Thunder Scientific's Guideline for Reporting Uncertainty

The Thunder Scientific line of humidity generators produce known humidity values for instrument calibration and evaluation using the fundamental principle of the "two pressure and two temperature" generator[i] (Figure 1) originally developed by NIST.

This process involves saturating air or some other gas, such as nitrogen, with water vapor at a given temperature and pressure. The saturated high-pressure gas flows through an expansion valve where it is isothermally reduced to test pressure.

The indications of saturation temperature, saturation pressure, test temperature, and test pressure are then used in the determination of all hygrometric parameters such as %RH, Dew Point, PPM, etc.

Humidity generation by this system does not depend upon measuring the amount of water vapor, but rather depends solely on temperature and pressure measurements. The accuracy of the system is determined by the uncertainty and consistency of the temperature and pressure measurements.

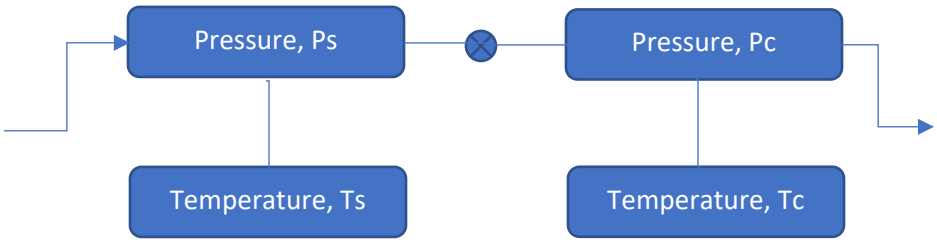


Figure 1

Thunder Scientific recommends the published uncertainty specification[ii] [iii] [iv] be used as the uncertainty specification for all Thunder Scientific Humidity generators. The published specification will remain valid as long as the generator is calibrated in accordance to the requirements outlined in the calibration section of each generator's Operation and Maintenance Manual[v] [vi] [vii].

The generator uncertainty specification is formulated on a single "worst case" value based on the in-depth uncertainty analysis of each particular generator.

To help remove any subject confusion, it is important to note that all Thunder Scientific calibration certificates include a "REPORT OF HUMIDITY COMPARISON" with a "REPORT OF TEMPERATURE CALIBRATION" and a "REPORT OF PRESSURE CALIBRATION".

The "REPORT OF HUMIDITY COMPARISON" is simply a comparison (verification) of a chilled mirror hygrometer to the generator showing the generator is operating correctly and has no corresponding effect on the uncertainty of the generator itself.

Thunder Scientific's line of humidity generators have industry leading uncertainties and the resulting comparison with a chilled mirror hygrometer is a one to one comparison at best, particularly at higher %RH values.

Given this, the "REPORT OF HUMIDITY COMPARISON" should never be used to determine the uncertainty of a Thunder Scientific generator but rather the REPORT OF TEMPERATURE CALIBRATION and the REPORT OF PRESSURE CALIBRATION be used in conjunction with the published specifications to determine if the generator is in tolerance and/or in specification.

It is important to note that the metrological traceability for the Thunder Scientific Humidity Generators is derived from PRESSURE AND TEMPERATURE CALIBRATION

See below for a Thunder Scientific Model 1200/2500 Humidity Generator measurement uncertainty estimation example.

Possible Contributors:

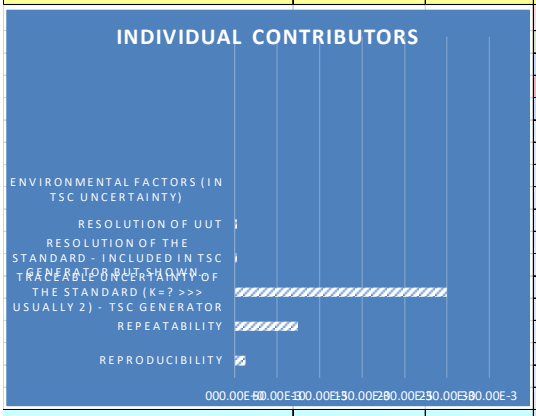
1. Repeatability (using the best possible device)
2. Resolution *
3. Reproducibility (if data is available and if it is significant)
4. Reference Standard Uncertainty (TSC Model 1200/2500: 0.5% (k=2))
5. Reference Standard Stability (if data is available and if it is significant)
6. Environmental Factors *

*Items are already components in the Reference Standard Uncertainty for the TSC Model 1200/2500

Measurement Uncertainty Budget Worksheet

Laboratory	**ABC Laboratory**								
Parameter	Relative Humidity	**Range**	0 - 99%	**Sub-Range**	50%				
Technician	IRA Technician	**Standards Used**	TSC Model 2500						
Date	4-Jun								
Uncertainty Contributor	**Magnitude**	**Type**	**Distribution**	**Divisor**	**df**	**Std. Uncert**	**Variance (Std. Uncert^2)**	**% Contribution**	**u^4/df**
Reproducibility	12.7431E-3	A	Normal	1.000	2	12.74E-3	162.39E-6	0.24%	13.2E-9
Repeatability	74.3705E-3	A	Normal	1.000	12	74.37E-3	5.53E-3	8.11%	2.5E-6
Traceable Uncertainty of the Standard (k=? >>> usually 2) - TSC Generator	500.0000E-3	B	Expanded (95.45% k=2)	2.000	100	250.00E-3	62.50E-3	91.63%	39.1E-6
Resolution of the Standard - included in TSC Generator but shown here since it is negligible.	10.0000E-3	B	Resolution	3.464	100	2.89E-3	8.33E-6	0.01%	694.4E-15
Resolution of UUT	10.0000E-3	B	Resolution	3.464	100	2.89E-3	8.33E-6	0.01%	694.4E-15
Environmental Factors (in TSC Uncertainty)			None	0.000					
			None	0.000					
			None	0.000					
			None	0.000					
			None	0.000					
			Combined Uncertainty (u_c) =			**261.17E-3**	**68.21E-3**	**100.00%**	**41.6E-6**
			Effective Degrees of Freedom			**111**	**Effective Degrees of Freedom Formula**		
			Coverage Factor (k) =			**1.98**			
			Expanded Uncertainty (U) =			**517.53E-3**			

$$V_{eff} = \frac{u_c^4(y)}{\sum_{i=1}^{N} \frac{c_i^4 u^4(x_i)}{v_i}}$$



Repeatability and Reproducibility Worksheet

	Technician 1	Technician 2	Technician 3	Technician 4
1	50.10	49.93	49.99	
2	49.99	49.99	50.08	
3	49.87	50.08	50.11	
4	50.00	50.04	49.99	
5	50.09	50.11	49.98	
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
Std. Dev.	0.089738526	0.069292799	0.061142514	
Average	50.00804	50.03128	50.02872	
Variance	0.008053003	0.004801492	0.003738407	
Repeatability		**0.074370474**		
Reproducibility		**0.012743061**		

Distribution	**Divisor**	**1/Divisor**
Rectangular	**1.7321**	**0.5774**
Triangular	**2.4495**	**0.4082**
U - Shaped	**1.4142**	**0.7071**
Resolution of instrument	**3.4641**	**0.2887**

Coverage Factor (k)	**Confidence Level**
1.000	**68.27**
1.645	**90.00**
1.960	**95.00**
2.000	**95.45**
2.576	**99.00**
3.000	**99.73**

[i] NCSL International RISP-5, Two-Pressure, Two-Temperature Humidity Generator, Recommended Intrinsic/Derived Standards Practice, January 2002

[ii] Model 1200 Specifications

[iii] Model 2500 Specifications

[iv] Model 3900 Specifications

[v] Series 1200 operation and maintenance manual for the mini two-pressure humidity generator

[vi] Series 2500 operation and maintenance manual for the mobile two-pressure humidity generator

[vii] Series 3900 operation and maintenance manual for the low humidity generator

DOCUMENT REVISION HISTORY

Date	Description
05/16/23	➢ Removed broken hyperlinks to websites ➢ Fixed hyperlinks to manuals