How Hard Could That Be? Practical Humidity Calibration Experiences

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Relative humidity (RH) calibration is a growing discipline that requires specialized knowledge and systems. Gaining that knowledge and determining which system is best is a challenge facing many companies who wish to save time and money by bringing their processes in-house. Salesmen and marketing materials can help, but a practical review of systems by people who have actually used the equipment may be far more useful. Veriteq, a manufacturer of compact humidity data loggers, has experienced many of the difficulties with RH sensor calibration firsthand. Beginning with a dream of an "ideal" system (accurate, inexpensive, quick, easy to operate, and highly reliable), the following account describes some of the Company's own experiences with different calibration systems and represents a practical perspective on the challenges involved.

The Journey Begins...

Veriteq's initial humidity calibration challenge began when it introduced its flagship product, a palm-sized RH data logger in 1995. The goal at that time was to develop a functional calibration test to compare sensor accuracy against a more exacting standard. At the time the pervasive thought was "How hard could that be?"

The Futility of Ambient Checks

The first step was to purchase a "high-accuracy" RH meter and use it to compare readings with the production units. The idea was simple enough. After final assembly, perform a check by placing the meter's RH probe immediately next to the data logger. Then compare the readings and make a determination of the unit's calibration and functionality.

As easy as it seemed, testing in this manner failed to deliver repeatable results. Typical lab environments are uneven and dynamic with all sorts of temperature gradients, air patterns, and humidity and heat influences. Standing and breathing in close proximity to a RH sensor can cause it to jump several percent in RH and even a nearby computer can produce wafts of error-inducing heat. The inescapable conclusion was that this was no way to calibrate RH. What was needed a consistent and stable environment. How hard could that be?

The need for a chamber

Producing a small, insulated and sealed chamber with a rack for holding data logger units was easy. The insulation would shield the chamber from temperature fluctuations and the seal would prevent moisture ingress. Despite the promise of such a setup, the results were still not reliable. Even though the chamber was sealed, RH levels varied significantly. About this time it also became apparent that a single point RH check was not sufficient to verify a secondary RH sensor. What was needed was not only a stable system, but one that could generate multiple RH levels. How hard could that be?

Divided Flow

Portable, Programmable, Convenient, But...

The first RH generator that caught the Company's eye was a popular and compact unit based on a "divided flow" principle. Divided flow generators work by mixing two air streams, one saturated and one completely dry, to create a desired RH environment. A non-fundamental system, the chamber featured a small brick-sized test chamber and claimed an accuracy of ±1% RH.

In practice, the use of the RH generator proved convenient but the results were still unreliable, perhaps even more so than previous methods. The Company found that the uniformity of RH inside the chamber was surprisingly poor, up to several percent RH. Who would have thought this could happen in such a small chamber? Without uniformity in the test environment, there was no certainty that the sensing point of the calibrated instrument was representative of the reference point of the chamber.

Strange Temperature Errors

Another observation with this system was an unusual cyclical pattern in the recorded RH data. Initially thought to be a product design flaw, it soon became apparent that the pattern perfectly paralleled the cycling of the lab air conditioning system. A primary objective of the RH calibration process is to achieve a highly stable environment, yet this cycling was causing fluctuations of up to 3% RH, a highly unacceptable condition. Despite the initial promise, this would not be a useful production calibration system. It was time to move on to something different.

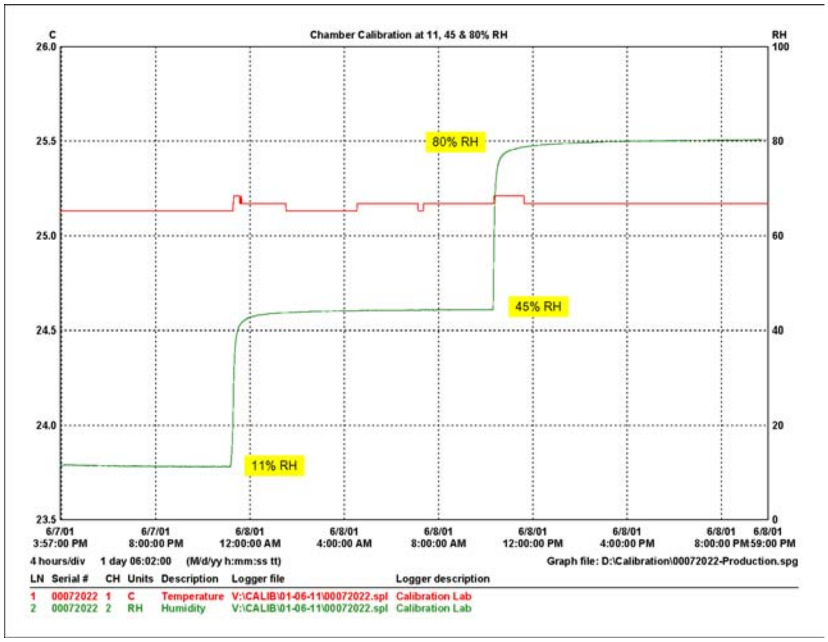
Saturated Salts

The Company's two main objectives in transitioning to a new RH calibration system were uniformity and thermal stability. For that purpose, saturated salt baths had several appealing characteristics. They could generate a fixed RH environment and, by performing the work in a specially-insulated and temperature-controlled chamber, the Company hoped to eliminate the problems with thermal stability. Although saturated salts are frequently used as a calibration check themselves, the Company's purpose was solely to generate a stable environment and to use the chilled mirror hygrometer as the reference standard.

An old and trusted method

Saturated salt baths are perhaps the oldest method for generating humidity at different levels. The actual RH value is a function of the chemical properties of the salt when mixed with water, with different salts yielding different values. Although cumbersome, several advantages over the previous RH generator stood out:

1. The controlled chambers could be made substantially larger and a number of chambers could be maintained for different RH environments, allowing more products to be calibrated quickly.
2. With the experience gained from controlling room environmental factors, there was confidence that a stable environment could be achieved.



A typical 3-point data logger calibration cycle.

The salt bath chambers were implemented in a large heavily insulated cabinet fitted with a precision heat control system. Salt baths were created for RH environments of 11%, 43% and 75% at 25°C. Each salt mixture was placed in a large sealed glass basin. A chilled-mirror hygrometer with (1% RH specified accuracy was installed in each of the salt baths to verify the RH regularly and check the salt bath mixture as needed.

But Not Reliable Enough

The salt bath calibration proved more reliable than the earlier RH generator. For a production calibration system, however, it had severe limitations. The system lacked the convenience of the prior system and RH conditions took up to 20 hours for a chamber to stabilize. The use of highly corrosive salt solutions was also problematic and it was difficult to maintain consistent RH levels without constant maintenance. Contamination of the salt mixture and the metallic mirror surface of the chilled mirror sensor was a continual concern. All of these factors added unacceptable levels of uncertainty, inconvenience and time to the calibration process. It was time to move on to a better system.

Two-Pressure System

The Company's new quest was to find a system that was more efficient, more stable and capable of a higher level of accuracy. A key feature of interest was the ability to automatically create multiple temperature and RH environments with a high degree of stability and accuracy.

A primary standard with double the accuracy

The system the Company chose was a self-contained two-pressure humidity generator. An appealing aspect of this type of system for the Company was that it is considered a primary standard, the highest classification of RH calibration equipment recognized by NIST. The system works by producing known humidity levels by saturating air at a given pressure and temperature and then isothermally bringing the saturated air to chamber pressure. The advantage of such a system is that it does not rely on the direct measurement of water vapor and the higher levels of error associated with such methods. Instead, it is solely dependent on the measurement of pressures and temperatures and the degree of uniformity in the chamber. These factors allow the system to claim an accuracy twice that of the previous chilled mirror systems.

Hard to Beat

What was most appealing to the Company was the impressive specifications: With a rated range of 0°C to 70°C and 10% to 98% RH, an accuracy of ±0.5% RH, and a temperature uniformity of ± 0.1°C., the system looked likely to help the Company forget all the difficulties of past systems.

As with any calibration system, however, there were some surprises. The Company discovered during initial validation that the settling time of the chamber at programmed levels proved to be much longer than expected. At elevated RH levels, it took up to nine hours to become stable enough to perform calibration work. In contrast, the chamber's control software assumed conditions had stabilized within only one hour, a determination that would have caused a calibration error of several percent RH. By installing a special air stirring apparatus, the Company managed to reduce the stabilization time to six hours, a significant improvement but still surprisingly long.

The Need for Independent Verification

Another difficulty with the system was the absence of an independent RH sensor in the chamber. In practice, this caused a degree of doubt on the part of the operator who must operate without verification that the conditions inside the chamber match that indicated on the system control panel. This limitation prevents an operator from independently confirming that conditions in the chamber have stabilized. The Company addressed this shortcoming by installing a "control" humidity logger in the chamber as a secondary reference and an indicator of comparative performance.

Those troubling microenvironments

A third concern with the system was that thermal uniformity was not as tight as expected. The chamber seemed to have its own dynamic microenvironments resulting in temperature variations up to 0.15°C., even after lengthy stabilization times. A temperature difference this small may seem insignificant, but in a 0.5% RH calibration environment, such a difference can more than double the uncertainty! To prevent this from affecting calibration accuracy, the Company now measures dewpoint as a reference in the chamber. The advantage of dewpoint is that it is relatively constant and is not affected by temperature changes. The Company then uses each data logger's own precision calibrated thermistor, located immediately adjacent to the RH sensor under calibration, to minimize uniformity errors.

A System for the Long Haul

Overall, the two-pressure system has been an important element in achieving a first-rate process for high accuracy RH calibrations. It wasn't as easy as it initially appeared and many unexpected adjustments to both equipment and procedures had to be made. The end result, though, has been a process that delivers a high level of repeatable accuracy and does it efficiently and with less cost.

Summary

At first glance, a lot of challenges seem easy. Calibrating for relative humidity was one of those challenges for Veriteq. As the company found out, there's a lot more to calibrating RH than simply buying systems and following generally accepted procedures. There are many complexities to learn and a myriad of potential systems, product features, and techniques to consider. Calibration of RH has proven not to be a trivial task, nor is it one that is intuitively understood. If accurate RH measurement is important in an organization, the right equipment and proven processes are essential for achieving consistent and repeatable results.

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