution.

Listed below are the identified major uncertainty contributors and their components for the Model 1200 humidity generator.

- Uncertainty contribution from pressure (P_s and P_c) which includes
  - Measurement uncertainty
  - Measurement resolution
  - Measurement hysteresis

- Uncertainty contribution from temperature (T_s and T_c), which includes
  - Measurement uncertainty
  - Measurement resolution
  - Self heating

- Uncertainty contribution from Equations (e(T) and f(T,P)), which includes
  - Saturation Vapor Pressure Equation (e(T))
  - Enhancement Factor Equation (f(T,P))

- Uncertainty contribution from percent efficiency of the saturator (η_S)

3.1 Pressure Uncertainty Contribution

The pressure terms, P_c or P_s, in a two-pressure humidity generator are major determining factors. The Model 1200 humidity generator uses one pressure transducer to measures the chamber pressure and the saturation pressure. Due to this design many pressure uncertainties are shared between the chamber and saturation pressure. Any uncertainty contributed by this single transducer will simultaneously affect both the chamber and saturation pressure readings.

The pressure uncertainty contribution in terms of relative humidity can be determined by the partial numeric differential of the RH equation with respect to pressure, multiplied by the uncertainty of the pressure component. The equation for this becomes

$$uRH_{[component]} = \frac{\partial}{\partial P}\left[\frac{e_S(T_S)\, f(T_S, P + (P_S - P_C))}{e_S(T_C)\, f(T_C, P)} \cdot \frac{P}{P + (P_S - P_C)} \cdot \eta_S\right] \cdot uP_{[component]} \qquad (9)$$

$uRH_{[component]}$ = Pressure component uncertainty in terms of percent relative humidity.

$uP_{[component]}$ = Pressure component uncertainty in terms of pressure.

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The pressure uncertainty contribution in terms of dew or frost point temperature can be determined by the partial numeric differential of the iterative dew or frost point equation with respect to pressure, multiplied by the uncertainty of the pressure component. The equations for these become

$$\mathrm{uT}_{\mathrm{D[component]}} = \frac{\partial}{\partial P}\left[e_W(T_D)\cdot f(T_D,P) = f(T_S, P+(P_S-P_C))\cdot e(T_S))\cdot \frac{P}{P+(P_S-P_C)} \right]\cdot \mathrm{uP}_{\mathrm{[component]}} \tag{10}$$

$$\mathrm{uT}_{\mathrm{F[component]}} = \frac{\partial}{\partial P}\left[e_I(T_F)\cdot f(T_F,P) = f(T_S, P+(P_S-P_C))\cdot e(T_S))\cdot \frac{P}{P+(P_S-P_C)} \right]\cdot \mathrm{uP}_{\mathrm{[component]}} \tag{11}$$

$\mathrm{uT}_{\mathrm{D[component]}}$ = Pressure component uncertainty in terms of dew point temperature.

$\mathrm{uT}_{\mathrm{F[component]}}$ = Pressure component uncertainty in terms of frost point temperature.

$\mathrm{uP}_{\mathrm{[component]}}$ = Pressure component uncertainty in terms of pressure.

3.1.1 Pressure Measurement Uncertainty Component

Pressure Measurement uncertainty of Model 1200 humidity generator's pressure transducer is specified as 0.04% of the full scale. Based on a rectangular distribution, the uncertainty component of the pressure measurement is then

$\mathrm{uP}_{\mathrm{[measurement]}}$ = (155 psia (full scale) * 0.04%) / √3
= ±(0.062 psia) / √3 (DOF=infinite)

3.1.2 Pressure Resolution Uncertainty Component

The Model 1200 humidity generator uses an Analog to Digital device to translate the pressure transducer's voltage reading into a digital value. The Analog to Digital conversion process resolves over the range of the pressure transducer. Based on a rectangular distribution of the half-interval of resolution, the uncertainty component of pressure resolution is then

$\mathrm{uP}_{\mathrm{[resolution]}}$ = 155 psia (transducer range) / 2^15 * 0.5/√3
= ±0.00473022460938 psia / √12 (DOF=infinite)

3.1.3 Pressure Hysteresis Uncertainty Component

Since the Model 1200 humidity generator incorporates only one pressure transducer in a time-shared approach, the transducer is subject to some measurement hysteresis. For around 99.7% of the time, the transducer monitors the saturation pressure. For less than 0.3% of the time (once every 30 minutes for approximately 5 seconds), the transducer monitors the chamber pressure. By this criterion, it is only the chamber pressure, which is affected by hysteresis and therefore only applied to the chamber pressure component. To determine this uncertainty in terms of relative humidity we have to isolate only the chamber pressure component. This can be determined by the partial numeric differential of the RH equation with respect to only the chamber pressure, multiplied by the uncertainty of the chamber pressure component. The equation for this becomes.

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$$uRH_{[component]} = \frac{\partial}{\partial P_C}\left[\frac{e_S(T_S)f(T_S,P_S)}{e_S(T_C)f(T_C,P_C)}\cdot\frac{P_C}{P_S}\cdot\eta_S\right]\cdot uP_{C\,[component]} \qquad (12)$$

$uRH_{[component]}$ = Pressure component uncertainty in terms of relative humidity.

$uP_{C[component]}$ = Chamber Pressure component uncertainty in terms of pressure.

The pressure uncertainty contribution in terms of dew or frost point temperature can be determined by the partial numeric differential of the iterative dew or frost point equation with respect to chamber pressure, multiplied by the uncertainty of the chamber pressure component. The equations for these become

$$uT_{D[component]} = \frac{\partial}{\partial P_C}\left[e_W(T_D)\cdot f(T_D,P_C) = f(T_S,P_S)\cdot e(T_S))\cdot\frac{P_C}{P_S}\right]\cdot uP_{C\,[component]} \qquad (13)$$

$$uT_{F[component]} = \frac{\partial}{\partial P_C}\left[e_I(T_F)\cdot f(T_F,P_C) = f(T_S,P_S)\cdot e(T_S))\cdot\frac{P_C}{P_S}\right]\cdot uP_{C\,[component]} \qquad (14)$$

$uT_{D[component]}$ = Pressure component uncertainty in terms of dew point temperature.

$uT_{F[component]}$ = Pressure component uncertainty in terms of frost point temperature.

$uP_{[component]}$ = Pressure component uncertainty in terms of pressure.

The maximum amount of hysteresis specified for the Model 1200 humidity generator’s pressure transducer is ±0.04% of the measured difference between the saturation and chamber pressures, with a rectangular distribution.

$uP_{C[hysteresis]}$ = ±{0.04% * (P_s-P_c) } psia / √3 (DOF=infinite)

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3.1.3 Pressure Uncertainty Contribution Summary

The standard uncertainties, uRH, components calculated using equation 9 and 12 from the associated individual pressure components previously shown are summarized in the following table.

Note: The Model 1200 humidity generator is limited to a maximum dew point temperature of 50°C. Any value calculated above this limit is grayed out of the following table.

Standard Pressure Uncertainty Components of RH (±%)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								**Degrees of Freedom**	**Evaluation**
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
Saturation Temperature	**Description**	94.9 %RH	73.6 %RH	49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
10 °C	Pc Hysteresis	0.00119	0.00611	0.01178	0.01464	0.01638	0.01875	0.02001	0.02139	Infinity	Type B
	P Measurement	0.01192	0.04748	0.06106	0.05692	0.05094	0.03888	0.03111	0.02217	Infinity	Type B
	P Resolution	0.00045	0.00181	0.00233	0.00217	0.00194	0.00148	0.00119	0.00085	Infinity	Type B
		94.9 %RH	73.6 %RH	49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
35 °C	Pc Hysteresis	0.00119	0.00611	0.01178	0.01463	0.01636	0.01872	0.01995	0.02129	Infinity	Type B
	P Measurement	0.01192	0.04747	0.06101	0.05685	0.05086	0.03879	0.03100	0.02205	Infinity	Type B
	P Resolution	0.00045	0.00181	0.00233	0.00217	0.00194	0.00148	0.00118	0.00084	Infinity	Type B
				49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
60 °C	Pc Hysteresis			0.01177	0.01463	0.01635	0.01869	0.01991	0.02121	Infinity	Type B
	P Measurement			0.06094	0.05678	0.05078	0.03871	0.03092	0.02196	Infinity	Type B
	P Resolution			0.00232	0.00217	0.00194	0.00148	0.00118	0.00084	Infinity	Type B

Table 1

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The standard uncertainties, uT_D, components calculated using equation 10 and 13 from the associated individual pressure components previously shown are summarized in the following table.

Note: The Model 1200 humidity generator is limited to a maximum dew point temperature of 50°C. Any value calculated above this limit is grayed out of the following table.

Standard Pressure Uncertainty Components of Dew Point Temperature (±°C)

Saturation Temperature	Description	Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								Degrees of Freedom	Evaluation
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
		9.2 °C Td	5.5 °C Td	-0.2 °C Td	-4.0 °C Td	-6.9 °C Td	-12.0 °C Td	-15.5 °C Td	-20.2 °C Td		
10 °C	Pc Hysteresis	0.00019	0.00119	0.00329	0.00527	0.00718	0.01174	0.01612	0.02455	Infinity	Type B
	P Measurement	0.00186	0.00928	0.01706	0.02049	0.02232	0.02435	0.02507	0.02545	Infinity	Type B
	P Resolution	0.00007	0.00035	0.00065	0.00078	0.00085	0.00093	0.00096	0.00097	Infinity	Type B
		34.0 °C Td	29.6 °C Td	22.7 °C Td	18.1 °C Td	14.6 °C Td	8.6 °C Td	4.5 °C Td	-1.1 °C Td		
35 °C	Pc Hysteresis	0.00022	0.00144	0.00395	0.00630	0.00856	0.01393	0.01906	0.02890	Infinity	Type B
	P Measurement	0.00225	0.01119	0.02046	0.02448	0.02659	0.02886	0.02962	0.02994	Infinity	Type B
	P Resolution	0.00009	0.00043	0.00078	0.00093	0.00101	0.00110	0.00113	0.00114	Infinity	Type B
				45.4 °C Td	40.0 °C Td	35.9 °C Td	28.8 °C Td	23.4 °C Td	17.5 °C Td		
60 °C	Pc Hysteresis			0.00467	0.00743	0.01006	0.01629	0.02222	0.03354	Infinity	Type B
	P Measurement			0.02419	0.02884	0.03124	0.03374	0.03452	0.03473	Infinity	Type B
	P Resolution			0.00092	0.00110	0.00119	0.00129	0.00132	0.00132	Infinity	Type B

Table 2

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The standard uncertainties, uT_F, components calculated using equation 11 and 14 from the associated individual pressure components previously shown are summarized in the following table.

Note: Any frost point value that is theoretically not possible is grayed out of the following table.

Standard Pressure Uncertainty Components of Frost Point Temperature (±°C)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								**Degrees of Freedom**	**Evaluation**
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
Saturation Temperature	**Description**			-0.1 °C Tf	-3.6 °C Tf	-6.2 °C Tf	-10.7 °C Tf	-13.8 °C Tf	-18.1 °C Tf		
10 °C	Pc Hysteresis			0.00290	0.00468	0.00641	0.01057	0.01460	0.02239	Infinity	Type B
	P Measurement			0.01505	0.01820	0.01992	0.02191	0.02269	0.02321	Infinity	Type B
	P Resolution			0.00057	0.00069	0.00076	0.00084	0.00087	0.00089	Infinity	Type B
									-0.9 °C Tf		
35 °C	Pc Hysteresis								0.02554	Infinity	Type B
	P Measurement								0.02646	Infinity	Type B
	P Resolution								0.00101	Infinity	Type B
60 °C	Pc Hysteresis									Infinity	Type B
	P Measurement									Infinity	Type B
	P Resolution									Infinity	Type B

Table 3

3.2 Temperature Uncertainty Contribution

The temperature terms, T_c or T_s, in a two-pressure humidity generator are another major contributor of uncertainty and are used mathematically to calculate saturation vapor pressures. The Model 1200 humidity generator uses two temperature probes to measures the chamber temperature and the saturation temperature. Due to this design each temperature probe contributes its own uncertainty to the over all system and will be addressed independent of one another.

3.2.1 Saturation Temperature Uncertainty Contribution

The saturation temperature uncertainty contribution in terms of relative humidity can be determined by the partial numeric differential of the RH equation with respect to saturation temperature, multiplied by the uncertainty of the saturation temperature component. The equation for this becomes

$$uRH_{[component]} = \frac{\partial}{\partial T_S}\left[\frac{e_S(T_S)\, f(T_S,P_S))}{e_S(T_C)\, f(T_C,P_C)} \cdot \frac{P_C}{P_S} \cdot \eta_S\right] \cdot uT_{S[component]} \qquad (15)$$

$uRH_{[component]}$ = Sat Temperature component uncertainty in terms of percent relative humidity.

$uT_{S[component]}$ = Sat Temperature component uncertainty in terms of pressure.

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The saturation temperature uncertainty contribution in terms of dew or frost point temperature can be determined by the partial numeric differential of the iterative dew or frost point equation with respect to saturation temperature, multiplied by the uncertainty of the saturation temperature component. The equations for these become

$$\mathrm{uT}_{\mathrm{D[component]}} = \frac{\partial}{\partial T_S}\left[e_W(T_D)\cdot f(T_D,P_C) = f(T_S,P_S)\cdot e(T_S))\cdot \frac{P_C}{P_S} \right]\cdot \mathrm{uT}_{\mathrm{S\,[component]}} \qquad (16)$$

$$\mathrm{uT}_{\mathrm{F[component]}} = \frac{\partial}{\partial T_S}\left[e_I(T_F)\cdot f(T_F,P_C) = f(T_S,P_S)\cdot e(T_S))\cdot \frac{P_C}{P_S} \right]\cdot \mathrm{uT}_{\mathrm{S\,[component]}} \qquad (17)$$

$\mathrm{uT}_{\mathrm{D[component]}}$ = Pressure component uncertainty in terms of dew point temperature.

$\mathrm{uT}_{\mathrm{F[component]}}$ = Pressure component uncertainty in terms of frost point temperature

$\mathrm{uT}_{\mathrm{S[component]}}$ = Pressure component uncertainty in terms of pressure.

3.2.1.1 Saturation Temperature Measurement Uncertainty Component

Temperature measurement uncertainty of Model 1200 humidity generator's saturation temperature probe is specified as 0.05 °C. Based on a rectangular distribution, the uncertainty component of saturation temperature measurement is then

$\mathrm{uT}_{\mathrm{S[measurement]}}$ = ±0.05 °C / √3 (DOF=infinite)

3.2.1.2 Saturation Temperature Resolution Uncertainty Component

The Model 1200 humidity generator uses a computer module to translate the saturation temperature probe readings into digital values. The computer module has a specified resolution of 0.01°C. Based on a rectangular distribution of the half-interval of resolution, the uncertainty component of saturation temperature resolution is then

$\mathrm{uT}_{\mathrm{S\,[resolution]}}$ = 0.01°C * 0.5/√3
= ±0.01°C / √12 (DOF=infinite)

3.2.1.3 Saturation Temperature Self-Heating Uncertainty Component

The saturation temperature probe is installed in a thermo-well, affixed with heat sink compound, within the fluid jacket at the outlet of the Model 1200's saturator. This design is similar to a well-stirred fluid bath and since the probe is not in air, the effects of self-heating associated with its measurement are considered insignificant and will not be considered.

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3.2.2 Chamber Temperature Uncertainty Contribution

The chamber temperature uncertainty contribution in terms of relative humidity can be determined by the partial numeric differential of the RH equation with respect to chamber temperature, multiplied by the uncertainty of the chamber temperature component. The equation for this becomes

$$\mathrm{uRH}_{[\mathrm{component}]} = \frac{\partial}{\partial T_C}\left[\frac{e_S(T_S)\,f(T_S,P_S))}{e_S(T_C)\,f(T_C,P_C)}\cdot\frac{P_C}{P_S}\cdot\eta_S\right]\cdot \mathrm{u}T_{C[\mathrm{component}]} \tag{18}$$

$\mathrm{uRH}_{[\mathrm{component}]}$ = Chamber Temperature component uncertainty in terms of percent relative humidity.

$\mathrm{uT}_{C[\mathrm{component}]}$ = Chamber Temperature component uncertainty in terms of pressure.

Examining equations 3 and 4, dew and frost point equations, we see that the chamber temperature has no component and therefore no uncertainty contribution to the generated dew or frost point temperatures.

3.2.2.1 Chamber Temperature Measurement Uncertainty Component

Temperature measurement uncertainty of Model 1200 humidity generator's chamber temperature probe is specified as 0.05 °C. Based on a rectangular distribution, the uncertainty component of chamber temperature measurement is then

$\mathrm{uT}_{C[\mathrm{measurement}]} = \pm 0.05\ °\mathrm{C} / \sqrt{3}$ (DOF=infinite)

3.2.2.2 Chamber Temperature Resolution Uncertainty Component

The Model 1200 humidity generator uses a 16 Bit computer module to translate the chamber temperature probe readings into digital values. The computer module has a specified resolution of 0.01°C. Based on a rectangular distribution of the half-interval of resolution, the uncertainty component of chamber temperature resolution is then

$\mathrm{uT}_{C\ [\mathrm{resolution}]} = 0.01°\mathrm{C} * 0.5/\sqrt{3}$
$= \pm 0.01°\mathrm{C} / \sqrt{12}$ (DOF=infinite)

3.2.2.3 Chamber Temperature Self-Heating Uncertainty Component

Unlike the saturation temperature probe, the chamber temperature probe is used in air and there is the possibility of some self-heating associated with this measurement that must be considered. The self-heating, with temperature measurements in °C, is estimated to be 0.05% of reading. The equation for the chamber temperature uncertainty of self-heating is then

$\mathrm{uT}_{C\ [\mathrm{self\text{-}heating}]} = \pm (0.05\% * T_c) / \sqrt{3}$ (DOF=infinite)

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3.2.3 Temperature Uncertainty Contribution Summary

The standard uncertainties, uRH, components calculated using equation 15 and 18 from the associated individual temperature components previously shown are summarized in the following table.

Note: The Model 1200 humidity generator is limited to a maximum dew point temperature of 50°C. Any value calculated above this limit is grayed out of the following table.

Standard Temperature Uncertainty Components of RH (±%)

Saturation Temperature	Description	Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								Degrees of Freedom	Evaluation
		15.5	20.0	30.0	40.0	50.0	75.0	100.0	150.0		
		94.9 %RH	73.6 %RH	49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
10 °C	Ts Measurement	0.18350	0.14233	0.09507	0.07144	0.05726	0.03836	0.02891	0.01946	Infinity	Type B
	Tc Measurement	0.18350	0.14236	0.09511	0.07149	0.05732	0.03842	0.02897	0.01953	Infinity	Type B
	Tc Self Heating	0.01835	0.01424	0.00951	0.00715	0.00573	0.00384	0.00290	0.00195	Infinity	Type B
	Tc Resolution	0.03670	0.02847	0.01902	0.01430	0.01146	0.00768	0.00579	0.00391	Infinity	Type B
	Ts Resolution	0.01835	0.01423	0.00951	0.00714	0.00573	0.00384	0.00289	0.00195	Infinity	Type B
		94.9 %RH	73.6 %RH	49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
35 °C	Ts Measurement	0.15156	0.11755	0.07849	0.05896	0.04725	0.03162	0.02381	0.01600	Infinity	Type B
	Tc Measurement	0.15156	0.11756	0.07851	0.05899	0.04728	0.03166	0.02385	0.01605	Infinity	Type B
	Tc Self Heating	0.05305	0.04114	0.02748	0.02065	0.01655	0.01108	0.00835	0.00562	Infinity	Type B
	Tc Resolution	0.03031	0.02351	0.01570	0.01180	0.00946	0.00633	0.00477	0.00321	Infinity	Type B
	Ts Resolution	0.01516	0.01175	0.00785	0.00590	0.00472	0.00316	0.00238	0.00160	Infinity	Type B
				49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
60 °C	Ts Measurement			0.06574	0.04939	0.03957	0.02647	0.01992	0.01337	Infinity	Type B
	Tc Measurement			0.06571	0.04936	0.03955	0.02647	0.01993	0.01339	Infinity	Type B
	Tc Self Heating			0.03943	0.02962	0.02373	0.01588	0.01196	0.00803	Infinity	Type B
	Tc Resolution			0.01314	0.00987	0.00791	0.00529	0.00399	0.00268	Infinity	Type B
	Ts Resolution			0.00657	0.00494	0.00396	0.00265	0.00199	0.00134	Infinity	Type B

Table 4

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The standard uncertainties, uT_D, components calculated using equation 16 from the associated individual temperature components previously shown are summarized in the following table.

Note: The Model 1200 humidity generator is limited to a maximum dew point temperature of 50°C. Any value calculated above this limit is grayed out of the following table.

Standard Temperature Uncertainty Components of Dew Point Temperature (±°C)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								**Degrees of Freedom**	**Evaluation**
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
Saturation Temperature	**Description**	9.2 °C Td	5.5 °C Td	-0.2 °C Td	-4.0 °C Td	-6.9 °C Td	-12.0 °C Td	-15.5 °C Td	-20.2 °C Td		
10 °C	Ts Measurement	0.02869	0.02784	0.02658	0.02574	0.02511	0.02404	0.02332	0.02236	Infinity	Type B
	Ts Resolution	0.00287	0.00278	0.00266	0.00257	0.00251	0.00240	0.00233	0.00224	Infinity	Type B
		34.0 °C Td	29.6 °C Td	22.7 °C Td	18.1 °C Td	14.6 °C Td	8.6 °C Td	4.5 °C Td	-1.1 °C Td		
35 °C	Ts Measurement	0.02867	0.02772	0.02632	0.02540	0.02471	0.02354	0.02277	0.02173	Infinity	Type B
	Ts Resolution	0.00287	0.00277	0.00263	0.00254	0.00247	0.00235	0.00228	0.00217	Infinity	Type B
				45.4 °C Td	40.0 °C Td	35.9 °C Td	28.8 °C Td	23.4 °C Td	17.5 °C Td		
60 °C	Ts Measurement			0.02607	0.02506	0.02433	0.02307	0.02223	0.02114	Infinity	Type B
	Ts Resolution			0.00261	0.00251	0.00243	0.00231	0.00222	0.00211	Infinity	Type B

Table 5

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The standard uncertainties, uT_F, components calculated using equation 17 from the associated individual temperature components previously shown are summarized in the following table.

Note: Any frost point value that is theoretically not possible is grayed out of the following table.

Standard Temperature Uncertainty Components of Frost Point Temperature (±°C)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								**Degrees of Freedom**	**Evaluation**
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
Saturation Temperature	**Description**			-0.1 °C Tf	-3.6 °C Tf	-6.2 °C Tf	-10.7 °C Tf	-13.8 °C Tf	-18.1 °C Tf		
10 °C	Ts Measurement			0.02345	0.02286	0.02241	0.02164	0.02111	0.02039	Infinity	Type B
	Ts Resolution			0.00235	0.00229	0.00224	0.00216	0.00211	0.00204	Infinity	Type B
									-0.9 °C Tf		
35 °C	Ts Measurement								0.01921	Infinity	Type B
	Ts Resolution								0.00192	Infinity	Type B
60 °C	Ts Measurement									Infinity	Type B
	Ts Resolution									Infinity	Type B

Table 6

3.3 Equation Uncertainty Contribution

The equations used to calculate the saturation vapor pressure at a given temperature and its enhancement factor at the same temperature and given pressure have published uncertainties as determined by the author or authors of the equations. These equations are used throughout the Relative Humidity, Dew point and Frost point equations and therefore contribute their own uncertainty to the over all system.

3.3.1 Saturation Vapor Pressure Equation Uncertainty Component

The saturation vapor pressure is the partial pressure of the water vapor at a given temperature with respect to ice or water. The saturation vapor pressure is dependent on temperature only and is computed with the Wexler's [4] saturation vapor pressure equation. Wexler [4] also list a table of uncertainties at various temperatures for his saturation vapor pressure equation. These uncertainty values are interpolated to determine the saturation vapor pressure equation uncertainty component for a given temperature.

3.3.2 Enhancement Factor Equation Uncertainty Component

Enhancement factors are slight correction factors used to account for the non-ideal behavior of water vapor when admixed with other gases. The enhancement factor is dependent on both temperature and pressure and is computed with Greenspan's [5] enhancement factor equation. Wexler and R.W. Hyland [8] list a table of uncertainties for various temperatures and pressures for the enhancement factor equation. These uncertainty values are interpolated to determine the enhancement factors equation uncertainty component for a given temperature and pressure.

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3.3.3 Equation Uncertainty Contribution Summary

The standard uncertainties, uRH, components calculated using the associated equation uncertainty tables mentioned above are summarized in the following table.

Note: The Model 1200 humidity generator is limited to a maximum dew point temperature of 50°C. Any value calculated above this limit is grayed out of the following table.

Standard Equation Uncertainty Components of RH (±%)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								**Degrees of Freedom**	**Evaluation**
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
Saturation Temperature	**Description**	94.9 %RH	73.6 %RH	49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
10 °C	SVP@Tt	0.00590	0.00457	0.00306	0.00230	0.00184	0.00123	0.00093	0.00063	Infinity	Type B
	SVP@Ts	0.00590	0.00457	0.00305	0.00228	0.00183	0.00122	0.00091	0.00061	Infinity	Type B
	F@Tt,Pt	0.00960	0.00745	0.00497	0.00374	0.00300	0.00201	0.00152	0.00102	Infinity	Type B
	F@Ts,Ps	0.01006	0.00980	0.00951	0.00938	0.00931	0.00921	0.00901	0.00889	Infinity	Type B
		94.9 %RH	73.6 %RH	49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
35 °C	SVP@Tt	0.00795	0.00616	0.00412	0.00309	0.00248	0.00166	0.00125	0.00084	Infinity	Type B
	SVP@Ts	0.00794	0.00616	0.00411	0.00308	0.00246	0.00164	0.00123	0.00082	Infinity	Type B
	F@Tt,Pt	0.00722	0.00560	0.00374	0.00281	0.00225	0.00151	0.00114	0.00076	Infinity	Type B
	F@Ts,Ps	0.00764	0.00778	0.00795	0.00804	0.00810	0.00821	0.00838	0.00857	Infinity	Type B
				49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
60 °C	SVP@Tt			0.00118	0.00088	0.00071	0.00047	0.00036	0.00024	Infinity	Type B
	SVP@Ts			0.00117	0.00088	0.00070	0.00047	0.00035	0.00023	Infinity	Type B
	F@Tt,Pt			0.00252	0.00189	0.00151	0.00101	0.00076	0.00051	Infinity	Type B
	F@Ts,Ps			0.00705	0.00752	0.00781	0.00819	0.00822	0.00827	Infinity	Type B

Table 7

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The standard uncertainties, uT_D, components calculated using the associated equation uncertainty tables mentioned above are summarized in the following table.

Note: The Model 1200 humidity generator is limited to a maximum dew point temperature of 50°C. Any value calculated above this limit is grayed out of the following table.

Standard Equation Uncertainty Components of Dew Point Temperature (±°C)											
Saturation Temperature	**Description**	**Saturation Pressure Range (psia), Chamber pressure = 14.7 psia**								**Degrees of Freedom**	**Evaluation**
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
		9.2 °C Td	5.5 °C Td	-0.2 °C Td	-4.0 °C Td	-6.9 °C Td	-12.0 °C Td	-15.5 °C Td	-20.2 °C Td		
10 °C	SVP@Ts	0.00092	0.00089	0.00085	0.00082	0.00080	0.00076	0.00074	0.00070	Infinity	Type B
	SVP@Td	0.00087	0.00060	0.00022	0.00021	0.00021	0.00020	0.00019	0.00018	Infinity	Type B
	F@Ts,Ps	0.00157	0.00192	0.00266	0.00338	0.00408	0.00577	0.00727	0.01021	Infinity	Type B
	F@Td,Pt	0.00150	0.00146	0.00140	0.00162	0.00178	0.00203	0.00218	0.00235	Infinity	Type B
		34.0 °C Td	29.6 °C Td	22.7 °C Td	18.1 °C Td	14.6 °C Td	8.6 °C Td	4.5 °C Td	-1.1 °C Td		
35 °C	SVP@Ts	0.00150	0.00145	0.00138	0.00133	0.00129	0.00122	0.00118	0.00112	Infinity	Type B
	SVP@Td	0.00158	0.00190	0.00200	0.00159	0.00129	0.00082	0.00052	0.00022	Infinity	Type B
	F@Ts,Ps	0.00145	0.00184	0.00267	0.00346	0.00424	0.00612	0.00801	0.01165	Infinity	Type B
	F@Td,Pt	0.00128	0.00092	0.00144	0.00161	0.00156	0.00149	0.00145	0.00146	Infinity	Type B
				45.4 °C Td	40.0 °C Td	35.9 °C Td	28.8 °C Td	23.4 °C Td	17.5 °C Td		
60 °C	SVP@Ts			0.00047	0.00045	0.00043	0.00041	0.00039	0.00037	Infinity	Type B
	SVP@Td			0.00101	0.00112	0.00145	0.00196	0.00211	0.00153	Infinity	Type B
	F@Ts,Ps			0.00280	0.00382	0.00480	0.00714	0.00917	0.01308	Infinity	Type B
	F@Td,Pt			0.00144	0.00189	0.00146	0.00099	0.00135	0.00160	Infinity	Type B

Table 8

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The standard uncertainties, uT_F, components calculated using the associated equation uncertainty tables mentioned above are summarized in the following table.

Note: Any frost point value that is theoretically not possible is grayed out of the following table.

Standard Equation Uncertainty Components of Frost Point Temperature (±°C)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								Degrees of Freedom	Evaluation
		15.5	20.0	30.0	40.0	50.0	75.0	100.0	150.0		
Saturation Temperature	Description			-0.1 °C Tf	-3.6 °C Tf	-6.2 °C Tf	-10.7 °C Tf	-13.8 °C Tf	-18.1 °C Tf		
10 °C	SVP@Ts			0.00075	0.00073	0.00072	0.00069	0.00067	0.00064	Infinity	Type B
	SVP@Td			0.00029	0.00247	0.00405	0.00660	0.00800	0.00978	Infinity	Type B
	F@Ts,Ps			0.00235	0.00300	0.00364	0.00519	0.00658	0.00931	Infinity	Type B
	F@Td,Pt			0.00124	0.00141	0.00154	0.00175	0.00188	0.00204	Infinity	Type B
									-0.9 °C Tf		
35 °C	SVP@Ts								0.00099	Infinity	Type B
	SVP@Td								0.00080	Infinity	Type B
	F@Ts,Ps								0.01030	Infinity	Type B
	F@Td,Pt								0.00128	Infinity	Type B
60 °C	SVP@Ts									Infinity	Type B
	SVP@Td									Infinity	Type B
	F@Ts,Ps									Infinity	Type B
	F@Td,Pt									Infinity	Type B

Table 9

3.4 Saturator Efficiency Uncertainty Contribution

All two-pressure humidity generators rely on the ability of the saturator to fully saturate the gas with water vapor as it passes from inlet to outlet. The Model 1200 humidity generator incorporates a pre-saturator device along with the saturator to assure the full saturation of the gas with water vapor. Why this design helps assure 100% saturation of the gas, there may still be small amounts of uncertainty with regards to saturator efficiency, but they are considered insignificant and will not be considered. This analysis assumes 100% saturator efficiency.

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4.0 Combined Standard and Expanded Uncertainty

The combined standard uncertainty is obtained by the statistical combination of the individual standard uncertainty components of pressure, temperature, and equation in terms of relative humidity, dew point or frost point.

Utilizing a confidence level of 95.45% and a coverage factor k=2, the expanded uncertainty, U, is expressed by multiplying the combined standard uncertainty by the coverage factor as show in the following formula

$$U = k * u_c \qquad (19)$$

Using equation 6 and 19, the following tables reflect the standard uncertainty components, uRH, the combined standard uncertainty, u_cRH, and the combined expanded uncertainty, URH, at various temperatures and pressures.

Note: The Model 1200 humidity generator is limited to a maximum dew point temperature of 50°C. Any value calculated above this limit is grayed out of the following tables.

Uncertainty Components of RH (±%)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								**Degrees of Freedom**	**Evaluation**
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
Saturation Temperature	**Description**	94.9 %RH	73.6 %RH	49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
10 °C	Ts Measurement	0.18350	0.14233	0.09507	0.07144	0.05726	0.03836	0.02891	0.01946	Infinity	Type B
	Tc Measurement	0.18350	0.14236	0.09511	0.07149	0.05732	0.03842	0.02897	0.01953	Infinity	Type B
	Tc Resolution	0.03670	0.02847	0.01902	0.01430	0.01146	0.00768	0.00579	0.00391	Infinity	Type B
	Tc Self Heating	0.01835	0.01424	0.00951	0.00715	0.00573	0.00384	0.00290	0.00195	Infinity	Type B
	Ts Resolution	0.01835	0.01423	0.00951	0.00714	0.00573	0.00384	0.00289	0.00195	Infinity	Type B
	P Measurement	0.01192	0.04748	0.06106	0.05692	0.05094	0.03888	0.03111	0.02217	Infinity	Type B
	F@Ts,Ps	0.01006	0.00980	0.00951	0.00938	0.00931	0.00921	0.00901	0.00889	Infinity	Type B
	F@Tt,Pt	0.00960	0.00745	0.00497	0.00374	0.00300	0.00201	0.00152	0.00102	Infinity	Type B
	SVP@Tt	0.00590	0.00457	0.00306	0.00230	0.00184	0.00123	0.00093	0.00063	Infinity	Type B
	SVP@Ts	0.00590	0.00457	0.00305	0.00228	0.00183	0.00122	0.00091	0.00061	Infinity	Type B
	Pc Hysteresis	0.00119	0.00611	0.01178	0.01464	0.01638	0.01875	0.02001	0.02139	Infinity	Type B
	P Resolution	0.00045	0.00181	0.00233	0.00217	0.00194	0.00148	0.00119	0.00085	Infinity	Type B
Combined Standard Uncertainty		**0.26414**	**0.21031**	**0.15044**	**0.11871**	**0.09864**	**0.07067**	**0.05639**	**0.04258**	**Infinity**	
Expanded Uncertainty (k=2)		**0.52829**	**0.42061**	**0.30089**	**0.23742**	**0.19728**	**0.14133**	**0.11278**	**0.08517**		

Table 10

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Uncertainty Components of RH (±%)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								**Degrees of Freedom**	**Evaluation**
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
Saturation Temperature	**Description**	94.9 %RH	73.6 %RH	49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
35 °C	Ts Measurement	0.15156	0.11755	0.07849	0.05896	0.04725	0.03162	0.02381	0.01600	Infinity	Type B
	Tc Measurement	0.15156	0.11756	0.07851	0.05899	0.04728	0.03166	0.02385	0.01605	Infinity	Type B
	Tc Self Heating	0.05305	0.04114	0.02748	0.02065	0.01655	0.01108	0.00835	0.00562	Infinity	Type B
	Tc Resolution	0.03031	0.02351	0.01570	0.01180	0.00946	0.00633	0.00477	0.00321	Infinity	Type B
	Ts Resolution	0.01516	0.01175	0.00785	0.00590	0.00472	0.00316	0.00238	0.00160	Infinity	Type B
	P Measurement	0.01192	0.04747	0.06101	0.05685	0.05086	0.03879	0.03100	0.02205	Infinity	Type B
	SVP@Tt	0.00795	0.00616	0.00412	0.00309	0.00248	0.00166	0.00125	0.00084	Infinity	Type B
	SVP@Ts	0.00794	0.00616	0.00411	0.00308	0.00246	0.00164	0.00123	0.00082	Infinity	Type B
	F@Ts,Ps	0.00764	0.00778	0.00795	0.00804	0.00810	0.00821	0.00838	0.00857	Infinity	Type B
	F@Tt,Pt	0.00722	0.00560	0.00374	0.00281	0.00225	0.00151	0.00114	0.00076	Infinity	Type B
	Pc Hysteresis	0.00119	0.00611	0.01178	0.01463	0.01636	0.01872	0.01995	0.02129	Infinity	Type B
	P Resolution	0.00045	0.00181	0.00233	0.00217	0.00194	0.00148	0.00118	0.00084	Infinity	Type B
Combined Standard Uncertainty		**0.22424**	**0.18023**	**0.13178**	**0.10536**	**0.08829**	**0.06409**	**0.05166**	**0.03967**	**Infinity**	
Expanded Uncertainty (k=2)		**0.44848**	**0.36046**	**0.26357**	**0.21071**	**0.17657**	**0.12818**	**0.10333**	**0.07933**		

Table 11

Uncertainty Components of RH (±%)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								**Degrees of Freedom**	**Evaluation**
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
Saturation Temperature	**Description**			49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH		
60 °C	Ts Measurement			0.06574	0.04939	0.03957	0.02647	0.01992	0.01337	Infinity	Type B
	Tc Measurement			0.06571	0.04936	0.03955	0.02647	0.01993	0.01339	Infinity	Type B
	Tc Self Heating			0.03943	0.02962	0.02373	0.01588	0.01196	0.00803	Infinity	Type B
	Tc Resolution			0.01314	0.00987	0.00791	0.00529	0.00399	0.00268	Infinity	Type B
	Ts Resolution			0.00657	0.00494	0.00396	0.00265	0.00199	0.00134	Infinity	Type B
	P Measurement			0.06094	0.05678	0.05078	0.03871	0.03092	0.02196	Infinity	Type B
	F@Ts,Ps			0.00705	0.00752	0.00781	0.00819	0.00822	0.00827	Infinity	Type B
	F@Tt,Pt			0.00252	0.00189	0.00151	0.00101	0.00076	0.00051	Infinity	Type B
	SVP@Tt			0.00118	0.00088	0.00071	0.00047	0.00036	0.00024	Infinity	Type B
	SVP@Ts			0.00117	0.00088	0.00070	0.00047	0.00035	0.00023	Infinity	Type B
	Pc Hysteresis			0.01177	0.01463	0.01635	0.01869	0.01991	0.02121	Infinity	Type B
	P Resolution			0.00232	0.00217	0.00194	0.00148	0.00118	0.00084	Infinity	Type B
Combined Standard Uncertainty				**0.11969**	**0.09684**	**0.08177**	**0.06006**	**0.04877**	**0.03786**	**Infinity**	
Expanded Uncertainty (k=2)				**0.23939**	**0.19369**	**0.16353**	**0.12012**	**0.09755**	**0.07571**		

Table 12

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Using equation 7 and 19, the following tables reflect the standard uncertainty components, uT_D, the combined standard uncertainty, u_cT_D, and the combined expanded uncertainty, UT_D, at various temperatures and pressures.

Note: The Model 1200 humidity generator is limited to a maximum dew point temperature of 50°C. Any value calculated above this limit is grayed out of the following tables.

Uncertainty Components of Dew Point Temperature (±°C)

Saturation Temperature	Description	Saturation Pressure Range (psia), Chamber pressure = 14.7 psia 15.5	20.0	30.0	40.0	50.0	75.0	100.0	150.0	Degrees of Freedom	Evaluation
		9.2 °C Td	5.5 °C Td	-0.2 °C Td	-4.0 °C Td	-6.9 °C Td	-12.0 °C Td	-15.5 °C Td	-20.2 °C Td		
10 °C	Ts Measurement	0.02869	0.02784	0.02658	0.02574	0.02511	0.02404	0.02332	0.02236	Infinity	Type B
	Ts Resolution	0.00287	0.00278	0.00266	0.00257	0.00251	0.00240	0.00233	0.00224	Infinity	Type B
	P Measurement	0.00186	0.00928	0.01706	0.02049	0.02232	0.02435	0.02507	0.02545	Infinity	Type B
	F@Ts,Ps	0.00157	0.00192	0.00266	0.00338	0.00408	0.00577	0.00727	0.01021	Infinity	Type B
	F@Td,Pt	0.00150	0.00146	0.00140	0.00162	0.00178	0.00203	0.00218	0.00235	Infinity	Type B
	SVP@Ts	0.00092	0.00089	0.00085	0.00082	0.00080	0.00076	0.00074	0.00070	Infinity	Type B
	SVP@Td	0.00087	0.00060	0.00022	0.00021	0.00021	0.00020	0.00019	0.00018	Infinity	Type B
	Pc Hysteresis	0.00019	0.00119	0.00329	0.00527	0.00718	0.01174	0.01612	0.02455	Infinity	Type B
	P Resolution	0.00007	0.00035	0.00065	0.00078	0.00085	0.00093	0.00096	0.00097	Infinity	Type B
Combined Standard Uncertainty		**0.02900**	**0.02963**	**0.03203**	**0.03365**	**0.03476**	**0.03678**	**0.03869**	**0.04320**	**Infinity**	
Expanded Uncertainty (k=2)		**0.05800**	**0.05925**	**0.06405**	**0.06729**	**0.06951**	**0.07357**	**0.07737**	**0.08641**		

Table 13

Uncertainty Components of Dew Point Temperature (±°C)

Saturation Temperature	Description	Saturation Pressure Range (psia), Chamber pressure = 14.7 psia 15.5	20.0	30.0	40.0	50.0	75.0	100.0	150.0	Degrees of Freedom	Evaluation
		34.0 °C Td	29.6 °C Td	22.7 °C Td	18.1 °C Td	14.6 °C Td	8.6 °C Td	4.5 °C Td	-1.1 °C Td		
35 °C	Ts Measurement	0.02867	0.02772	0.02632	0.02540	0.02471	0.02354	0.02277	0.02173	Infinity	Type B
	Ts Resolution	0.00287	0.00277	0.00263	0.00254	0.00247	0.00235	0.00228	0.00217	Infinity	Type B
	P Measurement	0.00225	0.01119	0.02046	0.02448	0.02659	0.02886	0.02962	0.02994	Infinity	Type B
	F@Ts,Ps	0.00158	0.00190	0.00200	0.00159	0.00129	0.00082	0.00052	0.00022	Infinity	Type B
	F@Td,Pt	0.00150	0.00145	0.00138	0.00133	0.00129	0.00122	0.00118	0.00112	Infinity	Type B
	SVP@Ts	0.00145	0.00184	0.00267	0.00346	0.00424	0.00612	0.00801	0.01165	Infinity	Type B
	SVP@Td	0.00128	0.00092	0.00144	0.00161	0.00156	0.00149	0.00145	0.00146	Infinity	Type B
	Pc Hysteresis	0.00022	0.00144	0.00395	0.00630	0.00856	0.01393	0.01906	0.02890	Infinity	Type B
	P Resolution	0.00009	0.00043	0.00078	0.00093	0.00101	0.00110	0.00113	0.00114	Infinity	Type B
Combined Standard Uncertainty		**0.02904**	**0.03023**	**0.03391**	**0.03620**	**0.03771**	**0.04037**	**0.04282**	**0.04847**	**Infinity**	
Expanded Uncertainty (k=2)		**0.05809**	**0.06046**	**0.06781**	**0.07239**	**0.07542**	**0.08075**	**0.08564**	**0.09693**		

Table 14

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Uncertainty Components of Dew Point Temperature (±°C)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								Degrees of Freedom	Evaluation
		15.5	20.0	30.0	40.0	50.0	75.0	100.0	150.0		
Saturation Temperature	Description			45.4 °C Td	40.0 °C Td	35.9 °C Td	28.8 °C Td	23.4 °C Td	17.5 °C Td		
60 °C	Ts Measurement			0.02607	0.02506	0.02433	0.02307	0.02223	0.02114	Infinity	Type B
	Ts Resolution			0.00261	0.00251	0.00243	0.00231	0.00222	0.00211	Infinity	Type B
	P Measurement			0.02419	0.02884	0.03124	0.03374	0.03452	0.03473	Infinity	Type B
	F@Ts,Ps			0.00280	0.00382	0.00480	0.00714	0.00917	0.01308	Infinity	Type B
	F@Td,Pt			0.00144	0.00189	0.00146	0.00099	0.00135	0.00160	Infinity	Type B
	SVP@Ts			0.00101	0.00112	0.00145	0.00196	0.00211	0.00153	Infinity	Type B
	SVP@Td			0.00047	0.00045	0.00043	0.00041	0.00039	0.00037	Infinity	Type B
	Pc Hysteresis			0.00467	0.00743	0.01006	0.01629	0.02222	0.03354	Infinity	Type B
	P Resolution			0.00092	0.00110	0.00119	0.00129	0.00132	0.00132	Infinity	Type B
Combined Standard Uncertainty				**0.03613**	**0.03927**	**0.04127**	**0.04471**	**0.04772**	**0.05441**	**Infinity**	
Expanded Uncertainty (k=2)				**0.07226**	**0.07854**	**0.08255**	**0.08942**	**0.09544**	**0.10882**		

Table 15

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Using equation 8 and 19, the following tables reflect the standard uncertainty components, uT_F, the combined standard uncertainty, u_cT_F, and the combined expanded uncertainty, UT_F, at various temperatures and pressures.

Note: Any frost point value that is theoretically not possible is grayed out of the following tables.

Uncertainty Components of Frost Point Temperature (±°C)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								**Degrees of Freedom**	**Evaluation**
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
Saturation Temperature	**Description**			-0.1 °C Tf	-3.6 °C Tf	-6.2 °C Tf	-10.7 °C Tf	-13.8 °C Tf	-18.1 °C Tf		
10 °C	P Measurement			0.01505	0.01820	0.01992	0.02191	0.02269	0.02321	Infinity	Type B
	Pc Hysteresis			0.00290	0.00468	0.00641	0.01057	0.01460	0.02239	Infinity	Type B
	Ts Measurement			0.02345	0.02286	0.02241	0.02164	0.02111	0.02039	Infinity	Type B
	SVP@Td			0.00029	0.00247	0.00405	0.00660	0.00800	0.00978	Infinity	Type B
	F@Ts,Ps			0.00235	0.00300	0.00364	0.00519	0.00658	0.00931	Infinity	Type B
	F@Td,Pt			0.00124	0.00141	0.00154	0.00175	0.00188	0.00204	Infinity	Type B
	Ts Resolution			0.00235	0.00229	0.00224	0.00216	0.00211	0.00204	Infinity	Type B
	P Resolution			0.00057	0.00069	0.00076	0.00084	0.00087	0.00089	Infinity	Type B
	SVP@Ts			0.00075	0.00073	0.00072	0.00069	0.00067	0.00064	Infinity	Type B
Combined Standard Uncertainty				**0.02826**	**0.02998**	**0.03128**	**0.03376**	**0.03592**	**0.04060**	**Infinity**	
Expanded Uncertainty (k=2)				**0.05652**	**0.05997**	**0.06256**	**0.06751**	**0.07183**	**0.08119**		

Table 16

Uncertainty Components of Frost Point Temperature (±°C)											
		Saturation Pressure Range (psia), Chamber pressure = 14.7 psia								**Degrees of Freedom**	**Evaluation**
		15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**		
Saturation Temperature	**Description**								-0.9 °C Tf		
35 °C	P Measurement								0.02646	Infinity	Type B
	Pc Hysteresis								0.02554	Infinity	Type B
	Ts Measurement								0.01921	Infinity	Type B
	F@Ts,Ps								0.01030	Infinity	Type B
	Ts Resolution								0.00192	Infinity	Type B
	F@Td,Pt								0.00128	Infinity	Type B
	P Resolution								0.00101	Infinity	Type B
	SVP@Ts								0.00099	Infinity	Type B
	SVP@Td								0.00080	Infinity	Type B
Combined Standard Uncertainty									**0.04284**	**Infinity**	
Expanded Uncertainty (k=2)									**0.08568**		

Table 17

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5.0 Summary

A summary of the final combined expanded uncertainty is summarized in the following tables.

Note: The Model 1200 humidity generator is limited to a maximum dew point temperature of 50°C. Any value calculated above this limit or that is theoretically not possible, is grayed out of the following tables.

Expanded %RH Uncertainty (k=2)								
	Saturation Pressure Range (psia), Chamber pressure = 14.7 psia							
	15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**
Saturation Temperature	94.9 %RH	73.6 %RH	49.1 %RH	36.9 %RH	29.6 %RH	19.9 %RH	14.9 %RH	10.0 %RH
10 °C	±0.528	±0.421	±0.301	±0.237	±0.197	±0.141	±0.113	±0.085
35 °C	±0.448	±0.360	±0.264	±0.211	±0.177	±0.128	±0.103	±0.079
60 °C			±0.239	±0.194	±0.164	±0.120	±0.098	±0.076

Table 18

Expanded Dew Point Temperature Uncertainty (k=2)								
	Saturation Pressure Range (psia), Chamber pressure = 14.7 psia							
	15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**
Saturation Temperature	9.2 °C Td	5.5 °C Td	-0.2 °C Td	-4.0 °C Td	-6.9 °C Td	-12.0 °C Td	-15.5 °C Td	-20.2 °C Td
10 °C	±0.058	±0.059	±0.064	±0.067	±0.070	±0.074	±0.077	±0.086
	34.0 °C Td	29.6 °C Td	22.7 °C Td	18.1 °C Td	14.6 °C Td	8.6 °C Td	4.5 °C Td	-1.1 °C Td
35 °C	±0.058	±0.060	±0.068	±0.072	±0.075	±0.081	±0.086	±0.097
			45.4 °C Td	40.0 °C Td	35.9 °C Td	28.8 °C Td	23.4 °C Td	17.5 °C Td
60 °C			±0.072	±0.079	±0.083	±0.089	±0.095	±0.109

Table 19

Expanded Frost Point Temperature Uncertainty (k=2)								
	Saturation Pressure Range (psia), Chamber pressure = 14.7 psia							
	15.5	**20.0**	**30.0**	**40.0**	**50.0**	**75.0**	**100.0**	**150.0**
Saturation Temperature			-0.1 °C Tf	-3.6 °C Tf	-6.2 °C Tf	-10.7 °C Tf	-13.8 °C Tf	-18.1 °C Tf
10 °C			±0.057	±0.060	±0.063	±0.068	±0.072	±0.081
								-0.9 °C Tf
35 °C								±0.086

Table 20

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6.0 References

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