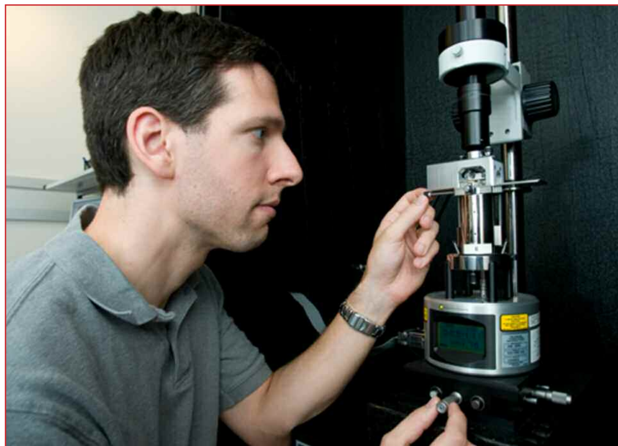
Humidity Accuracy Demystified

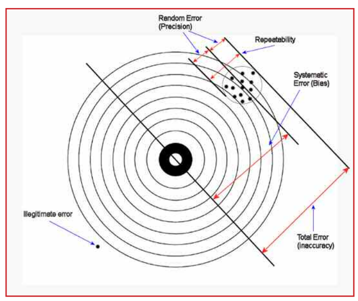
4 Key Issues You Need to Know

Comparing long term performance of RH measurement instruments involves more than simply comparing the Accuracy Specifications listed on the datasheets. The Accuracy Specification provides only part of the information needed to determine overall instrument performance. In some cases, the Accuracy Specification may not be the most significant contributor to the overall performance. Relying solely on this specification may create a high risk of out of tolerance results at the end of a calibration cycle.

There are 4 key specifications or data sets needed to make a proper comparison between instruments. Keep in mind instruments manufactured by the same company should be evaluated separately. The most obvious place to start any comparison is with the Accuracy Specification.



There is no such thing as a true value, all measurements have some degree of error.



Accuracy

Before discussing Accuracy Specifications, it is important to ensure a common definition of the term "Accuracy" to avoid confusion. When referring to Accuracy in the context of measurement instruments, and, in particular, relative humidity measurement instruments, the most commonly used definition is: ***"closeness of agreement between a measured quantity value and a true quantity value of a measurand" (JCGM 200:2012, 3rd edition)***

What this definition means is that the Accuracy Specification listed on a datasheet is describing the allowable difference between a unit under test (UUT) and the reference device. This definition of accuracy does not take into consideration the uncertainty of the reference device or the long term drift of the UUT (unit under test). Therefore, an Accuracy Specification as defined above, will not provide a complete summary of an instrument's performance over a period of time or even the performance of the instrument brand new out of the box. The Accuracy Specification is limited to describing the closeness of readings between the UUT and the specific reference used during the calibration process.

Typically, the Accuracy Specification will include hysteresis, repeatability and linearity of the device. As such it is an important starting point for our analysis, but we do need to look beyond the Accuracy Specification to other available data.

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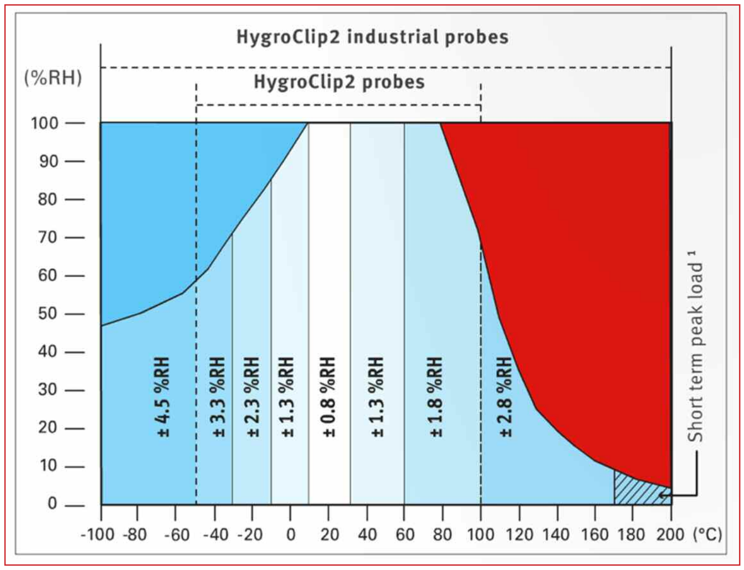
Accuracy Variations over Temperature Ranges

Typically, the specification for a RH measurement instrument will provide an accuracy at a specific temperature, or over a small temperature range. Some common examples of this may be ±1 %RH at 23 °C or ±1 %RH over 23 °C ± 5 °C. If the instrument is used outside of this limited temperature range the accuracy of the device will change. This variation is due to temperature sensitivities of the RH sensor itself as well as the electronics measuring the sensor output. This relationship between temperature and accuracy should not be conflated with the relationship between the parameters temperature and relative humidity.

Use of RH measurement instruments at temperatures other than ambient is common in environmental chambers and many process control systems. For any such application, the Accuracy Specification will increase (the device becomes less accurate) as the temperature deviates from the calibration test temperature. Manufacturers will often provide the extended range Accuracy Specification either as a fixed value over a specific temperature range or as a formula dependent on the change in temperature.

Calibration Uncertainty

It is important to recognize that all measurements have an uncertainty associated with them. Even measurements made by National Metrology Institutes such as NIST have an uncertainty. From a measurement perspective there is no such thing as an exact value.



Relative humidity instrument accuracy varies at different temperatures.

The calibration uncertainty is the value that provides a point of reference to the Accuracy Specification and is key to the traceability of the measurements. The calibration uncertainty listed on a specification sheet describes the performance of the reference system used to calibrate the RH measurement instrument. This uncertainty provides context to the Accuracy Specification. When the uncertainty is combined with the Accuracy it provides an indication of the initial performance of an instrument. Still missing from our overall comparison is the stability of the instrument.

Calibration Uncertainty needs to be used carefully in any analysis of humidity instrument performance. A manufacturer data sheet indicates the calibration uncertainty from their own manufacturing process. When the instrument is sent for calibration, either to the original manufacturer or to a third party calibration laboratory, it is not guaranteed that the same calibration uncertainty will be used. The different uncertainties will have an impact on the instrument performance going forward.

Long Term Drift (aka Stability)

A reality for all measurement equipment is that the readings of the instrument will change over time. This can be caused by a number of factors including but not limited to:

- Aging of electronic components
- Mechanical changes to materials
- Corrosion
- Buildup of dust or contaminants in sensitive areas of the instrument

For some instruments, the behavior can be very predictable and will happen at a fairly constant rate or at least follow a known degradation path. For other instruments, the behavior can be less predictable or related to very specific incidents.

Relative Humidity sensors have a higher inherent risk of drift due to the simple fact that the sensor is exposed to the air or gas it is measuring. Temperature sensors, for example, can be hermetically sealed and therefore isolated from any potential contaminants in the environment they are measuring. Depending on the level of protection, the largest compromise is a reduction in response time. Capacitive RH sensors are not hermetically sealed as they are "air-breathers". In other words, they need to be exposed to the environment they are measuring. The result of being exposed to the environment is the increased risk for contaminants in the environment to either permanently or temporarily shift the readings of the RH sensor.

The resistance of RH sensors to different contaminants varies considerably between manufacturers. It is, therefore, critically important to include the effect of various chemicals and the related concentrations in our instrument comparison.

There are two common types of contaminants that can potentially affect the readings of a RH sensor.

1. Particulate Contaminants

This refers to any particle suspended in the air that can be deposited on the RH sensor. Some dust particles may not have a significant effect on the sensor readings other than potentially slowing down the response time if too much has built up. Other particles, such as salts, which can be added to the environment from water sources can have a significant effect on sensors readings if sufficient quantities build up on the sensors. In most cases, the RH sensors can be protected from these contaminants by selecting an appropriate filter, reducing the risk of drift.

2. Vapor Contaminants

Vapor contaminants could be any volatile chemical that has evaporated and is present in the air. There are usually some vapor contaminants present in very small concentrations in most environments. The concentration of these vapors may increase in closed systems such as environmental chambers. Once the vapor reaches a certain concentration there is a potential for the RH sensor readings to shift. Unlike particulate contaminants, vapors cannot easily be filtered from the air. Other strategies, such as shortening calibration cycles, are often effective for reducing the risk of an out of tolerance condition being reported.

Pollutant	Formula	Allowed Concentration Continuous Operation	
		ppm	mg/m^3
Acetic acid	CH_3COOH	800	2000
Acetone	CH_3COOH_3	3300	8000
Ammonia	NH_3	5500	4000
2-Butanone (MEK)	$C_2H_5COCH_3$	3300	8000
Chlorine	Cl_2	0.7	2
Ethanol	C_2H_5OH	3500	6000
Ethyl acetate	CH_3COOC_2H	4000	15000
Ethylene glycol	$HOCH_2CH_2OH$	1200	3000
Ethylene oxide	C_2H_4O	3	
Formaldehyde	HCHO	2400	3000
Hydrochloric acid	HCl	300	500
Hydrogen sulfide	H_2S	350	500
Isopropanol	$(CH_3)_2CHOH$	4800	12000
Methanol	CH_3OH	3500	6000
Nitrogen oxides	NO_X	5	9
Ozone	O_3	0.5	1
Petrol			150000
Sulfur dioxide	SO_2	5	13
Toluene	$C_6H_5CH_3$	1300	5000
Xylene	$C_6H_5(CH_3)_2$	1300	5000

Critical Chemical Concentrations for Rotronic Humidity Sensors.

While all capacitive RH sensors have a similar basic construction, the materials used and the overall design of the sensors will vary significantly. The long term stability is directly related to these differences in material and construction thereby affecting the long term performance of the RH measurement instrument. Unfortunately, information regarding long term drift can be hard to find. Few data sheets list it, but in some cases it can be found in user manuals. In many cases, it will take a call to the manufacturer to find the data.

Instrument Comparisons

Now that we have the key components contributing to long term instrument performance identified, we need to define a mechanism to normalize the data. Different manufacturers will present data in different formats so the analysis is not as simple as adding together the components. For this comparison, we will perform an uncertainty analysis on the instrument using a standard methodology described in a document commonly referred to as the GUM. (JCGM 100:2008, 2008) The GUM is used by all accredited calibration labs as well as National Metrology Institutes such as NIST for evaluating measurement uncertainties.

Following these methodologies we can create the following examples

INSTRUMENT A

Parameter	U	Distribution	Divisor	Standard Uncertainty	Comment
Accuracy (Linearity, Repeatability, Hysteresis)	1	Rectangular	1.732	0.577	From Data Sheet
Calibration Uncertainty	1	Normal	2	0.500	From Data Sheet
Annual Drift	1	Rectangular	1.732	0.577	From Historical Data Sheet
		Combined Uncertainty		0.957	
		Expanded Uncertainty k=2		**±2.0 %RH**	

INSTRUMENT B

Parameter	U	Distribution	Divisor	Standard Uncertainty	Comment
Accuracy	0.8	Rectangular	1.732	0.462	From Data Sheet
Calibration Uncertainty	0.5	Normal	2	0.250	From Calibration Certificate
Annual Drift	1	Rectangular	1.732	0.577	From Data Sheet
		Combined Uncertainty		0.780	
		Expanded Uncertainty k=2±1.6 %RH			

INSTRUMENT C

Parameter	U	Distribution	Divisor	Standard Uncertainty	Comment
Measurement Uncertainty (Linearity, Repeatability, Hysteresis, Calibration Uncertainty)	1.46	Normal	2	0.730	From Data Sheet
Annual Drift	1	Rectangular	1.732	0.577	Best Estimate
		Combined Uncertainty		0.9307	
		Expanded Uncertainty k=2		**±1.9 %RH**	

INSTRUMENT D

Parameter	U	Distribution	Divisor	Standard Uncertainty	Comment
Accuracy (Linearity, Repeatability, Hysteresis)	1.5	Rectangular	1.732	0.863	From Data Sheet
Calibration Uncertainty	0.6	Normal	2	0.300	From Associated Calibrator Data Sheet
Annual Drift	1	Rectangular	1.732	0.577	Best Estimate
		Combined Uncertainty		1.081	
		Expanded Uncertainty k=2		**±2.2 %RH**	

In these examples it is the Expanded Uncertainty which provides the estimated instrument performance after 1 year. Further analysis shows that a comparison of Accuracy Specifications does not always show which instrument will perform better over time.

Summary

It is important to look beyond the Accuracy Specifications when selecting a RH measurement instrument. Matching process requirements to only an Accuracy Specification can lead to out of tolerance conditions being found when the instrument is calibrated after 1 year. It is critical to delve deeper into product data sheets, user manuals and potentially technical experts at a manufacturer to acquire the remaining details which are key to making a proper estimation of performance.

Bibliography

JCGM 100:2008. (2008). Evaluation of measurement data - Guide to the expression of uncertainty in measurement.

JCGM 200:2012. (3rd edition). International vocabulary of metrology - Basic and general concepts and associated terms (VIM).

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