

# Choosing the Correct Moisture Calibration System

The following guide will help you to understand your moisture calibration requirements, as well as the options available, to help you correctly select an appropriate system.



# Setting up in-house moisture calibration

Once you have decided that carrying out moisture calibrations in-house is the most appropriate option for your business, it's important to ensure you specify the correct system. This guide is designed to help you understand more about the options available, however guidance from an expert in the field is also strongly recommended. Michell Instruments offer a full support service for customers wishing to set up a moisture calibration system.

The key elements for you to consider before choosing a system are:

- The measured parameter of your devices
- The measurement range of your devices
- How much automation is required
- How to install your devices into the system

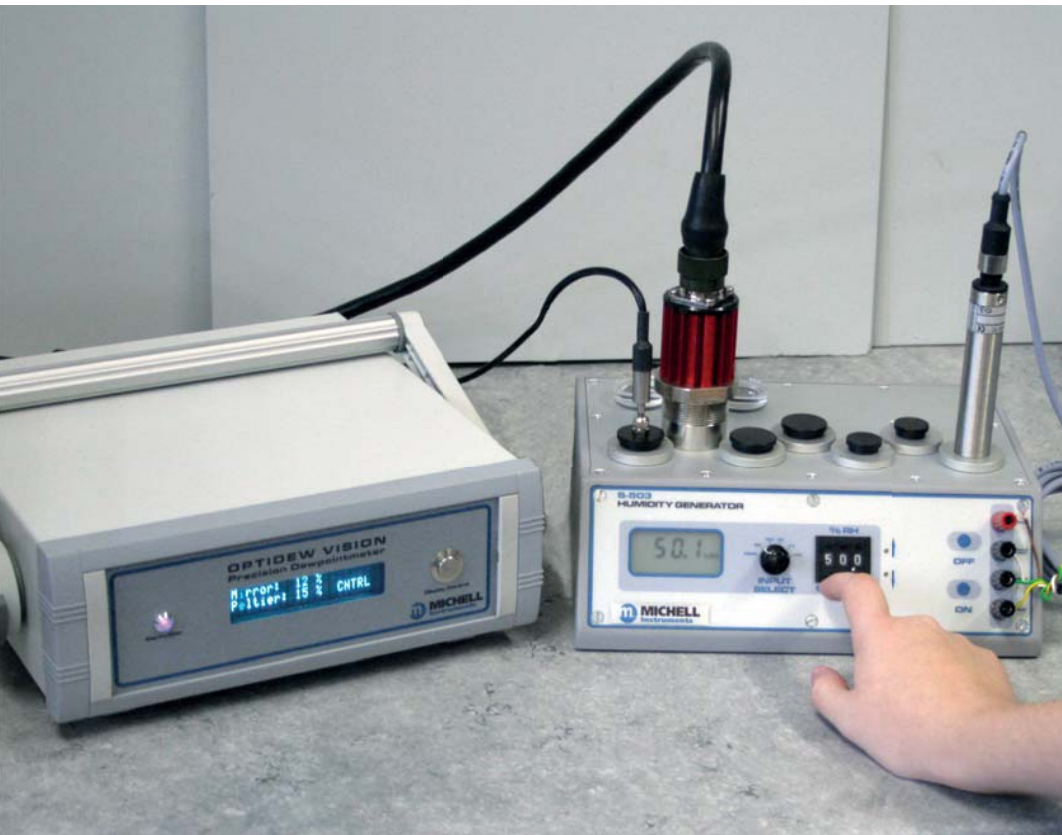
These are dealt with in the sections that follow.

There is a useful glossary at the back which explains the technical terms used.



# Measurement Parameter

The process of deciding which calibration system is best suited to your needs is dependent on the devices to be calibrated and their measurement parameters.



## Dew Point

If the devices are measuring dew point, then the calibration manifold is usually situated in an ambient temperature environment. As dew-point calibration systems are frequently intended to produce very low moisture contents, the manifold needs to be of a high integrity design; working with the sealing mechanism of the sensor to ensure that moisture ingress from the ambient environment is prevented. For extremely low dew points ( $<-80^{\circ}\text{C}$  ( $<-112^{\circ}\text{F}$ )) it is sometimes necessary, (depending on the ambient conditions) to enclose the manifold in a chamber which can be purged with dry air, thus limiting the effects of ingress.

## Relative Humidity and Temperature

There are two different approaches to calibrating relative humidity sensors. One approach is to place the sensors directly into a calibration 'chamber', which is a temperature and humidity controlled self-contained environment. This functions in a similar way to a climatic chamber, only on a much smaller scale and with much greater uniformity. Calibration chambers without temperature control also exist, meaning that the selected relative humidity will be generated at the prevailing ambient temperature—however, it is important to ensure that when these types of generator are used, they are placed into an environment with a stable temperature.

The other approach is to use an external dew-point generator to pass a flow through a manifold into which the sensors are mounted. The manifold is placed inside a larger, temperature controlled chamber.

The advantages of this second approach are:

- The volume of the manifold is quite small, and there are few ingress points, so step changes tend to happen more quickly
- Using a volumetric mixing dew-point generator allows much lower humidities to be achieved compared with a calibration chamber

The disadvantages are:

- The components involved are physically much larger
- They can be significantly more expensive than a self contained chamber



# Measurement Range

The next deciding factor is measurement range. The questions to ask here are:

- What is the complete operating range of your devices? (Also consider temperature range if the probes in question are measuring relative humidity.)
- Do you need to calibrate across the complete range, or do you have a specific area or areas of interest?

## Relative Humidity

The range of an RH calibration system depends on the ability to control two separate parameters: the temperature range of the chamber and the relative humidity range (the lowest RH point being the limiting factor in most cases). All Michell relative humidity chambers (S503, S904, OptiCal) are capable of drying their internal volumes to just 10% RH at any temperature within their operating range. It is challenging to dry a comparatively large volume below this point, as the system is simply extracting the air, drying it with a desiccant cartridge and re-injecting it with a slightly lower moisture content. It is possible to humidify the chamber up to 90% RH which, generally speaking, is a sensible limit set for the purpose of

preventing condensation. If condensation should occur, it would take a long period of time (and a significant strain on the desiccant cartridge) to dry the chamber out again.

The Michell Instruments' HG10 uses an external humidity generator to feed a stream of air, with a precisely controlled humidity, directly into a manifold within a temperature controlled chamber. The humidity generator is fed with fresh dry air from a pressure swing dryer, and can achieve very low humidities at a specific temperature, with a total range of 1 to 95% RH.

## Dew Point

Dew-point calibration systems generally produce much lower absolute humidities than RH calibration systems. The generation range of dew-point systems depends on two factors:

- The output dew point of the pressure swing dryer used to provide the dry air source to the humidity generator (sometimes referred to as 'full dry').
- The resolution of the dew-point generator—which is its ability to mix specific quantities of full dry and saturated air together, in stages, to achieve

accurate outputs of very low moisture content. Where volumetric flow mixing generators are concerned; the more stages of mixing, the lower the dew point the generator can control to. For example, a single stage DG3 can only control to a minimum dew point of approximately  $-40^{\circ}\text{C}$  ( $-40^{\circ}\text{F}$ ), no matter how dry the input air is; whereas a two stage DG2 can generate dew points to  $-75^{\circ}\text{C}$  ( $-103^{\circ}\text{F}$ ). Three stages of mixing give the capability to generate dew points to  $-100^{\circ}\text{C}$  ( $-148^{\circ}\text{F}$ ).

# Calibration Technology

## Air Sources

Michell Instruments' dew-point calibration systems require clean and dry compressed air to operate correctly. The required specification of this air varies depending on the model of pressure swing dryer selected, but typically it should be at a pressure of approximately 7 barg (100 psig). For calibration systems designed to generate  $<-80^{\circ}\text{C}$  ( $<-112^{\circ}\text{F}$ ) dew point (generally those utilizing the PSD4), the supply air will need to be pre-dried to  $<-40^{\circ}\text{C}$  ( $<-40^{\circ}\text{F}$ ) dew point, in order to maximize the effectiveness of the pressure swing dryer.

For users who do not have a supply of compressed, or instrument air readily available on site, Michell Instruments can provide compressors suited to each type of system, and a pre-dryer for use with systems designed for  $<-80^{\circ}\text{Cdp}$  ( $-112^{\circ}\text{Fdp}$ ) capability.

## Pressure Swing Dryers

Michell Instruments' air dryers operate on the 'pressure swing' principle. Two desiccant columns are connected to each other in parallel. Compressed air from the dryer inlet is passed through the first desiccant column to remove virtually all of the moisture present. The majority of the dry air from this column is partially expanded to further reduce the dew point and then directed to the dryer outlet. The remaining dry air is used to purge the second, off-line desiccant column to sweep away the moisture it collected during its on-line cycle to the atmosphere.

After a pre-determined period of time, the function of the two columns is switched - the first column is re-generated while the second column is on-line, producing a flow of dry air. As part of the changeover, the off-line column is rapidly de-pressurized which causes the moisture adsorbed by the desiccant to be released and purged away. One cycle of this operation is represented diagrammatically in Figure 1.

The dryers require minimal maintenance and, under normal operating conditions, only require a desiccant change approximately once every 5 years. The highly efficient purge/regenerate system enables the dryer to operate at the same high performance levels throughout the lifetime of the desiccant.

There are two models of dryer in Michell's PSD range. The PSD-2 gives an output of  $-80^{\circ}\text{C}$  ( $-112^{\circ}\text{F}$ ) dew point air or better, and the PSD-4 gives an output of  $-100^{\circ}\text{Cdp}$  ( $-148^{\circ}\text{Fdp}$ ) or better. The PSD-4 requires an input source of dry instrument or calibration air of  $-50^{\circ}\text{Cdp}$  ( $-58^{\circ}\text{Fdp}$ ).

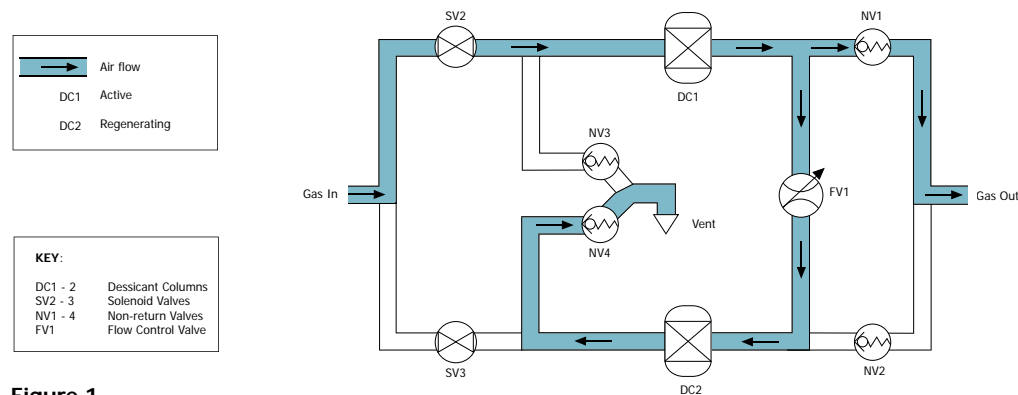
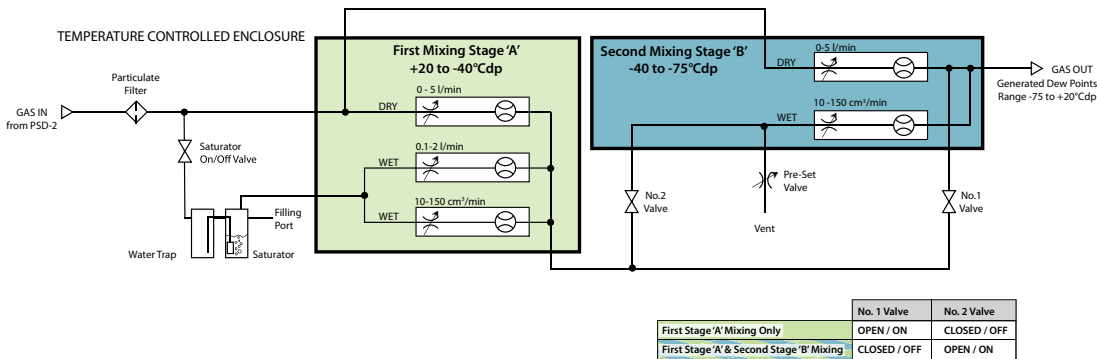


Figure 1

# Calibration Technology

## Dew-Point Generators

A dry gas source is fed to the generator from a pressure swing dryer, and split into two streams. One stream is bubbled through liquid water via a sintered glass nozzle, ensuring it is completely saturated with water vapor, while the other stream remains dry. The two gas streams are then mixed at atmospheric pressure, in a single or multi-stage process to generate the target humidity level. The entire enclosure is insulated and temperature controlled ensuring the saturation, and therefore the output, is always consistent.



A single stage of mixing provides a coarse adjustment, limited to around -40°Cdp (-40°Fdp). In order to generate drier dew points the output of this first stage, is mixed with the dry gas source a second time, providing finer adjustments for low moisture concentrations down to -75°Cdp (-103°Fdp). For trace moisture levels, a third stage can be added, where the output of the second stage is again mixed with the dry gas source, giving the possibility to generate dew points as low as -90°Cdp (-130°Fdp). The -100°C (-148°F) dew point is taken directly from the output of the dryer.

The DG Series dew-point generators are based on the volumetric mixing of dry and wet gases. This gives the fastest response when changing between set points when compared to other dew-point generation technologies, (such as two-temperature, two-pressure or the combination of both). The mixing is either controlled by flow metering valves for a manual control of the target dew point, or automated using a bank of preset metering valves, selected by actuating combinations of solenoids to switch between the different wet-dry mixing ratios.

### Manual Mixing – DG2 & DG3

The DG3 with manual single-stage mixing has the ability to generate dew points ranging from -40 to +20°Cdp (-40 to +68°Fdp). Drier dew points, down to -75°Cdp (-103°Fdp), can be reached by the DG2 which has a second stage of gas-flow mixing. The great strengths of the DG2 and DG3 are their ease of use and flexibility in manually generating an accurate target dew point by fine tuning the gas mix via the flow metering valves. A table of nominal flows is supplied with the generator to guide the user in setting the metering valves appropriately for each desired set point.

### Automatic Mixing – DG4

The DG4 uses a two-stage flow mixing system with calibrated needle valves controlled by solenoid drivers to mix dry air and saturated air in precisely pre-metered proportions. This allows the operator to generate a range of dew-point levels from -75 to +20°C (-103 to +68°F). The exact number of presets can be specified at the time of order (normally, 11 are chosen), giving +10°Cdp (+18°Fdp) intervals across the range. The generator can be driven by computer software, the RS232 interface, or via the front panel manual override switches.

### Automatic Mixing – VDS

In order to generate dew points down to -100°C (-148°F), a more sophisticated system is required. The software controlled Vapor Delivery System (VDS) generator gives precise, repeatable and flexible control of the generated dew point. Individual, three-stage, mass flow controllers select precise proportions of wet and premixed air.

Humidity injection is achieved by a liquid mass flow controller and controlled evaporation system. The entire system is controlled by dedicated PC software, allowing automatic calibration programs to be created, or set points to be triggered manually.

# Control

There are three options of set point control, which vary between models of generator. This is an important factor to consider, as some systems may have a greater requirement for automation. This is especially applicable if the system is being designed to calibrate a large volume of sensors:

- Manual flow mixing (such as Michell's DG3 and DG2) – The wet and dry flows are manually altered by metering valves on the front panel of the generator. On the DG2 these are monitored by means of a flow meter for each valve. A table of nominal flow values for each set point is provided, and full analog adjustability is possible across the complete range of the device.
- Locally controlled automatic flow mixing (such as Michell's DG4) – The generator is supplied with a number of user-defined (at the time of order) humidity set points (minimum of 4, including full dry, maximum of 11), which are selected by means of buttons on the front panel.
- Remote controlled automatic flow mixing (such as Michell's DG4 and VDS3) – Control is implemented by sending serial commands to the generator via RS232, or USB, either through dedicated control software (which can run user-defined sequences), or via the customer's own system.



# Reference Instruments

Chilled mirror hygrometers are precision instruments for critical measurement and control applications. Chilled mirror sensors measure a primary characteristic of moisture - the temperature at which condensation forms on a surface. This means that chilled mirror hygrometers:

- Have no drift: the temperature at which condensation forms is measured directly so there are no calculated variables that could shift over time.
- Are inherently repeatable, giving reliable results every time.

## Chilled Mirror Operation

The chilled mirror sensor consists of a temperature-controlled mirror and an advanced optical detection system. A beam of light from an LED is focused on the mirror surface with a fixed intensity. As the mirror is cooled, less light is reflected due to the scattering effect of the condensate formed on the mirror surface. The levels of reflected and scattered light are measured by two photo-detectors and compared against a third reference detector measuring the intensity of light from the LED.

The signals from this optical system are used to precisely control the drive to a solid state thermoelectric cooler (TEC), which heats or cools the mirror surface. The mirror surface is then controlled in an equilibrium state whereby evaporation and condensation are occurring at the same rate. In this condition the temperature of the mirror, measured by a platinum resistance thermometer, is equal to the dew-point temperature of the gas.

In the S8000 RS and S4000 TRS from Michell Instruments, an auxiliary cooling system is used to remove heat from the 'hot' side of the TEC. This supplements the depression capabilities of the heat pump, and enables measurement of very low dew points.

# Choosing a Reference Instrument

The Michell Instruments' range of chilled mirror reference hygrometers have measurement capabilities matched to the performance of each of the different RH and dew-point generator options. For reasons explained earlier in this guide, a high accuracy reference is a necessity for performing traceable, credible calibrations.

Ambient temperature measurement accuracy of all Michell Instruments' chilled mirror products is  $\pm 0.1^{\circ}\text{C}$  ( $\pm 0.18^{\circ}\text{F}$ ). When the calibration parameter is relative humidity, then a measurement of ambient temperature is also necessary as the other input to the equation which determines this from dew point: Vapor pressure ( $e$ ) is determined by solving the Sonntag (1990) formula for the current dew-point temperature. Saturation vapor pressure ( $e_s$ ) is found by repeating the process for the ambient temperature.

Relative humidity is then (in %): This calculation is recognized and published in the National Physical Laboratory's 1996 publication 'A Guide to the Measurement of Humidity'. Its use will, in most cases, still yield lower uncertainties of measurement than can be achieved with hygrometers which directly measure relative humidity.

## Calibration

Although Michell Instruments' chilled mirror hygrometers are fundamental and do not drift, in order to maintain the traceability of your reference it is advisable to return it to Michell Instruments to be calibrated against one of our transfer standards on an annual basis.

## Manifold

Standardized or customized designs of manifold are available for Michell Instruments' sensors depending on how many sensors are intended to be calibrated on the system at any one time. Manifolds to accept non-Michell sensors or instruments can also be custom designed; the optimal configuration can be designed from the dimensions of the device and its mounting arrangement.

## Integration

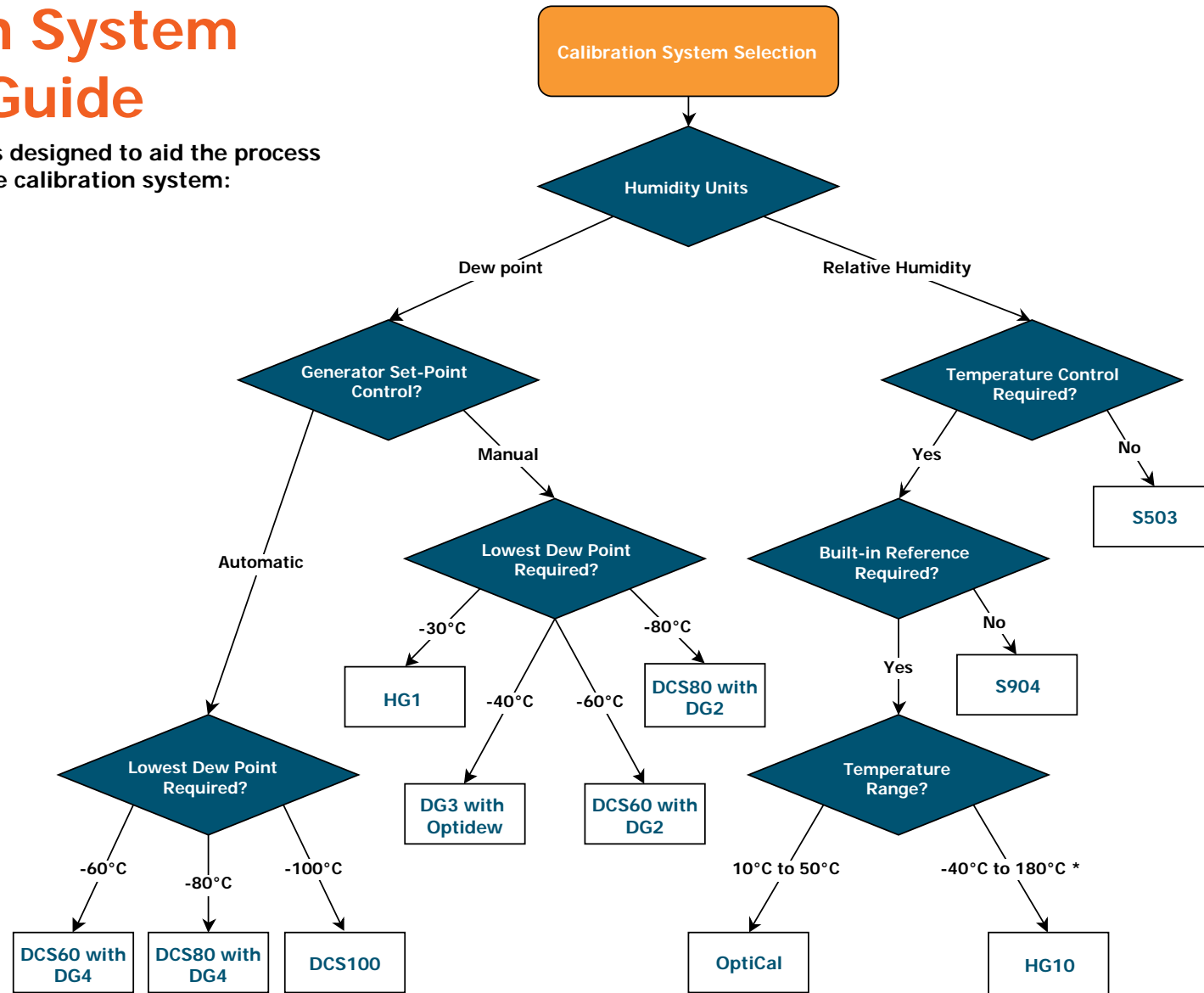
Integration of the system components, such as logging of sensors under test, the reference instrument and other further enhancements, can be realized. Please contact a Michell Instruments' representative for further details.





# Calibration System Selection Guide

The following flow chart is designed to aid the process of selecting an appropriate calibration system:



\* Typical range, dependent on customers specification at time of order

# Glossary

## Absorption (of water vapor)

Retention (of water vapor) by penetration into the bulk of a material

## Adsorption (of water vapor)

Retention (of water vapor) as a surface layer on a material

## Condensation

Condensation occurs when a vapor is compressed or cooled to its dew point, at which point its state changes from gas to liquid. This is often manifested as liquid droplets on a solid surface which is cooler than the dew-point temperature of the vapor.

## Contaminant

An undesirable particulate, liquid or vapor component in a sample gas.

## Desiccant

Any substance which exerts a drying action by chemically absorbing water vapor

## Humidity

The presence of water vapor in air or other gas

## Hygrometer

Any instrument for measuring humidity

## Hygrometry

The measurement of humidity is called hygrometry, derived from the Greek term 'hygros' meaning moist. Hygrometry is the subject of humidity measurement

## Inert gas

Chemically nonreactive gas, such as nitrogen, helium, argon etc

## Manifold

A sample chamber designed to accommodate multiple probes or sensors, for the purpose of exposing them to humidity controlled calibration air or gas.

## Moisture

Refers to liquid water or water vapor in any form

## Platinum Resistance Thermometer

A highly accurate type of resistance temperature sensor commonly used in instrumentation. Also known as an RTD, PRT or PT100

## Probe

Part of the instrument that houses the sensor remotely from the main body of the instrument

## Sensor

The active or sensing part of a measuring instrument

## Transmitter

Instrument which normally gives an electrical output (analog or digital) rather than a displayed result

## Partial pressure (of water vapor)

The part of the overall pressure exerted by the water vapor component in a gas. Expressed in units of pressure such as Pascal (100 kPa = 1 bar)

## Saturated vapor pressure

Maximum pressure of water vapor that can exist at a given temperature. Expressed in units of pressure such as Pascal (100 kPa = 1 bar)

## Dew Point (or dew point temperature) (°Cdp or °Fdp)

The dew point is the temperature at which condensation occurs if a gas is cooled (at constant pressure). This is in effect, the temperature at which a gas becomes saturated in equilibrium with water vapor. Dew point relates directly and uniquely to the water vapor pressure

## Frost point (or frost-point temperature)

The temperature at which ice forms on cooling a gas. This is, in effect the temperature at which air is saturated in equilibrium with ice. It is the exact counterpart to dew point (though values differ).

Confusion can arise from the fact that condensation formed below 0°C is not necessarily ice. At temperatures down to -30°C there is a high likelihood that condensation will occur in liquid phase, known as super-cooled water. The condensation temperatures for water and ice differ in this temperature range for a gas of the same moisture content.

Care must be taken when interpreting the measurements of condensation dew-point meters, to correctly determine the state of the condensate. The term "dew point" is often used generally to include "frost point".

## Mixing Ratio

Mass of water vapor per unit mass of dry air with which it is associated. It is a dimensionless ratio, but is often expressed in grams of water per kilogram of dry gas (g.kg<sup>-1</sup>) or in other units of mass. For low levels of moisture content, this may be expressed in parts per million by weight, i.e. mass of water vapor per million parts of dry gas (ppm or ppm<sub>w</sub>).

## Parts per million

The total quantity of water vapour present in a gas, expressed as a fraction of 1x10<sup>6</sup>. Abbreviated as "ppm", the unit can be in terms of total gas volume (ppm<sub>v</sub>), or molecular weight (ppm<sub>w</sub>). For actual vapour pressure; e (in Pascals), and total gas pressure; p (in Pascals):

$$\text{ppm}_v = \frac{e}{p} \times 100000$$

## Relative Humidity

The relative humidity of a gas expresses how much water vapor it contains in relation to the total amount of water vapor sustainable at that temperature. This is defined as: The ratio of the actual vapor pressure to the saturation vapor pressure over a plane liquid water surface at the same temperature, expressed as a percentage.

Although this is not a recognised abbreviation, the phrase "relative humidity" is commonly abbreviated

RH, as in "X% RH". For actual vapor pressure; e (in Pascals) and saturation vapor pressure; e<sub>s</sub> (in Pascals):

$$\text{RH (in \%)} = \frac{e}{e_s} \times 100$$



## Michell Instruments' Calibration Services

Michell Instruments offers a calibration service for most moisture sensors and instrumentation, carried out in our ISO 17025, ISO 9001:2008 certified laboratories. Our four laboratories are accredited by UKAS (United Kingdom Accreditation Service), and maintain full traceability to NPL (National Physical Laboratory, London, UK) & NIST (National Institute of Standards & Technology, Washington DC, USA).

We provide traceable calibration from -100 to +90°C (-148 to +194°F) dew point, or full ISO 17025 accredited calibrations from -90 to +90°C (-130 to +194°F) dew point.

## Michell Instruments' Service Exchange Scheme



In some cases it is not practical for a user to remove a working sensor in order to return it to our lab for recalibration. For this reason Michell Instruments offers an exchange program for sensors, to help customers keep their processes running cost effectively with virtually no down-time.

Before re-calibration is due, the customer orders an exchange sensor from Michell Instruments or one of our global representatives. Once received at the customer's premises, the original sensor is removed and replaced with the exchange sensor, and the original is returned to Michell Instruments. All calibration data is stored within the sensor, so no additional work is required. Each sensor comes with a traceable calibration certificate as standard.

The returned sensor is refurbished and fitted with a replacement sensor tile, and is then used for future service exchange replacements. This means that the service can be offered for the same price as a return-to-base re-calibration.

Michell Instruments also offer a range of extended maintenance policies, which cover annual servicing, recalibration & software upgrades for a wide range of instruments.

**Please contact your Michell Instruments representative for pricing details on policies providing cover for up to 4 years.**

## About Michell Instruments

Michell Instruments is an international leader in high-precision sensing, with 40 years experience in the field, specializing in instrumentation for dew point, relative humidity and oxygen analysis.

Michell Instruments has a long history in the field of humidity calibration, originating in the design and provision of the Transfer Standard Dew-point Hygrometer (TSDH) to provide traceability to NIST (National Institute of Standards and Technology) for European calibration laboratories.

As the largest manufacturer of dew-point sensors in Europe, Michell Instruments has over 2000 sensors under calibration at any moment in time, in our own production facility in Ely, UK, in addition to local calibration centres in Netherlands, France, Italy, Germany, China, Japan and USA. The development and optimization of our own calibration systems has helped us to build a comprehensive portfolio of calibration products and solutions that enable our customers to perform their own on-site humidity calibrations.

## Manufacturing, Research & Development

Michell Instruments has three manufacturing and R&D locations: Oosterhout, The Netherlands; Lyon, France and Ely UK. The UK location is the main BS EN ISO 9001:2008 certified manufacturing facility.

## Service and Support

Michell Instruments offers practical and flexible after-sales service: Whether you prefer on-site maintenance, return to base or service exchange; we provide the simplest way to maintain your measurement. Michell Instruments operates an extensive network of subsidiaries and distributors stretching across 56 countries, offering the services of trained application engineers. Service centres and calibration laboratories are located on three continents: North America, Europe and Asia.

## Accreditations

Michell Instruments understands and endorses the need to conform to recognized standards for quality and calibration. Our calibration laboratory maintains full traceability to British (NPL) and American (NIST) Humidity Standards.

### UKAS

Michell Instruments Limited has been accredited to ISO 17025 by UKAS (United Kingdom Accreditation Service) for the calibration of dew-point hygrometers since 1986 (laboratory number 0179) and our current dew-point calibration range is -90 to +90°C (-130 to +194°F). For full details of our measurement capability please see our Schedule of Accreditation. Our traceability to NIST (National Institute of Standards & Technology) is over the range -75 to +20°C (-103 to +68°F).

### NVLAP

Our UKAS accreditation is commonly recognised elsewhere in the world as EAL, or NVLAP (National Voluntary Laboratory Accreditation Program) in the USA.

### ISO 9001

Michell Instruments Ltd UK manufacturing facility has been continuously registered to BS EN ISO9001 since 1989.

### Hazardous Area Products

Michell Instruments also produces instruments specifically designed for use within hazardous areas. All such products are independently assessed and certified to many international standards, including, but not limited to, ATEX (European), IECEx, CSA, FM, UL, GOST-R and GOST-K.

Accreditations and certificates for these products can be downloaded from the Michell website [www.michell.com](http://www.michell.com) under the 'Product Documents/Accreditations' section'.



[www.michell.com](http://www.michell.com)

The fundamentals of moisture calibration  
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Need advice or support? Contact us on 01353 658000, [uk.info@michell.com](mailto:uk.info@michell.com)