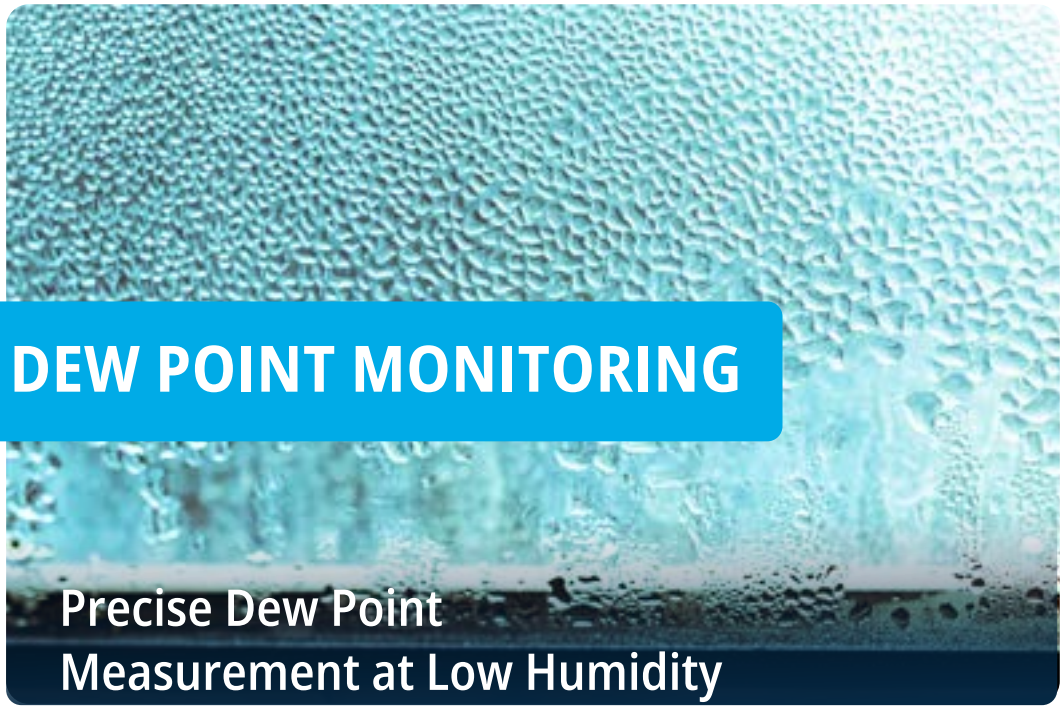
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DEW POINT MONITORING

Precise Dew Point Measurement at Low Humidity

WHITEPAPER

Precise dew and frost point measurement at very low humidity is essential in industries such as semiconductor manufacturing, gas analytics, cleanrooms, compressed air systems, and battery production, where minimal moisture can compromize product quality and process stability.

Because dew point depends on temperature and pressure, concepts such as pressure dew point and the distinction between dew and frost point below 0 °C are critical for accurate interpretation. Achieving reliable measurements at these levels is challenging, as sensors must detect tiny amounts of water vapor with high sensitivity, remain stable over long periods, and withstand condensation and chemically aggressive environments.

Innovative Sensor Technology IST AG addresses these challenges with capacitive polymer-based humidity sensors and HYT modules that offer high sensitivity, excellent long term stability, and strong condensation and chemical resistance suitable for dew point applications below -60 °C, providing fully calibrated and temperature compensated digital outputs, pressure-tight designs, and customization options for seamless industrial integration.

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Measuring the dew point at extremely low humidity levels is a key challenge in many industrial applications – from semiconductor manufacturing and gas analytics to process air monitoring. iST offers high-precision sensor solutions specifically designed to meet these demanding requirements.

1.0 Fundamentals on Dew Point

Dew point is the temperature at which air becomes saturated with water vapor, causing condensation to start. At this point, the partial pressure of water vapor equals the saturation vapor pressure at a given temperature. A lower dew point indicates lower water vapor pressure, which corresponds to reduced absolute humidity and therefore a drier gas phase.

The saturation vapor pressure depends on temperature, i.e. warm air can hold more water than cold air. Increasing system pressure, however, raises the water vapor pressure as well, resulting in a higher dew point. Consequently, in pressurized systems, the dew point is higher than at atmospheric pressure, even though the absolute water content remains unchanged. To account for this effect, industrial applications typically specify the **pressure dew point** (e.g., -20 °C at 7 bar) rather than the atmospheric dew point.

It is important to note that below 0 °C, water can either freeze into ice or remain in a liquid state as supercooled water. Because the water-vapor equilibrium over water and over ice is different, distinguishing between dew point and **frost point** is essential for accurate low humidity measurements. For example, a saturation vapor pressure of 51 Pa corresponds to a dew point of −30 °C or a frost point of −27.1 °C. While frost point generally makes more sense for most applications below 0 °C, the term dew point is still widely used in industry.

The conversion between dew/frost point and relative humidity, and vice versa, can be easily calculated using the formulas discussed later.



Ultra-dry environments, such as battery manufactuing (right), or industrial air compressors in factory air supply sytems (below) , are highly dependent on reliable dew point monitoring.



2.0
Dew Point Measurement Applications

Dew point monitoring is essential in numerous industrial and technological processes where low levels of humidity need to be measured to ensure quality, safety, and efficiency.

Typical applications include:

- **Compressed air monitoring in HVAC systems:**
  Preventing condensation and corrosion in air distribution networks
- **Drying processes:**
  Controlling moisture levels for optimal product quality
- **Gas analytics:**
  Ensuring accurate measurements in sensitive gas mixtures
- **Glove boxes and cleanrooms:**
  Maintaining ultra-dry environments for research and production
- **Environmental measurement technology:**
  Monitoring humidity for climate and environmental studies
- **Battery manufacturing:**
  Avoiding humidity-related defects in sensitive components
- **Semiconductor production:**
  Protecting wafers and electronics from humidity damage
- **Data centers:**
  Preventing condensation that could harm critical IT infrastructure
- **Laser systems:**
  Ensuring stable operation by controlling humidity in optical paths
- **Transformer switches:**
  Monitoring insulation integrity by controlling humidity levels

... and many more areas where precise humidity control is critical



3.0
Challenges in Low Humidity Monitoring

As dew point is typically important for low humidity applications, there are numerous challenges for accurate dew point measurements. At extremely low humidity levels, the water vapor content is minimal, which means sensors must be exceptionally **sensitive** to detect even the smallest traces of humidity.

Long-term stability is another critical factor, as instruments are often deployed in continuous operation for years. Any drift in measurement can lead to costly process deviations.

In addition to sensitivity and stability, dew point sensors must withstand challenging environmental conditions. **Condensation resistance** is crucial to prevent damage during sudden humidity spikes or system failures, which could otherwise compromise sensor integrity.

Many industrial applications also involve aggressive chemicals or contaminants, making **chemical resistance** a key requirement for durability and reliability.

4.0
iST Sensor Solutions

The **capacitive polymer-based humidity sensors** developed by iST have been successfully used for years in demanding dew point applications, even at dew points below -60 °C.
The sensitive polymer layer is specifically optimized for extremely dry conditions, ensuring accurate detection even at very low humidity levels while providing outstanding long-term stability. In addition, the sensors are resistant to condensation and designed to withstand industrial environments, guaranteeing reliable performance even under challenging conditions.

iST's proven capacitive polymer-based sensor technology is integrated into our **HYT modules**, combining precision and durability for demanding applications.
Each module provides fully calibrated and temperature compensated digital output for temperature and relative humidity. Its compact, robust design ensures long-term stability and reliable performance.
With pressure-tight designs and communication interfaces such as I²C and SPI, HYT modules are engineered for seamless integration into industrial environments.

Additionally, customer-specific calibrations are available, enabling tailored accuracy for your application requirements.

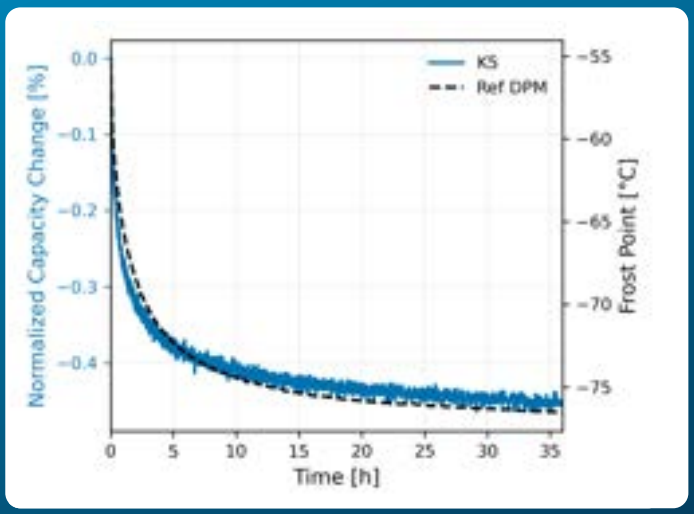


Figure 1: Drying curve of a K5 sensor over time down to a frost point below –75 °C (y_1-axis). The sensor's response aligns with the drying curve measured by the humidity reference (dew point mirror), which indicates the frost point (y_2-axis).

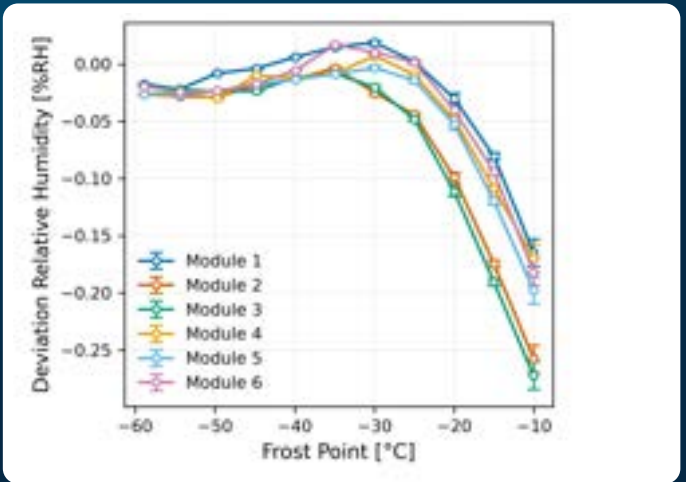


Figure 2: Deviation of the relative humidity signal (y-axis) of HYT 939p K5 humidity modules as a function of the frost point temperature (x-axis), including the calculated standard deviation (error bars).

By measuring temperature and relative humidity, the module provides the necessary data to compute the dew/frost point $T_{d/f}$. As an easy approximation, the dew/frost point $T_{d/f}$ can be calculated using the Magnus formula as described by Sonntag [1]:

$$T_{d/f} = \frac{b_{d/f} \cdot \gamma(T,RH)}{a_{d/f} - \gamma(T,RH)} \quad (1)$$

where:

$$\gamma(T,RH) = \frac{a_d \cdot T}{b_d + T} + \ln\left(\frac{RH}{100}\right) \quad (2)$$

and ambient temperature T in [°C] and relative humidity RH in [%RH] with constants as stated in Table 1. Because it is important to distinguish between dew point and frost point, iST recommends calculating frost point for temperatures below 0 °C. Please note that in Equation (2), the parameters over water must be applied irrespective of whether a dew point or a frost point is calculated, provided the ambient temperature T exceeds 0 °C. For ambient temperatures below 0 °C, the corresponding parameters over ice shall be used instead, when calculating frost point. Humidity calculations with higher accuracy and broader ranges are available, such as those described by Hardy [2].

Condition	Temperature T [°C]	a [-]	b [°C]
Over water (dew point)	-45 – 60	17.62	243.12
Over ice (frost point)	-80 – 0.01	22.46	272.62

Table 1: Magnus parameters for saturation vapor pressure as described by Sonntag [1]

CUSTOMIZED SOLUTIONS

In addition to calibrating and adjusting the humidity modules to an application-specific measuring range, the HYT modules can be pre-assembled to meet specifications for an easy integration into the customer application. The iST toolbox contains an ever-growing choice of cables, connectors, housing, as well as sealing, coating, and filtering materials compatible with the HYT humidity modules. We are happy to collaborate on the design of **custom sensor probes** and look forward to your call or email!





Gas blending in pharmaceutical manufacturing requires ultra-dry conditions

5.0
About iST

Your partner and manufacturer for physical, chemical and biological sensors



With 35 years of experience iST is one of the world's leading manufacturers of physical, chemical and biological sensors.

We specialize in the development and manufacturing of temperature sensors, thermal mass flow sensors and modules, humidity sensors and modules, conductivity sensors and biosensors. In addition to our standard products, we offer sensor adaptions to individual, customer-specific application needs – right up to the joint development of new technologies. iST-sensors are characterized by their accuracy and consistency in various measurement conditions. They are used in measuring and monitoring instruments for numerous applications across all industries.

Out of our state-of-the-art-facilities we manufacture varying quantities from small order numbers to fully automated high-volume manufacturing.

iST is a company of the Endress+Hauser Group, headquartered in Reinach, Switzerland.
Endress+Hauser is among the global leaders in measuring instruments, services and solutions for industrial process engineering.

The products



Product code 150464

K5
Excellent sensitivity and stability in low humidity



Product code 153398

HYT 939p K5 Module
Factory-calibrated module up to 16bar with digital I²C interface

Product code 154814

Dew Point Probe
Ready-to use probe with leakage tight steel housing and M8 connection



References
[1] D. Sonntag, „Important new values of the physical constants of 1986, vapour pressure formulations based on the ITS-90, and psychrometer formulae," Zeitschrift für Meteorologie, pp. Page 340-344, 1990.

[2] B. Hardy, „ITS-90 Formulations for Vapor Pressure, Frost Point Temperature, Dew Point Temperature and Enhancement Factors in the Range -100 to +100°C," in The Proceedings of the Third International Symposium on Humidity & Moisture, Teddington, England, 1998.

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