The Trouble With Humidity: The Hidden Challenge of RH Calibration

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A year after installation, the new high-accuracy relative humidity transmitters are removed from service and returned to the lab for routine testing and re-calibration. A few days later they return, more out-of-calibration than ever before. But nobody notices— at first. Sound impossible? Well, it happens more often than you think. Humidity calibration is difficult and there is plenty that can go wrong. This article will help companies examine their own calibration processes and assess how they measure up to today's demanding requirements.

Is Accuracy That Important?

Calibrating relative humidity instruments accurately and efficiently is a daunting challenge more and more companies are facing as the need for relative humidity (RH) monitoring and control proliferates. A critical environmental factor in thousands of processes and materials, the accurate measurement of RH is rapidly becoming a quality and regulatory concern in applications ranging from product shipping and storage to electronics manufacturing and food processing to pharmaceutical research.

In response, many companies are scrutinizing their RH calibration methods to ensure adherence to required standards. Along the way, many are finding that their processes are inefficient, incomplete or incapable of providing reliable results. Others remain unaware of the effectiveness of their processes and may be surprised that that the high accuracy they assumed may not exist. Is accuracy that important? As competitive and cost pressures mount, companies are determining with ever-greater clarity the effects of RH on their operations.

In pharmaceutical manufacturing facilities, out-of-tolerance RH levels cause clumping in fine powders, fouling expensive tableting processes and affecting finished product quality. In the photographic film, pulp and paper, semiconductor, and textile industries, slight variations in RH can have disastrous effects on process efficiency and output. To ensure high product quality, companies are incorporating their RH discoveries into process control specifications and into their monitoring procedures.

These developments, combined with recent technology advancements, have led the industry to demand ever higher levels of RH accuracy. Many secondary RH sensors today boast of accuracies ranging from ± 1 to 4%RH. This performance is impressive compared to the state of the industry 20 years ago when horse hair hygrometers at ±10% RH were the norm. But what about calibration? If these modern systems are capable of achieving such accuracy, it puts enormous pressure on the higher-accuracy (typically three times or better) systems used to calibrate them.

The Pivotal Role of Calibration

All secondary RH sensors are absolutely dependent on accurate calibration in order to deliver their specified performance. While the best RH sensor may boast an intrinsic accuracy of ±1%, calibration errors can render them useless. All secondary RH sensors require calibration to a higher standard, not only during production, but also as part of ongoing maintenance to correct for drift. Good calibration cannot save a bad sensor, of course, but improper calibration will cause an otherwise excellent system to produce erroneous and potentially damaging results.

As a manufacturer of RH data loggers since 1995, Veriteq Instruments has experienced, first-hand, the complexities of the RH calibration process. Portable, self-contained recorders, data loggers, uniquely introduce the element of time to the measurement of RH, an extremely important factor in accurate calibrations. The units work by producing a time-based record of temperature and RH that can be graphically displayed on a computer.

The advantage of such a record is that it details the level of thermal and RH stability during calibration and, if multiple units are tested, also indicates the homogeneity of the test chamber. Thus, data loggers make it easy to determine when, or if, a steady state has been achieved. Conversely, they also make it obvious when a calibration has been performed hastily or in unacceptable conditions.

A recent example of the value of such a record involved a customer preparing to use several data loggers for hygrothermal mapping of a stability chamber. Prior to use, a calibration check was made by placing the loggers in a specially-prepared, insulated and sealed chamber overnight to ensure that the units read identically under what was assumed to be identical conditions. Based on this assumption and after completing the test, the customer concluded that the loggers were not operating within their specifications — there was simply too much variability in the readings between units.

The real problem became clear after closely examining the data logging records. In these records a surprising level of instability in the test chamber was apparent, despite the special precautions. By installing a small device to stir the air, the customer was able to improve uniformity and the loggers reflected this by returning to their "in-spec" condition. So what began as a test of data loggers using a chamber became a test of the chamber using data loggers.

The State of RH Calibration Today

Veriteq's experience has also given it a strong sense of how the industry is dealing with the RH calibration burden. With this experience, the company has discovered that RH calibration is often a neglected or misunderstood aspect in RH monitoring. An example of this lack of understanding is the popular misconception that if an instrument has a "NIST-traceable" calibration certificate, the unit is not only accurate but it also "validated" for the user's application.

The truth is that many calibration processes themselves have not been validated. Equipment is often assumed to operate in accordance with the claims made in the sales brochures. Procedures are often borrowed and not questioned or tested. The end result is that calibrations are often performed:

- using reference standards that are not traceable or accurate enough to support the intended accuracy of the calibration
- far too hastily, preventing the essential stabilization of conditions necessary to calibrate properly
- without the use of adequate thermally-controlled chambers or in areas where thermal stability is poor
- with unacceptable uniformity of conditions or, at the very least, without air mixing provisions
- using methods or procedures that entail too much handling, are out-of-date, or otherwise incomplete
- without written or defined procedures that can affect the repeatability of results

The Trouble With RH

Why is there such a difficulty in working with RH? The basics seem elementary enough: humidity refers to air-borne water or vapor, which is water in a gaseous state. Relative humidity is simply the measure of the amount of water vapor in the air compared to how much it can possibly hold at that temperature. From a theoretical perspective, these concepts are easy to understand, but on a practical level, the process is not only complicated but even counter-intuitive.

Wide Dynamic Range

RH is more difficult to measure than most water-related or atmospheric properties, such as temperature, pressure, flow, volume, mass or level. The complexity begins with the broad range of moisture conditions RH sensors must operate in. For example, a sensor rated to measure 10 to 90% RH from -40 to 70C must perform in humidity conditions ranging from 10,000 parts per billion to 200,000,000 parts per billion. The dynamic range this represents is 20,000:1, a figure that would challenge the linearity of most measuring devices, regardless of the property measured.

If It Weren't for Temperature...

RH is troubling because it is a temperature-dependent variable. Its value can change significantly with even slight variations in temperature and without any increase in moisture. For example, a 1C variance in temperature at 20C and 50 % RH can introduce an error of ± 3 % RH, an enormous variance in a calibration process. At 90 % RH, even a 0.2C variance will result in a ± 1% RH error. These temperature effects highlight the importance of thermal stability, a condition that is often difficult to achieve in a calibration environment.

Air Is Harder to Measure

Perhaps the most significant calibration challenge is that RH testing must be carried out in air (or gas), unlike a temperature calibration, for example, that can be performed using a liquid bath. The advantage of a liquid bath is that it has a high heat transfer capability and can be brought to temperature quickly and uniformally to create a reliable test point. Not so with air. RH sensors measure only the water vapor in the immediate layer of gas contacting the surface of the sensor, a fact that emphasizes the need for stable and homogenous environmental conditions. Air is a poor thermal conductor and the temperature at any given point can be affected by thermal currents and temperature gradients that make such conditions not only difficult to achieve, but time-consuming.

Whereas a vigorously stirred liquid bath can be brought to temperature in a matter of minutes, an RH calibration environment may take hours to stabilize, even when generated by an expensive primary system. This slow rate of change, and the need to take time for conditions to equilibrate at a constant level, are anathemas to modern processing, with its high emphasis on speed and efficiency.

The Trouble With Sensors

All secondary RH sensors are non-linear devices with temperature dependencies. Most hygrometric sensors work by changing their electrical properties with variations in humidity and temperature. Because of this non-linearity and temperature dependency, it is necessary to validate sensor operation at multiple RH and temperature points, ideally covering the range of the intended application. This requirement is not only difficult to achieve without expensive equipment but is also time-consuming.

Verifying Your Measurements

Unless questioned or challenged, many flawed RH calibration processes may remain unchanged indefinitely. To avoid this, companies need to conduct periodic reviews of existing equipment and procedures and to look further at the effects and results of their calibration processes. The following questions will prove helpful in carrying out these reviews:

Reference standards: Are only NIST-traceable primary or transfer standards used? Have they been validated? Do the standards have an uncertainty sufficiently low enough to justify the final calibration accuracy claimed? Have all the elements of uncertainty been considered in determining the reference standard's accuracy statement?

Procedures: Have the procedures been validated? Do they clearly specify adequate times to allow for thermal and humidity stability? Are there provisions to ensure uniformity of the chamber environment? Are multiple RH and temperature calibration points tested? Are the procedures written, followed and periodically reviewed?

Instruments and sensors: Are the calibrated instruments trusted by those who use and rely on them? Do they need calibration more often than expected? Are the as-found calibration conditions frequently out-of-spec? Do the instruments require significant adjustments for each calibration? Are the instruments or sensing devices reasonably interchangeable or are their "unexplained" differences?

Products and processes: Are there recurring problems with product quality or efficiency that relate to temperature or humidity sensitivity?

Summary

RH calibration, at first glance, can appear simple and basic. In reality, it is a complex and time-consuming process filled with potential pitfalls. Despite the importance accurate RH can play in an organization, many are unaware of the pivotal role calibration plays and still more are unaware of the key factors in a successful calibration. With quality and regulatory pressures continually increasing, it is important for companies to fully understand and evaluate their processes to help prevent unpleasant surprises.

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