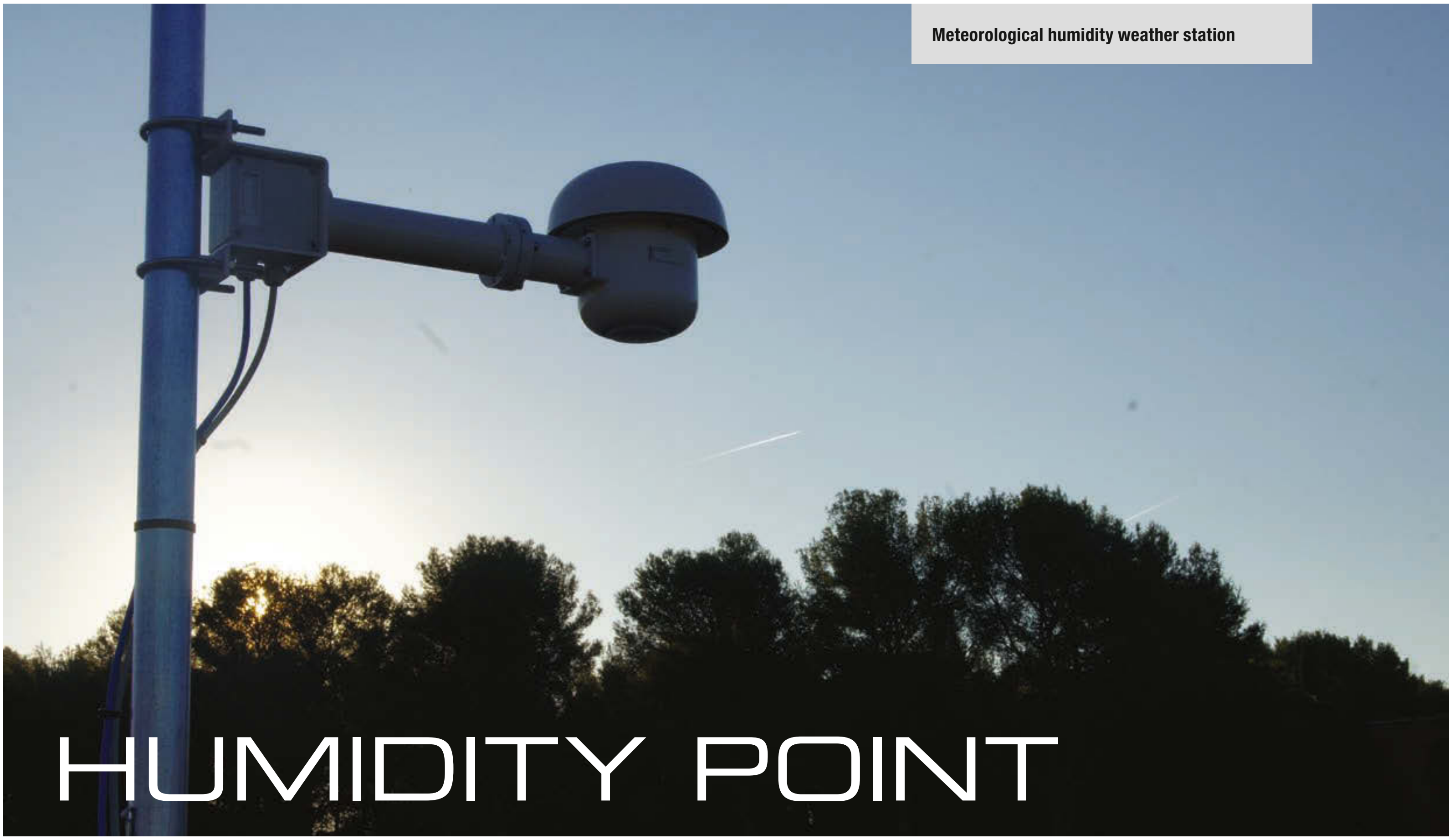
by Robin Farley



Meteorological humidity weather station

HUMIDITY POINT

Applying metrology to meteorological measurements

Metrology is the science of accurate measurements. Meteorology is the study of weather and climate. It's important to know the difference

An increasing focus on atmospheric water vapor concentration and its implication within the diverse fields of climatic research and meteorology has led to increasing scrutiny into the precision and reliability of humidity measurement data. Climatic water vapor is one of the more challenging aspects of meteorology, with unreliable results, variability of units and non-traceable calibration perhaps the most pertinent issues. Humidity measurement and calibration systems have consequentially become a hot topic.

Within the current European Meteorological Research Program (EMRP) there are several key work packages focused on humidity. The Metrology for Meteorology and Climate international workshop – MMC 2014 – that took place in Slovenia in September 2014 also had a major humidity focus.

Problems with humidity?

It's common for humidity measurements to be considered unreliable or specified with quite large tolerances. Often this position is based on an underestimate of the measurement challenges, a lack of fundamental knowledge of humidity and poor calibration.

It is not unusual for humidity to be incorrectly described; a single recent TV weather bulletin included the description of water vapor content as 'moisture', 'humidity', 'dew point' and 'relative humidity'. One would assume that qualified meteorologists would be consistent, but they are not alone. Metrologists and humidity specialists even at the highest level are similarly inconsistent. The latest humidity technology continues to improve measurement and calibration capability, but its application lacks coordination, uniformity and structure. Contact with metrology and meteorological institutes around the world provides an insight into the variability of methods and practices. Many organizations are not able to provide even the most basic calibration services and documented traceability that other well-regulated industries take for granted. Calibration at working temperature is one such example; the definition of calibration uncertainty is another.

Is humidity measurement really so difficult?

Unlike other key measurements such as

Table 1: Overall uncertainty of rh in chamber

Uncertainty source	Value	Units	Sensitivity	Distribution	Divisor	One SD	Squared
Humidity probe calibration	2.00	% rh	1.00	normal	2.00	1.000	1.000
Humidity probe repeatability	0.30	% rh	1.00	normal	1.00	0.300	0.090
Humidity probe drift	1.00	% rh	1.00	rectangular	1.73	0.577	0.333
Humidity probe linearity	0.50	% rh	1.00	rectangular	1.73	0.289	0.083
Temperature coefficient of the relative							
Humidity probe over validation range	0.50	% rh	1.00	rectangular	1.73	0.289	0.083
Resolution of the relative humidity probe	0.10	% rh	1.00	rectangular	1.73	0.058	0.003
Temperature gradients in chamber	0.30	°C	3.25	rectangular	1.73	0.563	0.317
Temperature fluctuations in chamber	0.20	°C	3.25	normal	1.00	0.650	0.423
Stabilization criterion for reference probe	0.10	% rh	0.00	rectangular	1.73	0.000	0.000
	Standard uncertainty					1.527	2.33
		Expanded uncertainty				**3.05 %rh**	**95% confidence (k=2)**

temperature and pressure, humidity sensors cannot be protected from the measured conditions by membranes, sheaths or other protective barriers. Some mechanical filtration can be applied to limit particulate contamination, but that does not protect humidity sensors from contaminants such as sulfur and nitrogen oxides that will cause degradation and instability in the measurement sensor. Consequently, relative humidity (RH) probes will drift at varying rates depending on their type, location-specific contamination, variation in humidity and temperature conditions and maintenance, so their calibration must be verified on a routine basis. Every measurement can be traceable and its uncertainty defined through the calibration process, provided it is correctly documented.

Surface observation systems, typically weather stations or screen assemblies, are widely used. Stated measurement performance will typically be based on manufacturers' specifications rather than on calculated uncertainties. Typical uncertainty contributions are shown in the calibration example above, but recent studies have shown considerable effects attributable to wind speed during measurements and mounting shield design.

Radiosondes are required to measure over a substantial temperature and humidity range within the same flight. To determine full system performance, the sensors should be tested over a wide range of humidity and temperature conditions, but though possible, this is often considered too expensive. Consequentially the sensors are often calibrated at only a limited number of temperature and humidity points, resulting in inconsistency and unproven traceability when used outside the calibrated range. The

Humidity generator TSC 2500ST

"Radiosondes are required to measure over a substantial temperature and humidity range within the same flight"

better manufacturers invest more substantially in calibration, and it is no coincidence that their products are more widely trusted and perform consistently well in comparative tests.

Humidity calibration uncertainty

Better standardization could go a long way to resolving many of the uncertainties. The ideal method of defining the precision of any measurement or generated condition is an assignment of uncertainty.

The *Guide to Uncertainty of Measurement* (GUM) is the reference for calibration metrologists, and the application of its structures can at least provide a means of validation or a more dependable comparison of data. An uncertainty budget combines the individual components of uncertainty to resolve an expanded uncertainty of measurement or a generated value.

For example (see table), if a meteorological probe were calibrated in a chamber, the uncertainty would propagate into an overall measurement uncertainty that cannot be smaller than that of the calibration chamber. In a typical weather station relative humidity measurement application, additional uncertainty components such as shield temperature effects, together with airflow, filter and contamination effects, would need to be included. This would typically resolve an expanded uncertainty at k=2 of 4-5% RH. The calibration of the humidity probe is the most important component in this example.

Calibration solutions

There are many methods of generating the stable humidity conditions needed to calibrate humidity instrumentation, but

Humidity generator HygroGen2 with dew point mirror 473-SH2

within the limited scope of this article, it's impossible to fully describe and compare them all. Any chosen method should be assessed in terms of its expanded uncertainty and based on a true evaluation, not just what the manufacturer claims. It's also worth considering the need for the calibration of temperature measurement, and the calibration of humidity at the instrumentation's working condition within any evaluation. Humidity measurement performance varies with temperature, so it's not really effective to calibrate only at one temperature, especially when field measurements are at low temperatures.

Each country's national metrology institute (NMI) provides the best source of advice and transfer-standard calibration, so it is recommended that this be a key element of evaluation of the options for improved calibration systems. This will also provide a mechanism for traceability to national and international standards once any system is implemented.

Humidity generators

Most NMIs operate a primary humidity generator based on using pressure and temperature control and measurement to provide direct traceability to SI units. These are usually customized and characterized by the NMI, so require operational expertise and fundamental knowledge to achieve the best results. But there are commercially available automated generators that provide practical and cost-effective solutions, and some include temperature-controlled chambers so that calibration at temperature can be performed.

By mixing flows of wet and dry gas, it is possible to generate a wide range of humidity conditions. In the RH range, the process can be automatically controlled, and commercially available solutions are capable of good control over a wide temperature range (-10°C to 70°C). Compact RH generators require good temperature control to achieve the best calibration capability, and with the application of a transfer standard, this means that RH and temperature calibration can be performed by the same system.

Salt solutions

Climatic chambers and salt solutions

Temperature- and humidity-controlled chambers are in use for testing products in many conditions. Typical performance is adequate for climatic testing, but for calibration tasks, optimized versions are increasingly available but depend on the application of careful temperature measurement and a calibrated humidity transfer standard. The non-uniformity of the chamber temperature must be evaluated.

The use of saturated and non-saturated salt solutions remain a practical and low-cost method for humidity calibration, but performance depends on stable temperature and pre-calibration of the salt solution or validation of its generated value using a transfer standard. Uncertainties tend to be higher and their use is probably best suited to temperature-controlled laboratories. With expert handling, salt solutions may be useful for humidity calibration, but careful validation is necessary to prove traceability.

Transfer standards

Within a calibration system, it is usual for a transfer standard to be applied to verify generated conditions and to provide traceability. It should be of a standard higher than the systems being calibrated, so for example an RH probe shouldn't really be used as a transfer standard for another RH probe, as both may have similar characteristics that will combine to influence the overall uncertainty of measurement or calibration.

Again, an evaluation of specifications and calibration performance within the structure of an uncertainty budget will support the correct specification of the type of transfer standard to use or specify.

The demand for better humidity data is challenging manufacturers and users to better measurement and calibration capability. The international metrology industry includes humidity expertise and a wide range of products help to support any organization wishing to improve its measurement capabilities and document traceability. If humidity calibration is a cause for concern, contact a reputable supplier, your local NMI or an accredited calibration laboratory for guidance. The Metrology for Meteorology Conference will be running alongside Tempmeko in 2016 and may be a useful event for interested parties to attend. ∎

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