Title:

Advanced Technology for Meteorological %rh and Temperature Measurement

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Sub Heading:

The measurement of humidity is of key importance in the field of meteorology. Weather forecasting, environmental research, pollution control, horticultural research and ice-warning systems are examples of applications that depend on accurate humidity measurement. Electronic %rh sensors are widely used, but there are many users whose understanding of the technology, its application, maintenance and calibration is often unclear. This article summarises the technology employed, and overviews current %rh sensing technology and how the user can make informed decisions about its suitability for purpose.

Sensing Humidity

There are many techniques for the measurement of humidity, and none are perfected. If you judge science and industry's satisfaction with humidity measurement technology by the number of new research projects and proposed new measurement techniques, it is clear that this area of metrology has some way to go!

The most significant problem with humidity sensing is the need for the measurement device to be in contact with the environment. With parameters such as temperature and pressure, there is the opportunity to protect the actual measurement device with mechanical protection, coatings or membranes to maintain performance over time, but with humidity this is obviously not possible. The sensor is exposed to everything that the environment presents, including chemical pollution and particulate contaminants, and this inevitably affects the long-term stability of every humidity measurement technique to some extent.

There are three most widely used methods used for the measurement of humidity in meteorological applications:

%rh sensors

Two types are in widespread use, both are based on the variation of capacitance or impedance of a hygroscopic polymer. In meteorological applications, the capacitive type is most widely used because of good speed of response, reasonable cost and low power consumption. The main disadvantages of this sensing technology is its sensitivity to chemical pollution, reduced accuracy over wide temperature ranges and need for routine calibration for best possible performance. Despite these factors, this type can be considered the 'workhorse' of meteorological humidity measurements.

Wet / Dry Bulb Psychrometers

Psychrometers work on the principle of the depression of the temperature caused by the evaporation of water from a saturated 'wick' covering a temperature probe. The decrease in temperature is directly related to the humidity of the air, and in combination with a dry bulb measurement of temperature, humidity can be derived from the psychrometer equation. Performance capability of this technique is theoretically very good, but practical considerations limit their application in modern systems. These include the need for a continuous and clean source of water, regular wick maintenance, and the more complex data acquisition requirement to convert the two measurement temperatures into a compatible parameter. Furthermore, the technique's precision is dependent on carefully matched temperature probes, and practical terms, the management of this issue can have a major impact on installation and maintenance requirements.

Condensation Hygrometers

Often referred to as 'Chilled Mirror' or 'Dew Point' hygrometers, these instruments are without question the most precise and dependable currently available. All national standard institutions throughout the world use them as either the primary National Standard, or as a transfer standard for comparison with first-principles systems such as two pressure/two temperature or gravimetric generators.

Condensation hygrometers are also used in field meteorological measurements, and they provide precise measurements in almost any condition. The measurement of dew point is unaffected by variations in temperature, so in combination with precise temperature measurements, very accurate humidity data can be achieved.

In this application field, condensation hygrometers have two significant flaws. Each measurement system is many times the cost of a high quality %rh sensor, making deployment throughout a network of weather stations extremely expensive. Secondly, the measurement principle requires the presence of a dew or ice layer on the surface of a temperature controlled mirror, and any residual contamination will cause measurement errors. Accordingly, mirror cleaning is required on a regular basis, so in combination with the high capital cost this renders the condensation hygrometer best suited to only the most critical applications and reference installations where maintenance can be easily performed.

Most Commonly Used

The explosion in the number of weather stations deployed throughout the world means that humidity measurement in meteorological applications has also grown in significance. By far the most commonly used measurement technique is the %rh probe, and it is this type that I will discuss in more detail.

The main problems associated with %rh probes are:

- Long term stability
- Tolerance to condensation
- Temperature measurement accuracy
- Temperature compensation
- Mounting hardware and its influence on measurement precision
- Calibration

No single manufacturer can claim to have absolutely dealt with these issues, but in recent times, the measurement capability and practicality of today's instruments has improved significantly. It must be said that in many installations, cost is also a key factor and accuracy is less critical, so manufacturers have therefore been forced into developing a range of solutions to best suit each installation's requirements.

Long Term Stability

%rh probes drift over time, that's a fact. Each product will have different characteristics and may be well suited to some, but not all, environments. Long term stability is mostly related to chemical contamination, so the chemistry of the sensor defines its tolerance to pollutants. Manufacturers increasingly understand their sensor's characteristics, so can continuously develop their product to produce better results. Changes include better quality materials, alternative polymers and improved manufacturing techniques.

Typically, a sensor in a clean application should be able to stay within 1% of its original calibration over one year. But this must be defined for each installation by routine calibration, and this is often difficult to establish when probes are interchanged. However with good inventory management, the data can be highly useful in establishing long term stability, and is usually referred to as a 'calibration history'. Where calibration history is not maintained, the convenience of interchangeable probes cannot be understated. Digital signal communication simplifies the process and helps maintain measurement accuracy.

The combination of these improvements in sensors and innovative features means that long term stability can be well defined and managed to achieve the required performance for each application. There is no doubt that manufacturers at the leading edge of this technology will continue to strive for best performance.

Tolerance to Condensation

In almost all climates, condensation will occur at some time. A well known characteristic of %rh probes is their poor recovery from 100%rh conditions. For a period of time after the exposure, the probe will continue to measure 100% even when the actual conditions have dropped. The probe will also exhibit a more significant hysteresis, and long term stability can be affected.

There are various reasons for this, including slow evaporation of water from the installation and desorption of water from the probe's materials of construction and from within the sensor element.

Again, manufacturers have responded with solutions such as ventilated radiation shields and improvements in materials. The best sensors recover very quickly, and it is easy to check actual performance with a simple test, and suppliers should be able to provide data or better still, accredited certificates that show capability in this respect.

Temperature Measurement Accuracy

The measurement of temperature in air is not the precise science that you would imagine. The thermal conductivity of air is poor, so it is difficult to transfer energy without long stabilisation times. Most calibration equipment is fluid based, and this is not ideal for humidity probes, although using certain inert liquids, %rh sensors can now be calibrated in fluid baths.

But the main issue is the comparison of calibration data with actual measurement data. The thermal characteristics of electronic devices can vary substantially if it is not being continuously cooled in a fluid bath. Calibration in air, with conditions matched to the likely application, can be provided by many accredited laboratories world wide.

This issue is resolved in a number of ways, some of which are described elsewhere in this article. Using a separate and dedicated Pt100 in its own shield is very common, and direct Pt100s integrated within the %rh probe are available. Active probe ventilation is also a useful benefit in achieving best temperature measurement performance.

Temperature Compensation of %rh Probes

In a competitive market, manufacturers need to optimise the manufacturing time for their products; it is a simple fact of economics. So in general, %rh probes are adjusted during manufacture at ambient temperatures. Now as we all know, almost everything electrical has a temperature coefficient, and will behave slightly differently over a range of temperatures. %rh sensors have temperature coefficients, and in order to achieve best possible performance, most instruments have integral temperature compensation.

Increasingly manufacturers are supplying effectively temperature compensated probes with actual calibration data. It is simply a matter of requesting this information to establish actual performance. Again an accredited calibration certificate is the best option.

Mounting Hardware and its Influence on Measurement Precision

Typically %rh probes have been installed using the plate type radiation shield in a wide range of configurations, each designed to achieve best possible performance. The proliferation of shapes and sizes must lend one to the conclusion that there is still a need to develop the design.

It is well known that in hot conditions the plate type of shield can induce errors in temperature measurement. A shield can also exacerbate the problem of residual condensation in cold conditions. Various solutions have been proposed over the years, such as heating and ventilation.

Ventilated shields are increasingly popular in installations where power consumption is not critical. The continuous airflow over the sensors means that temperature measurement is precise and condensation is more rapidly evaporated. In comparative tests carried out during co-development with Meteo Swiss of Rotronic's RS ventilated shields, the combination was shown to match the measurement performance of reference condensation hygrometers. Of course, long term stability must still be assured by routine calibration.

Calibration

Throughout this article there has been frequent reference to calibration. Because of the unstable nature of %rh sensors, this is a key issue in development of improved measurement performance. Most meteorological organisations maintain their own in-house calibration standards, so are able to meet their own requirements. Accreditation of these laboratories and inter-comparisons such as Euromet, means that more than ever data can be trusted and compared with higher confidence.

Field calibration is however impractical, so features such as probe or sensor interchangeability and the increasingly high calibration standards that are available mean that measurement uncertainty can be maintained in all installations. In many other key industries such as climatic test, pharmaceutical, food and power generation, full uncertainty budgets for many measurement scenarios are now implemented and validated.

Vast arrays of calibration solutions are now available to support the drive for best measurement performance. Most manufacturers are able to provide specific guidance on achieving the required performance specifications with traceability.

Future Developments

The humidity industry has developed substantially over the past 20 years. Our ability to measure humidity precisely and substantiate the data means that climatic research, weather forecasting and weather management can perform to much higher standards. The future challenges that face the scientific community, including climatic change, will depend on accurate humidity data, so there will be continued pressure on manufacturers to develop more accurate and reliable instrumentation, at reasonable cost.

It is also clear that standards do still vary from country to country, from manufacturer to manufacturer and from installation to installation. But with the rapid development of calibration capability, and the better understanding of users and suppliers, poor measurements can be practically eliminated in any scenario.

It is difficult to see where a substantial leap forward in best measurement capability for %rh measurement at low cost could be achieved. The various topics detailed in this article hopefully demonstrate that the industry as a whole is constantly striving to develop better solutions at every level, and that the user should now expect precise and reliable performance. There are many specialist manufacturers who are always prepared to discuss the application requirements and apply the best possible solution, or even develop a customised product.

Each year new and innovative monitoring systems are developed, and the %rh probe requirements are often specialised. Future developments will be user driven, mostly in terms of measurement accuracy, but with the application of the latest technology it is certain that humidity measurement will continue to develop to meet the needs of the meteorological industry.

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