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APPLICATION NOTE

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Dew point sensing technologies and their performance differences in compressed air applications

Moisture is a constant issue in compressed air systems. When dew point sensors are working optimally, measures can be taken to avoid malfunctions, inefficient operations or poor quality end product. However, the measurement of dew point in compressed air systems can present many challenges that lead to erroneous readings, poor stability, and even sensor failures. The most common issues with dew point sensors in compressed air are usually centered on the following:

- Response time
- Reliability of the reading
- Recovery from water spikes or condensation
- Exposure to compressor oil

To better understand these challenges, it is worth first exploring the performance differences between the most common sensor technologies.

Different sensing technologies

The three most common types of sensors for measuring dew point are chilled mirrors, metal oxide, and polymer sensors.

Chilled mirror technology can offer the **highest accuracy** over a wide range of dew points. The operating principle is based on the fundamental definition of dew point – cooling a volume of air until condensation forms. A gas sample passes over a metallic mirror surface which is chilled by a cooler. Light is then directed at the mirror allowing an optical sensor to measure the amount of reflected light. When the mirror is cooled to the point at which condensation begins to form on its surface (i.e. the dew point has been reached), the amount of light reflected by the mirror diminishes which is in turn detected by the optical sensor. The rate of cooling is then carefully regulated by a temperature sensor on the mirror. Once a state of equilibrium has been reached between the rate of evaporation and condensation, the mirror temperature is equal to the dew point. Due to the chilled mirror's optical measurement principle, the sensor is highly sensitive to the presence of dirt, oil, dust, and other contaminants on the mirror surface. Similarly, accurate chilled mirror devices tend to be expensive and are often employed when absolute accuracy is essential and frequent maintenance and cleaning can be performed.

Sensor technology	Wide measure-ment range	High accuracy	Immune to dust and dirt	Immune to conden-sation	Long-term stability	Reason-able price
Chilled Mirror	+++	+++				
Capacitive Metal oxide	++	++	++	+	+	++
Capacitive Polymer	++	++	+++	+++	+++	++

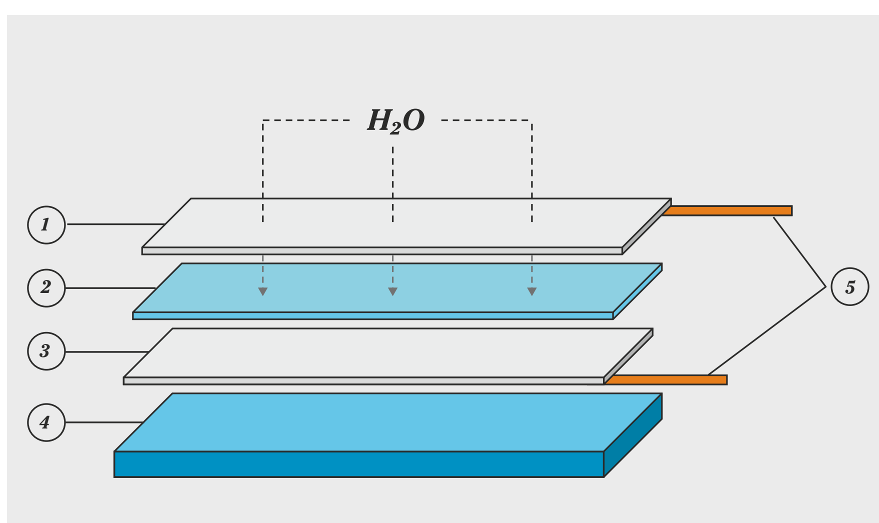
Next are **capacitive metal oxide sensors**, including aluminum oxide technology, which are designed for **very low dew point** measurement in industrial processes. While the types of materials used in construction can vary, the sensor structure and operating principle generally remain the same. These capacitive sensors are built in a layered structure sandwiching together a substrate base layer, a lower electrode, a hygroscopic metal-oxide middle layer, and a water permeable upper electrode. The capacitance across the upper and lower electrode changes based on the amount of water vapor absorbed by the metal oxide layer (the dielectric of the capacitor), which is a function of dew point. While providing excellent low dew point measurement accuracy to -100°C and lower, they tend to offer poor long-term stability in processes with varying dew points at the higher ranges (e.g. refrigerant dried systems). Metal oxide sensors can also be easily damaged by high humidity levels and condensation. This drift in the output reading means frequent calibration, which can typically be done only at the manufacturer's calibration lab.

Rounding out the sensor types, **capacitive polymer sensors** measure **accurately over a wide humidity range** in addition to offering excellent long-term stability. Since January 1997, when Vaisala launched the first ever polymer sensor for dew point measurements, DRYCAP® technology has been used in a wide variety of industrial and meteorological applications. New innovations have enabled polymer sensors to be utilized in low dew point applications as well. While the capacitive operating principle is similar to that of metal oxide, there are a few key differences. Beyond the obvious material difference in the hygroscopic layer (polymer vs. metal oxide), a capacitive polymer sensor is also bonded together with a resistive temperature sensor. The polymer sensor measures the humidity (amount of water molecules in the measured gas) in terms of relative humidity (RH) while the temperature sensor measures the temperature of the polymer sensor. From these two values, the microprocessor in the transmitter electronics calculates the dew point temperature. An auto-calibration feature, also invented by Vaisala, is used to measure accurate dew point values in very dry conditions with the polymer sensor. When relative humidity approaches zero, rather small changes in humidity will result in quite large changes in dew point readings. For example, dew points of -40°C and -50°C at room temperature correspond to relative humidities of 0.8% RH and 0.3% RH, respectively. With the typical ±2% RH accuracy specification of polymer sensors, an accuracy of ±2°C dew point can be achieved down to -9°C. Auto-calibration extends this accuracy from ±2ºC down to -80°C.

During auto-calibration, the sensor is heated and allowed to cool while the humidity and monitored readings of the sensor are monitoring and plotted. This data is analyzed and used to adjust the reading of the humidity sensor.

The key to this accurate calibration is that the sensor's output is equivalent to relative humidity (RH), which changes in relation to the temperature. This well-known physical dependence allows the auto-calibration to evaluate if the low humidity reading at 0% RH is correct. Any possible drift is then automatically corrected by the microprocessor. This results in an accuracy of better than ±2ºC even at low dew points.

Polymer technology, which is the result of years of testing and careful material selection, combined with intelligent electronics offer a high-performance solution in applications where minimal maintenance is required for the dew point transmitter.

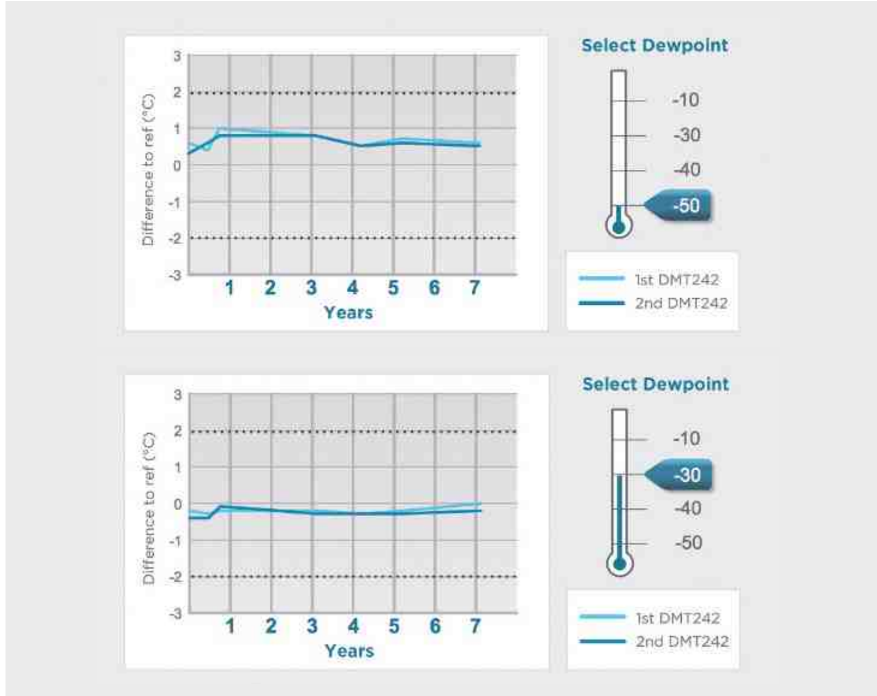


Layer construction of the DRYCAP® sensor. ***1.*** *Water vapor permeable upper electrode* ***2.*** *Humidity sensitive polymer layer* ***3.*** *Bottom electrode* ***4.*** *Sensor substrate* ***5.*** *Connection pins*

Issue #1: How can I ensure fast response time?

When installing a dew point probe that has acclimated to ambient dew points into a -40°C compressed air line, the response time required for traditional sensors to stabilize at this -40°C value can often take from several hours to several days for equilibrium to be reached. This is due to the fact that other capacitive sensor technologies must rely on the relatively slow process of using the dry process air to passively dry the hygroscopic (water absorbing) layer of the sensor.

A better solution is to use a capacitive polymer sensor with a purge function. Vaisala's DRYCAP® sensor reacts immediately when it senses a decrease in dew point of 10°C or more by initiating a sensor purge cycle that applies heat to the sensor. This expels water molecules from the polymer layer, drying the sensor, and providing a stabilized reading within 5-6 minutes.



The graphs above are derived from an ongoing test in which two Vaisala DRYCAP® DMT242 dewpoint transmitters were installed in a compressed air line seven years ago and have not been recalibrated or adjusted. The line conditions are representative of instrument air. x-axis represents years, y-axis represents difference to the reference value at periodic checks.

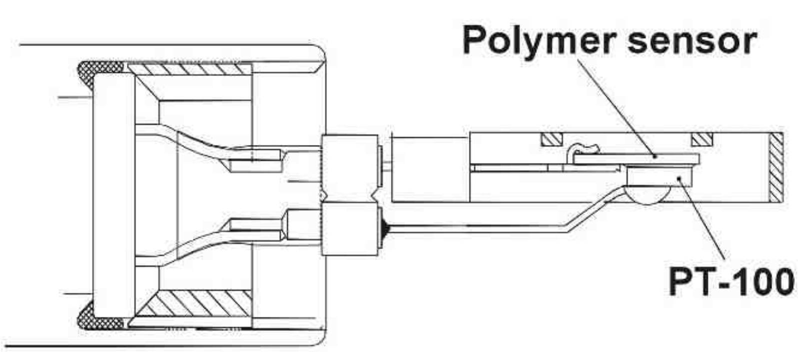
Issue #2: How can I ensure the reading is correct?

The most frequently asked question about dew point from compressed air technicians is – "I have several dew point instruments installed at the same installation point but they're all reading different values – how do I know which one is correct?"

This question is usually the most difficult to answer due to the number of variables that can affect the reading: process conditions, installation method, how the signal is being read, accuracy of sensors installed, and length of time since last calibration.

While it is widely known that every dew point sensor drifts, the critical questions are – by how much and how quickly?

Well-established high quality polymer sensor with auto-calibration provides a high level of accuracy due to a self-calibration method that activates once every hour in a stable environment (more frequently in varying conditions) to ensure the absolute minimum sensor drift – providing years of maintenance-free, reliable measurements you can rely on.



Vaisala DRYCAP® Capacitive polymer sensor structure

Issue #3: How does the sensor recover from water spikes or condensation?

Occasional high-humidity water spikes or exposure to water droplets are an unavoidable phenomenon in the normal operation of a compressed air system. Whether your dew point sensor can survive and recover from these events depends on the type of sensor installed.

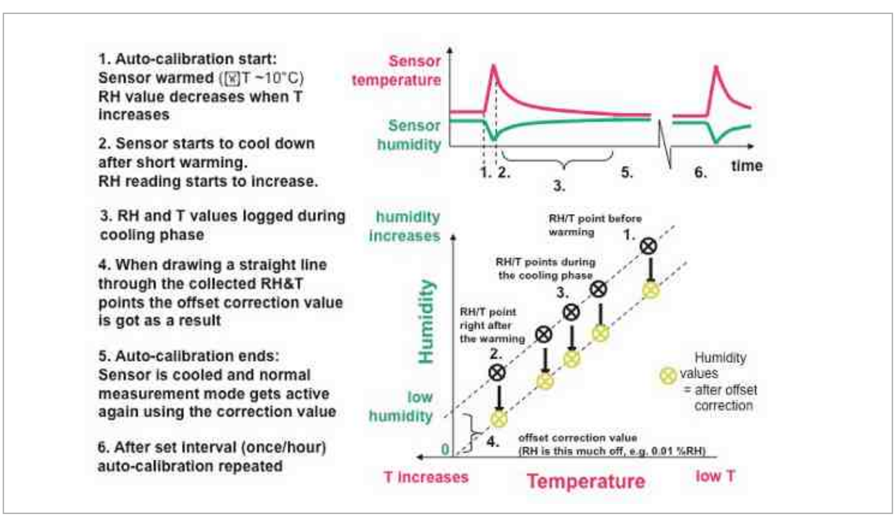
Metal oxide sensors continue to oxidize in the presence of water, resulting in a structural change in the porous oxide layer. This translates into measurement inaccuracy and sensor drift. Polymer sensors, on the other hand, are immune to water due to their inherent inert characteristics. When a polymer sensor with auto-calibration functionality senses a water spike, it initiates an auto-calibration cycle as normal dry air returns to the line, returning to normal operating values within a few minutes.

Issue #4: Can the sensor withstand exposure to entrained compressor oils?

Trace amounts of compressor oil suspended in compressed air can spell disaster for some sensor technologies. Fortunately, the structure of some polymer sensors, like Vaisala DRYCAP®, have been specifically designed to be selective to only water molecules. This is achieved by a specially designed permeable upper electrode with a pore size allowing only water vapor to pass through it. By comparison, much larger hydrocarbon molecules (i.e. oils) are unable to pass through these pores, thereby eliminating any cross-sensitivity to oils. Clearly by design, chilled mirror optics and reflective surfaces need to remain clean in order to maintain their performance – and thus have a minimal tolerance for oil contamination.

In brief

- Chilled mirror technology offers the highest accuracy over a wide range of dew points, but its performance can be limited by the presence of contaminants.
- Capacitive metal oxide sensors provide very low dew point measurement, but they can be damaged by high humidity levels and condensation.
- Capacitive polymer sensors with auto-calibration functionality operate over a wide humidity range, are unaffected by condensation and ensure long term stability.



Auto-calibration function.