Relative Humidity: Measuring the Unmeasurable?

In a real-life situation there is always a mixture of materials, each with its own relative equilibrium humidity **(%REH)** and each of these will contribute to the final answer when relative humidity is measured under these conditions. In the controlled environment of a laboratory, life is much easier, and reaching both temperature and humidity equilibrium is not difficult, but pity the person who has to take a measurement in the ever-changing environment out in the open or in an industrial area.

More on the behaviour of water molecules

Water molecules will move around until equilibrium is reached. A sealed packet of instant soup provides the ideal example. All the ingredients are sealed in an airtight packet, and water molecules will move from those ingredients with a high **%REH** level to those with lower values, and eventually an environment will be reached where all the ingredients are at a mean value. The mean value of the mixture is usually well below the **%REH** level to prevent any bacterial growth or deterioration of the product. In an open environment it is safe to assume that there will be a continuous movement of water molecules, and that it is usually unlikely that all the components will ever reach the **%REH** value of the area. Moving in closer to individual components, it is possible to detect the natural **%REH** of each of these. These values can be used as reference values for various products to simplify quality assurance and conformity checks on products which are extremely difficult to evaluate in any other way. Examples are the piping used in vehicle air-conditioning units, where the **%REH** value is an indication of both the quality of the metal, and the manufacturing processes. Any residue left behind on the inner surface of the metal will change %REH value. This type of measurement may be classified as an extreme measure to ensure quality, but it gives an indication of just how useful this surface **%REH-effect** is in a practical application. Similarly, food and pharmaceutical products are evaluated by means of REH measurements, but it is more often referred to as water activity measurements and expressed in aw units on a scale of 0 to l.. (The aw unit is defined as the water vapour pressure of the product divided by the water vapour pressure of pure water, or to put it more simply, aw = **%REH/** 100.)

The effect of temperature and pressure on measuring instruments

In most of the modern hand-held temperature and relative humidity measuring instruments, it is standard practice to reference the relative humidity values to the standard pressure of 1 013,2 mb. If a phychrometer is used, it is unlikely that it will come up with a corresponding value unless the relative humidity value is first obtained from the ambient temperature (dry-bulb), wet-bulb temperature, and the actual pressure, before a conversion to standard (sea-level) pressure is made. Only one manufacturer, Vaisala, currently manufactures an instrument with the option to enter the actual pressure in order to simplify this conversion by modifying the electronic instrument's reading to coincide with that of the phychrometer. The mutual distrust found between the users of modern electronic instrumentation for the measurement of relative humidity and the users of the traditional wet and dry-bulb standards of yesteryear can so easily be avoided if this basic difference between the two systems is understood. There are more than enough obstacles in the way to measure relative humidity accurately to add these! Components at different temperatures will also give off or absorb heat to reach equilibrium, and very large errors can result in relative humidity or water activity measurements if the various components are not all at the same temperature. Experiments have shown that an instrument which was left on the front seat of a car in the sun can have offsets in the order of **30%RH** to **50%RH** when referencing it to a saturated salt standard, which has been in laboratory environment at 20ºC! Care must also be taken when taking measurements in an area well below the outside ambient temperature, and then bringing the instrument out again. This is one sure way permanently to damage certain sensors in the resulting condensation.

The effects of temperature and pressure on reference standards

The use of sealed saturated-salt standards as reference standard for relative humidity and water activity measuring instrumentation is a low-cost way to obtain traceable verification and calibration. Sudden changes in ambient pressure conditions can, however, cause unexplainable results when the pressure in the area surrounding a sensor is different to that of the salt mixture on the other side of the membrane. This is again something one does not experience often in a laboratory, but even under controlled conditions, it may happen from time to time. The only answer then is to assign values relative to the standard's certified value. Temperature differences between a sensor and a reference capsule will cause large offsets, as was mentioned above. Experimentation with both sealed saturated-salt capsules and non-saturated salt ampoules have shown that the latter can give reliable results over a much wider temperature range. This is true both for high temperatures and very low temperatures. The range over which the non-saturated ampoules can be used is also considerably wider than that of the saturated-salt capsules. The statements above should not be seen as a recommendation to use the one and not the other. In a working laboratory it was found that the sealed capsule with a typical useful lifespan of more than five years, and often up to eight years, has definite advantages over the ampoules which are basically used once when it came to performance history. It was, however, also found that the two types of standards compliment each other, and that a low cost verification and calibration system should be based on a combination of them. The ampoules have uncertainties at a 95% confidence level which are one order better than that of the capsules, and this alone allows considerable improvement in the best measuring capabilities of the laboratory. The ampoules are also less prone to change value with temperature changes, which makes them the ideal verification standards during on-site calibrations [2,3].

Sensor response times

Response times of sensors can severely influence measurement results - this is one important principle that is often overlooked. A sensor that is good in one application may be the worst choice for another. Response time is (in many cases) a trade-off between measurement accuracy, ruggedness and cost. Each of these factors are important, making the choice of the correct sensor for the application more serious than one would expect. In a stable laboratory environment, a sensor with high accuracy, fast response and high cost is acceptable even if it is less rugged. Out in the field, the opposite is expected to be true: one can afford to trade accuracy and a slower response time for a sturdier sensor. The damping effect of a sensor with a slow response may give better measurement results in an unstable environment than a fast-responding sensor. There is no sensor which would give perfect results in all possible measurement environments. The selection should be based on the requirements of the main application of the instruments. If operation in other areas is less acceptable, this is an unfortunate situation which cannot be avoided. [4].

Sensor linearity

It is impossible to achieve linear performance from 0%RH to 100%RH if there are only two adjustments. A minimum of five points can achieve very good linearity, but with the two-point calibration (usually around 11%RH and 75%RH) it is often necessary to set the calibration for optimum performance in the relative humidity range where it is going to be used. Many systems have only a low and a high setting point with no linearity control. Others have special trimming controls to try and achieve reasonable results above and below these points, but at best this is a compromise situation. As is the case with response time and accuracy, the more expensive instruments will allow better linearity over the full relative humidity range, especially in cases where there has been a degree of deterioration.

Conclusion

The accurate measurement of relative humidity seems to be hampered by a never-ending series of obstacles, but this is not unique to this metrology discipline. What is different is that humidity is still .one of the new disciplines (in spite of Leonardo da Vinci's work! [1]), and it is only now that problems are coming to light and solutions to overcome these are found. One does feel a bit despondent at times, but after six years in the calibration of relative humidity instrumentation, certain repeatable patterns are beginning to emerge. There is a lot to be learned in this discipline, but by avoiding the issues no progress will be made. Hopefully the readers of this article will have a better understanding of the task of the calibration laboratory to which he/she has submitted a humidity measuring instrument with the instruction please to calibrate and with the added prompt of urgent! There are not many laboratories with accreditation for humidity calibration, but those who are take the task very seriously. A little bit of understanding of the intricacies which are encountered in relative humidity metrology will go a long way towards an improvement of the currently available calibration methods. For some time to come humidity metrology will be faced with the situation of having the old 'traditional' instrumentation in the field together with the latest designs, and it is in this diversity that the real challenge lies. Education of both the end user and the metrologist is of importance and all those who are interested in this field are encouraged to attend the annual Humidity Metrology short course. This course is presented under the auspices of SANAS, the SADC Resource Centre for Metrology Education (SCARME) and the Technikon Pretoria.

References

[1] Jones C. 'A caution: H_2O is not just a Mickey Mouse™ molecule'. Electricity + Control, November 1998. pp 35-39.

[2] Hattingh JJ. 'Affordable traceability in the measurement of relative humidity', Papers and abstracts from the Third International Symposium on Humidity and Moisture, vol l, National Physics Laboratory, April 1998, pp 223-23p.

[3] Hattingh JJ. 'International traceability in the measurement of humidity'. SA Instrumentation and Control, December 1993, p 8.

[4] Hattingh JJ. 'Selecting humidity standards and measuring equipment'. SA Instrumentation and Control, August 1995, pp 89-90.