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Study of the need for traceability for humidity measurements above 100 °C – summary report

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Department for **Innovation, Universities** & **Skills**

Study of the need for traceability for humidity measurements above 100 °C – summary report

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SUMMARY

The following is a concise summary of findings and recommendations arising from a review conducted as part of Deliverable 2 of Project SI10, NMS Programme for Materials and Thermal Metrology 2007-10

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1. INTRODUCTION

1.1 BACKGROUND

In certain applications, humidity conditions are controlled or monitored at relatively high temperatures, above 100 °C.

NPL and some other laboratories provide calibrations at (or near) air temperature of 100 °C, and at dew points a little below this (e.g. up to 90 °C at NPL). However, numerous humidity instruments are specified to operate at temperatures well above 100 °C, and measurement standards and traceability do not yet extend into this range.

1.2 STUDY

Sectors to which humidity measurement at high temperatures is of importance were identified and current instrumentation, practical use and calibration techniques were reviewed.

2. THE MEASURED QUANITITY

Conditions of water vapour above 100 °C can be considered in three categories:

- Pure water vapour above 100 °C has many uses and is referred to as “steam”. Steam at temperatures above 100 °C has saturation pressures above atmospheric pressure. Pure steam is generally measured in terms of pressure and temperature.
- A gas mixture above a temperature 100 °C can have a dew point above 100 °C. Such a mixture has a saturation vapour pressure (SVP) above atmospheric pressure, and can only exist in non-condensing form at above-atmospheric pressures (above its SVP).
- A gas mixture above a temperature 100 °C can have a dew point below 100 °C. This can occur at atmospheric pressure, with relative humidities (RH) below 100 %rh.

Humidity instruments would rarely, if ever, be used to measure pure steam. The other two cases above 100 °C are addressed by humidity measurement.

The approximate relationship between pressure and saturation temperature for water vapour above 100 °C is shown in Table 1. In fact the definition of relative humidity is not well established above 100 °C, and is expressed by some in terms of a “virtual relative humidity”.

Table 1: Approximate pressure-temperature properties of water vapour above 100 °C from 0.1 MPa to 1 MPa (1 bar to 10 bar)

Pressure MPa	Saturation Temperature (T_s) °C	Maximum relative humidity at T_s at atmospheric pressure %rh
0.1	99.6	100.0
0.2	120.2	50.0
0.3	133.6	33.3
0.4	143.6	25.0
0.5	151.9	20.0
0.6	158.9	16.7
0.7	165.0	14.3
0.8	170.4	12.5
0.9	175.4	11.1
1.0	179.9	10.0

3 APPLICATIONS, USER NEEDS AND PRACTICES

Most applications for humidity measurement above 100 °C are in baking and drying applications. Numerous industries use kilns for processing wood, ceramics, building materials, etc, or ovens for food processing and many other heat treatments. In some of these applications water vapour is applied at close to saturation levels for “steam” processing (for heat transfer without significant evaporation from the product, and to inhibit surface crusting). In other cases, water vapour is released from product during processing (e.g. baking foodstuffs) and humidity measurement is used to monitor the process and detect the end point. In drying of powders (e.g. pharmaceuticals) humidity measurements are additionally used to infer product surface temperature. In many baking and drying applications, the process gases above 100 °C are far from saturation, with dew point well below 100 °C, and it is feasible to extract sample gas to below 100 °C and to reduce atmospheric pressure before measuring.
A small number of testing laboratories carry out humidity testing of products at temperatures above 100 °C (up to about 120 °C in some cases). These tend to be specified at or below atmospheric pressure, and hence would not exceed a dew point of 100 °C. These tests would be applied to a variety of defence, aerospace and other equipment used in extreme conditions.

There are rare examples of humidity testing being done significantly above 100 °C, for example BAM in Germany carries out humidity testing at temperatures up to 180 °C. However their dew-point range is stated to be no higher than 80 °C.

4 HYGROMETRS FOR USE ABOVE 100 °C

A selection of instruments commercially available to measure humidity near to or above 100 °C are summarised in Table 2 below, together with their quoted measurement ranges.

Table 2: Examples of hygrometers available for measurements near or above 100 °C

Supplier	Instrument	Upper range limit (nominal)			Notes
		Dew point °C	Temperature °C	Relative humidity %rh	
E+E	Various	up to 100	120/180	* 100	* at lower temperatures, specified graphically
MBW	373HX	95	n/a	n/a	
Michell	Optidew	90/130	130	n/a	
Michell	Various (RH)	** 60	180	100	**maximum mixing ratio of 0.25
Rotronic	Various	#	150/200	100	
Testo	177-H1	70	70	100	External temperature probe up to 120 °C
Vaisala	Various	#	120/180	100	

Not specified
n/a Not applicable

In addition, other instruments may be available or under development to measure above 100 °C, but not with wide availability.

Only some suppliers clearly express what part of relative humidity range is addressed above 100 °C (e.g. Michell specify overall limit of 250 g water per kilogram of dry gas). Typically, the suppliers caution users that although these sensors will function above 100 °C, performance in that range is unspecified.

5. PAST RESEARCH AND FEASIBILITY OF CALIBRATION ABOVE 100 °C

Few, if any, national standards institutes have explored the possibility of providing humidity calibrations above 100 °C.
One research study has been reported by PTB (Germany) in collaboration with E+E (Austria) [1]. A relative humidity (polymer) sensor was compared against a two-pressure generator used to generate a range of relative humidities at temperatures up to 157 °C. However, dew-point values were below 100 °C throughout. The work was used to demonstrate that there was no discontinuity at a temperature of 100 °C, and that a definition of relative humidity with respect to saturation temperatures above 100 °C did appear meaningful, even when operating at atmospheric pressure. Although comparison of a sensor against a primary generator might appear to enable a calibration, this was not the case, and the workers were not using this as a basis to disseminate traceability.
Any laboratory wishing to calibrate hygrometers at dew points above 100 °C would need a facility suitable for operating at elevated pressure, as well as high temperature. Many laboratories are equipped for humidity generation either at pressure, or at

temperature close to 100 °C – but not both. To do both is likely to require a significant change in technique, not just incremental extension of existing facilities.
However, calibrations at temperatures above 100 °C, for lower relative humidities (dew point below 100 °C) could in principle be provided relatively simply, using a chamber of sufficient temperature range. For many laboratories, including NPL, this would be an incremental development of existing capability.
In addition, there may be scope for extending the range of existing dew-point standards in range by a small amount, while still below 100 °C. The UK NMS dew-point standards at NPL have a validated upper limit of 90 °C. An extension of this by a small amount is more challenging than it might appear: in this range, thermal management, stability, and condensation protection are considerable practical difficulties. However if undertaken, a small upward extension of dew-point traceability would further support industrial measurements in this range.

6. CONCLUSIONS

There is some user need and instrument availability for humidity measurement at dew points over 100 °C, but demand for calibration in this range is not strong. Many hygrometer suppliers offer sensors to work significantly above 100 °C, but calibration and performance claims are typically only made below 100 °C. Overall, there would be some interest in measurement traceability or other developments for dew points above 100 °C, but at this time there are not clear arguments for the NMS to make provision for this.

However, many requirements for relative humidity measurements at air temperatures above 100 °C are for dew points well below 100 °C (i.e. low relative humidities). Relative humidity calibrations in this range could be provided by combining existing provision of dew point with extended range of temperature test chamber. An extension of this type would be a relatively simple incremental development of existing relative humidity capabilities. This would meet some of the need for traceability in the measurement range not yet covered.

Further to this, any small extension of dew-point traceability upwards in range, below 100 °C, would further support user measurements.

7. REFERENCE

[1] Böse, N., and Mitter, H., “Calculation and measurement of humidity at temperatures higher than 100 °C”, *Proceedings of TEMPMEKO 2004, 9th International Symposium on Temperature and thermal Measurements in Industry and Science” Volume 1 , pp 689-696. ISBN 953-6313-72-3*