DEW YOU GET THE POINT?

DEVELOPMENTS IN WATER VAPOUR METROLOGY ARE HELPING TO OPTIMIZE DRYING PROCESSES

Introduction:

Water is life. Each one of us is two-thirds water. The same goes for planet Earth's surface. Water enables our very existence. Where we choose to settle is driven by the availability of water. Too much or too little can be catastrophic. Climate change is often associated with rising temperatures, but it's the resulting impacts—shifts in weather patterns and changes in water movement, like torrential rain, floods, and drought—that cause the most harm.

What might be described as a niche industry – water vapour (better known as humidity) metrology, is actually playing a significant role in reducing carbon emissions and simultaneously improving quality and product performance with some very elegant new developments in measurement technology.

How much energy is used by industry in drying processes?

An EU project[1] on drying efficiency, in its executive summary mentions that 12…25% of industrial energy consumption is attributable to drying and dehydration processes.

Critical processes require that the gas water content is reduced to trace levels so that use, transportation or delivery is reliable. Examples include drying of compressed air, natural gas, hydrogen, specialty gases used in manufacturing, and freeze drying.

As drying processes remove water, the measurement of water content is needed to confirm specifications are met[2], or to enable efficient control of the drying process. In drying, determination of the 'end point' optimises process times, energy use and product quality. Water vapour or moisture measurement performance must therefore have an impact on dryer efficiency, so even incremental improvements can have a beneficial effect on energy consumption. The reality is that measurement performance below 1ppm (~ -75 °C dew/frost point at atmospheric pressure) remains a challenge for many instruments used in industrial applications[3].

There are many other drying applications such paper, textiles and wood that also depend on precise and reliable water content measurement, but within the limited scope of this article, we shall focus on the applications where the challenges most significant – trace humidity or moisture.

Measurement of Water in Drying Processes

Water content of gasses, including air, is correctly described as 'humidity'; for water in materials, it's 'moisture'. However, throughout industry, a range of terms and parameters are used, including dew point, frost point, moisture content, water vapour pressure, mole fraction, absolute humidity and quite a few more.

As well as a range of parameters, there are a range of measurement techniques, and working out which one is suitable for a given application can often be an expensive and frustrating exercise. A discussion of this nature often concludes that there needs to be a book on the subject. In fact, there is, the Guide to the Measurement of Humidity[4], but this only provides a very basic conceptual overview of the many techniques. Anyone working in specific applications such as speciality and natural gas will know that experience and specialist knowledge is vital to obtain dependable measurements.

To summarise (very simplistically) the measurement techniques widely used in drying:

- Dew point sensors – a sensor whose electrical properties change according to dew point, with analogue or digital output.
- Electrolytic sensors – based on Faraday's Law of Electrolysis, a Phosphorous Pentoxide (P_2O_5) cell electrolyzes water molecules and outputs an electrical value proportional to water content.
- Quartz crystal microbalance – detects changes in frequency of a quartz crystal resonator attributable to changes in water content
- Spectroscopic analysers – based on the Beer-Lambert law - the absorbance of laser light by water molecules. Cavity Ring Down and Tuneable Diode techniques are the most widely used.
- Dew point chilled mirrors – instruments with a temperature-controlled mirror surface with an optical system for detecting the temperature at which condensation (dew or frost) occurs.

PROMETH2O

EMPIR EURAMET

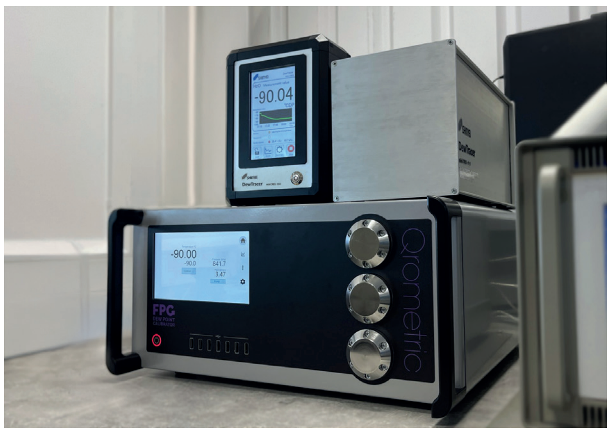
Diversity, Challenge, ProMetH$_2$O[5]

The diversity of water vapour measurement techniques is attributable to the diversity of applications. The evolution of water vapour measurement technology has been to meet the needs of applications not solved with pre-existing technology. Innovation continues to develop solutions to ongoing measurement challenges, and there's no doubt that technologies such as spectroscopic hygrometers and dew point sensors have improved the range and quality of the measurement options available to process engineers.

A significant challenge when measuring water content is that the sensor must be in contact with the sample gas. So, if the sample gas is hot, at pressure or contaminated, measurement performance can be compromised with inaccuracy, instability and drift the typical consequences. Well-designed sampling systems can mitigate some issues, but routine performance validation is essential to maintain measurement performance and process efficiency.

Test or validation of water vapour measurement performance has historically been limited to on-site spot checks within a live system. An alternative approach is the removal and replacement with a new or refurbished sensor. In an increasing range of industries, especially those running quality management systems, measurement performance validation should be (as a minimum) documented as traceable, and increasingly, accredited calibration is a regulatory requirement.

The challenge is to develop technologies and systems that meet these requirements, and as an excellent example of metrology and industry collaboration, the recently concluded European Union EMPIR Euramet ProMetH$_2$O[5] project resulted in useful progress and innovation.



Qrometric FPG Dew Point Calibrator with a Shinyei DewTracer miniCRDS hygrometer.

10ppb Water Vapour Validation

Objective 4 of the ProMetH$_2$O project was: Demonstration of improved methods for trace water measurement in industrially relevant facilities.

The FPG dew point (moisture) calibrator was integral to several work packages.

A direct quote from the final project report:

'The FPG was initially validated at INRIM (NMI Italy) to demonstrate the fundamental nature of the FPG generation technique and shows that measurement traceability can be made directly via calibration of its external platinum resistance thermometer (PRT). When used with a calibrated pressure sensor, this measurement combined with the FPG saturator temperature may be employed to provide humidity reference values in terms of dew/frost point or mole fraction.'

The FPG was provided to and tested by project partners who validated its performance and confirmed suitability as a metrologically traceable generator and reference for trace water conditions down to 10ppb. The final ProMetH$_2$O published report is available on-line at the links within the references.

Practical Calibration for Trace Water Vapour Measurement

The FPG only needs a source of power to operate, no gas or water supplies are needed thanks to its unique integrated temperature-based dew point generation system.

Since the successful validation of the FPG, it has been deployed in several key application scenarios where water vapour measurements are fundamental to system performance.

Examples include:

- Natural gas drying – validation of moisture analyser and dew point sensor performance
- Battery production – dry area sensor maintenance
- Compressed air dryers – calibration of control dew point sensors
- Speciality gases – moisture analyser calibration and validation
- Heat treatment processes – dry gas supply dew point sensor test and maintenance

In these scenarios, measurement performance and the importance of the water vapour measurement justifies the investment in the FPG. This is based on early adoption of the FPG. Its application enables users to assess instrument measurement performance and calibration traceability, in the laboratory and most importantly on-site or local to the installation.

Moisture Sensor Performance Validation

Figure 1 shows an example of a water vapour sensor subjected to automated repeat testing over a number of days in an FPG, it presents the accuracy and reproducibility of the measurement, and validates performance as being suitable for use to (say) -40°C dew-frost point.

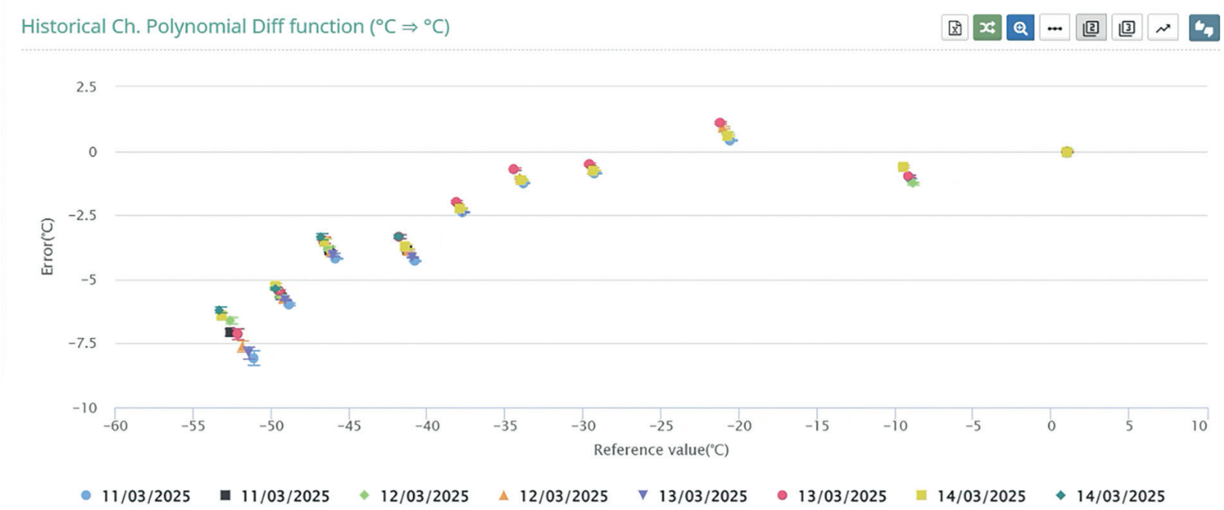
Figure 2 shows an example of a second sensor of the same type that exhibits different characteristics and could be considered unsuitable for use.

Previously, such performance qualification would only be possible by the manufacturer or with a laboratory system or specialised calibration facilities with highly skilled calibration engineers. Using the FPG, system integrators or users of moisture analysers are now able to directly test, validate performance and calibrate instruments. This often saves substantial costs – only instruments that need recalibration are replaced or sent for service.

The Importance of Stability

In calibration metrology, the long-term stability of a reference instrument is a significant contribution to overall uncertainty. For industrial applications, measurement long term stability will have an impact on control precision, energy efficiency, product quality, compliance with standards and operational costs.

Regular validation and optimisation of measurement performance can be achieved by calibration, which can also identify which instruments are working in the application, and which could be 'improved'. Routine calibration will develop a calibration history such as that shown below, and quite soon, this type of data will identify which instruments are best suited to the process application. Without calibration history, measurement traceability is difficult to document or evidence, a sensor that drifts significantly between calibration or service intervals will undermine process efficiency.



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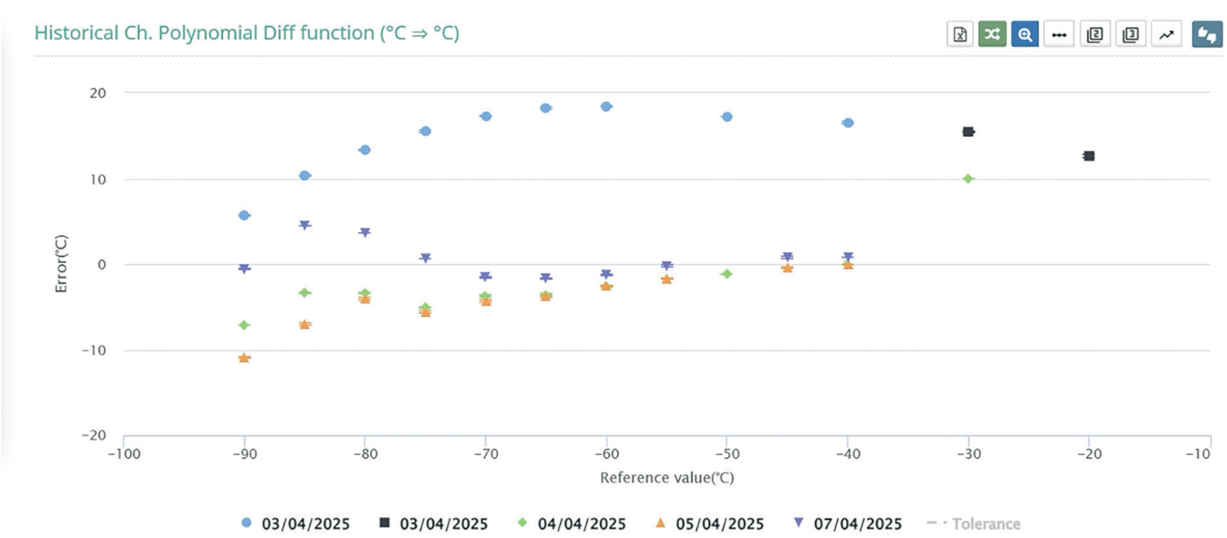

Figure 2 - an example of a second sensor of the same type that exhibits different characteristics and could be considered unsuitable for use.

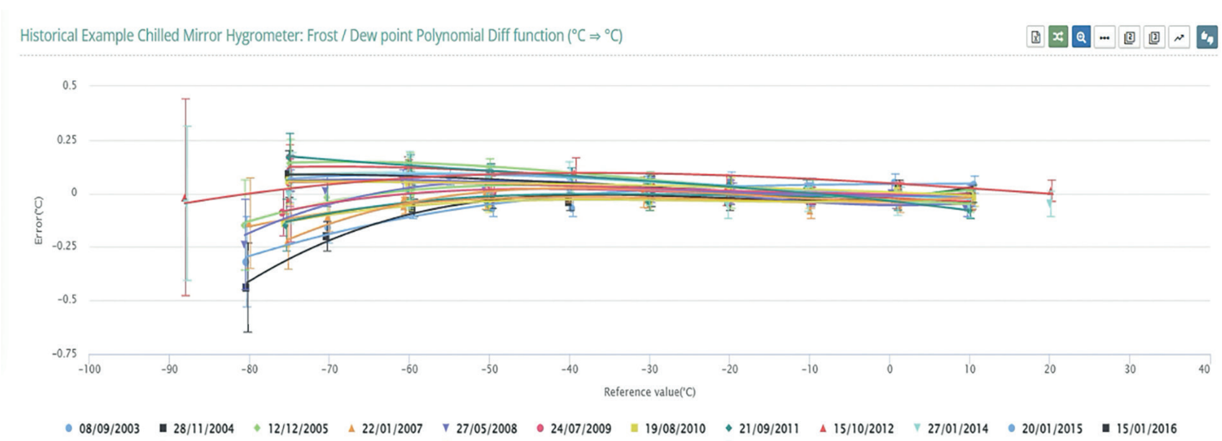

Figure 3 – example showing the drift history of a 20 year old chilled mirror hygrometer

Conclusion?

Measurement performance in the trace water vapour range has always been challenging[3]. Industrial applications add to the challenges thanks to factors such including variations in the matrix gas, site access, explosion risk, operator knowledge and cost factors. Core measurement parameters such as temperature and pressure have well evolved methods for on-site calibration. Water vapour or moisture, especially in the trace-moisture regime until recent developments, did not.

The FPG is a transportable instrument that creates high accuracy stable dew (frost) point reference conditions so that all types of water vapour (moisture) instrumentation can now be evaluated and calibrated in the lab or in-situ in a precise, practical, and cost-effective manner. For the first time, users of water vapour (moisture) instrumentation can validate their equipment themselves, taking away the guesswork from the drying process, enabling better measurement and control, saving money, energy and the planet.

References:

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3. An Evaluation of Performance of Trace Moisture Measurement Methods, National Physical Laboratory, BOC Edwards, United Kingdom
4. NPL – Guide to the Measurement of Humidity ISBN 0-904457-24-9
5. European Union EMPIR Euramet ProMetH20 Metrology for trace water in ultra-pure gases. https://www.prometh2o.eu/en/documents#doc-79

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