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How to Choose the Right Instrument for Measuring Humidity and Dew Point

Learn the basics and get the best out of your humidity measurements.

Humidity measurement and control is called for in a wide variety of industrial applications. Each application has a different set of requirements for humidity instruments, such as required measurement range, tolerance to extreme temperature and pressure conditions, ability to recover from condensation, ability to operate in hazardous environments, and options for installation and calibration. There is no single device that is suitable for all needs. In fact, the range of available equipment is quite large, varying both in cost and quality.

This paper discusses the following topics in order to help in selecting the right humidity instrument:

- Different humidity parameters
- Environmental conditions that influence the choice of humidity instrument
- Sensor properties that influence the choice of humidity instrument
- Practical guidelines for selecting a humidity instrument

What is Humidity? An Introduction to Humidity Parameters

Partial Pressure of Water Vapor

Humidity is simply water in its gaseous phase, properly called water vapor. Because water vapor is a gas, most of the common gas laws apply to it, including Dalton's law of partial pressures. Dalton's law says that the total pressure of a gas is equal to the sum of the partial pressures of each of the component gases:

$$P_{total} = P_1 + P_2 + P_{3...}$$

If we consider air, the equation means that the total atmospheric pressure of 1.013 bar (14.7psia) is the sum of the partial pressures of nitrogen, oxygen, water vapor, argon, carbon dioxide, and various other gases in trace amounts.

Definition of Water Vapor Pressure

Water vapor pressure (P_w) is the pressure exerted by the water vapor present in air or a gas. Temperature dictates the maximum partial pressure of water vapor. This maximum pressure is known as saturation vapor pressure (P_{ws}). The higher the temperature, the higher the saturation vapor pressure and the more water vapor the air can hold. Thus, warm air has a greater capacity for water vapor than cold air.

If saturation vapor pressure is reached in air or in a gas mixture, the introduction of additional water vapor requires that an equal amount condenses out of the gas as a liquid or a solid. A psychrometric chart shows graphically the relation between saturation vapor pressure and temperature. In addition, vapor pressure tables can be used to see the saturation vapor pressure at any temperature, and there are also a number of computer-based calculation programs available.

Effect of Pressure on Humidity

Dalton's law states that a change in the total pressure of a gas must have an effect on the partial pressures of all of the component gases, including water vapor. If, for example, the total pressure is doubled, the partial pressures of all component gases are doubled as well. In air compressors, a pressure increase "squeezes" water out of the air as it is compressed.

Humidity calculators are also available for mobile phones.

This happens because the partial pressure of water vapor (P_w) is increased, but the saturation vapor pressure is still only a function of temperature. As pressure builds in a receiver tank and P_w reaches P_{ws}, water condenses into liquid and must ultimately be drained from the tank.

Some humidity measurement instruments allow an individual humidity parameter to be chosen which can then be followed on a graphical display. This picture shows different views of the Vaisala HUMICAP Hand-Held Humidity and Temperature Meter HM70 display.

Relative Humidity

When thinking conceptually of water vapor as a gas, it's easy to define relative humidity. Relative humidity (RH) can be defined as the ratio of the partial water vapor pressure (P_w) to the water vapor saturation pressure (P_{ws}) at a particular temperature:

$$\%RH = 100\% \times P_w / P_{ws}$$

Relative humidity is strongly temperature dependent as the denominator in the definition (P_{ws}) is a function of temperature. For example, in a room with an RH of 50% and a temperature of 20°C, increasing the temperature of the room to 25°C will decrease the RH to about 37%, even though the partial pressure of the water vapor remains the same.

Pressure will also change relative humidity. For example, if a process is kept at a constant temperature, relative humidity will increase by a factor of two if the process pressure is doubled.

Dew Point Temperature

If a gas is cooled and gaseous water vapor begins to condense in the liquid phase, the temperature at which condensation occurs is defined as the dew point temperature (T_d). At 100%RH the ambient temperature equals the dew point temperature. The further negative the dew point is from the ambient temperature, the smaller the risk for condensation and the drier the air.

Dew point directly correlates with saturation vapor pressure (P_{ws}). The partial pressure of water vapor associated with any dew point can be easily calculated. Unlike RH, dew point is not temperature dependent but it is affected by pressure. Typical applications for dew point measurement include various drying processes, dry air applications, and compressed air drying.

Frost Point Temperature

If the dew point temperature is below freezing – which is the case in dry gas applications – the term frost point (T_f) is sometimes used to explicitly state that the condensing phase is ice. The frost point is always slightly higher than the dew point below 0°C as the water vapor saturation pressure of ice is different to water. People also often refer to dew point for subzero values, even though they mean frost point. Ask for clarification if you are not certain.

Parts Per Million

Unit parts per million (ppm) is sometimes used for low levels of humidity. It is the ratio of water vapor to dry gas or total (moist) gas, and is expressed either by volume/volume (ppm_{vol}) or mass/weight (ppm_w). Parts per million (ppm_{vol}) can be quantitatively expressed as follows:

$$ppm_{vol} = [P_w / (P - P_{ws})] \times 10^6$$

The ppm parameter is typically used when defining the water vapor content of pressurized and dry pure gases.

Mixing Ratio

The mixing ratio (x) is the ratio of water vapor mass to the mass of dry gas. It is dimensionless but often expressed in grams per kilogram of dry air. The mixing ratio is mainly used in drying processes and HVAC applications for calculating water content when the mass flow of air is known.

Wet Bulb Temperature

Traditionally, the wet bulb temperature (T_w) is the temperature indicated by a thermometer wrapped in a wet cotton sheath. The wet bulb and ambient temperatures can be used together to calculate relative humidity or dew point. For example, the wet bulb temperature is used in air conditioning applications where it is compared to the dry bulb temperature to determine the cooling capacity of evaporative coolers.

Absolute Humidity

Absolute humidity (a) refers to the mass of water in a unit volume of moist air at a given temperature and pressure. It is usually expressed as grams per cubic meter of air. Absolute humidity is a typical parameter in process control and drying applications.

Water Activity

Water activity (aw) is similar to equilibrium relative humidity and uses a scale of 0 to 1, instead of 0% to 100%.

Enthalpy

Enthalpy is the amount of energy required to bring a gas to its current state from a dry gas at 0°C. It is used in air conditioning calculations.

The Effect of Environmental Conditions on Humidity Measurement

Environmental conditions can have a significant effect on humidity and dew point measurements. Take the following environmental factors into consideration to achieve the best possible measurement result:

Select a Representative Measurement Location

Always choose a measuring point that is representative of the environment being measured, avoiding any hot or cold spots. A transmitter mounted near a door, humidifier, heat source, or air conditioning inlet will be subject to rapid humidity changes and may appear unstable.

As relative humidity is strongly temperature dependent, it is very important that the humidity sensor is at the same temperature as the measured air or gas. When comparing the humidity readings of two different instruments, the thermal equilibrium between the units/probes and the measured gas is particularly crucial.

Unlike relative humidity, dew point measurement is independent of temperature. However, when measuring dew point, pressure conditions must be taken into account.

Beware of Temperature Differences

When mounting a humidity probe into a process, avoid temperature drops along the probe body. When there is a large temperature difference between the probe and the external environment, the whole probe should be mounted within the process and the cable entry point should be insulated.

When there is a risk of condensation, the probe should be mounted horizontally to avoid water dripping down the probe/cable and saturating the filter (see figure 1).

Ensure that air is allowed to flow around the sensor. Free air flow ensures that the sensor is in equilibrium with the process temperature. At 20°C and 50%RH, 1°C difference between the sensor and the measurement zone will cause an error of 3%RH. At 100%RH the error is 6%RH (see figure 2).

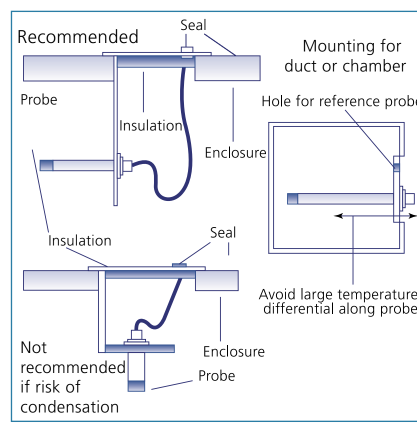


Figure 1: Mounting a humidity probe in a condensing environment.

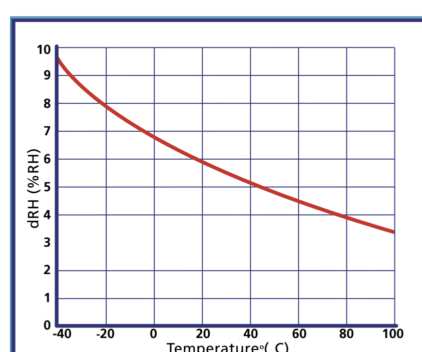


Figure 2: Measurement error at 100%RH at various temperatures when the temperature difference between the ambient air and the sensor is 1°C.

The Right Instrument for High Humidity

Environments with >90%RH are defined here as high humidity environments. At 90%RH a difference of 2°C can cause water to condense on the sensor, which in an unventilated space may take hours to dry. Vaisala humidity sensors will recover from condensation. However, if the condensed water is contaminated, the instrument accuracy can be affected due to deposits on the sensor, especially salt deposits. Even the life of the sensor may be shortened. In applications with high humidity where condensation can occur, a warmed sensor head probe such as the Vaisala HUMICAP® Humidity and Temperature Transmitter HMT337 should be used.

The Right Instrument for Low Humidity

Environments with <10%RH are defined here as low humidity environments. At low humidities, the calibration accuracy of instruments measuring relative humidity may not be adequate. Instead, measuring dew point will provide a good indication of humidity. For example, Vaisala DRYCAP® products are designed for measuring dew point.

If a dryer fails in a compressed air system, water condensation may appear and the instrument will need to recover. Many dew point sensors are damaged or destroyed in such situations, but Vaisala DRYCAP® dew point sensors withstand high humidity – and even water spikes.

The Right Instrument for Extreme Temperature and Pressure Conditions

Continuous exposure to extreme temperatures may affect sensor and probe materials over time. It is therefore very important to select a suitable product for demanding environments. In temperatures above

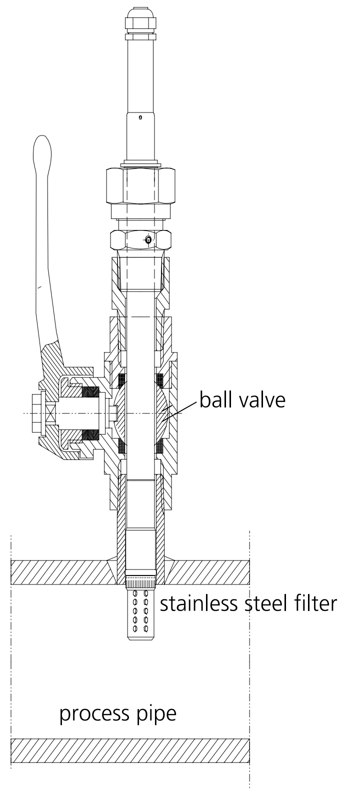


Figure 3: *A ball valve installation in a process pipe line.*

60°C the transmitter electronics should be mounted outside the process and only a suitable high temperature probe should be inserted into the high temperature environment. Moreover, built-in temperature compensation is required to minimize the errors caused by large temperature swings or operation at temperature extremes.

When measuring humidity in processes operating at around ambient pressure, a small leak may be tolerable and can be reduced by sealing around the probe or cable. However, when the process needs to be isolated, or when there is a large pressure difference between the process and the external environment, a sealed probe head with appropriate mounting must be used. Pressure leaks at the point of entry will alter the local humidity and result in false readings.

In many applications it is advisable to isolate the probe from the process with a ball valve to enable the removal of the probe for maintenance without shutting down the process (see figure 3).

When is a Sampling System Needed for Dew Point Measurement?

Wherever possible, the probe should be mounted in the actual process to achieve the most accurate measurements and a rapid response time. However, direct installations are not always feasible. In such situations, sample cells installed in-line provide an entry point for a suitable measurement probe.

Note that external sampling systems should not be used to measure relative humidity because the change in temperature will affect the measurement. Sampling systems can instead be used with dew point probes. When measuring dew point, sampling systems are typically used to lower the temperature of the process gas, to protect the probe against particulate contamination, or to enable easy connection and disconnection of the instrument without ramping down the process.

The simplest dew point sampling setup consists of a dew point transmitter connected to a sampling cell. Vaisala has several models suitable for the most common applications and sampling needs. For example, the easy to install DSC74 sampling cell is designed for the flow and pressure conditions in compressed air applications.

In demanding process conditions, sampling systems must be designed carefully. As dew point is pressure dependent, a flow meter, pressure gauge, special non-porous tubing, filters, and pump may be needed. As an example, a flow chart showing the Vaisala DRYCAP® Portable Sampling System DSS70A for DM70 is shown in figure 4.

In a pressurized system a sample pump isn't needed as the process pressure induces a large enough flow to the sampling cell.

When measuring dew point with a sampling system, trace heating should be used when the ambient temperature around the cooling coil or connecting tube is within 10°C of the dew point temperature. This prevents condensation in the tubing that connects the dew point instrument to the process.

Hazardous Environments

Only products with appropriate certification can be used in potentially explosive areas. For example, in Europe products must comply with the ATEX100a directive, which has been mandatory since 2003. Intrinsically safe products are designed in such a manner that even in the event of failure they do not generate enough energy to ignite certain classes of gas. The wiring from the intrinsically safe product into the safe area must be isolated via a safety barrier. For example, the Vaisala HMT360 series of intrinsically safe humidity transmitters are specially designed for use in hazardous environments.

Vaisala HUMICAP® Humidity and Temperature Transmitter Series HMT360 is designed for hazardous and explosive environments.

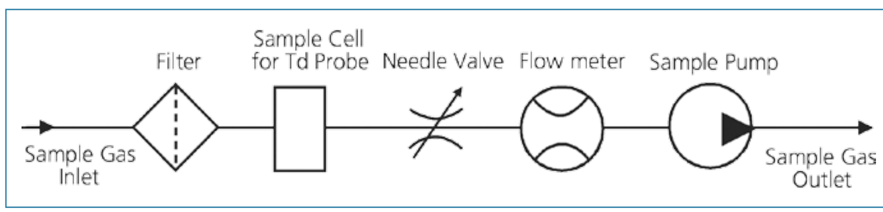


Figure 4: *The DSS70A sampling system includes a filter to clean the gas and a needle valve to control the sample flow rate. A sample pump is needed to generate flow from an unpressurized process gas.*

Shock and Vibration

When the probe will be subject to excessive shock or vibration, the choice of probe, mounting method, and installation location needs careful consideration.

What Makes a Good Humidity Sensor?

Humidity sensor performance is a critical contributor to the overall quality of the humidity measurement. Consider the importance of the following sensor properties:

Fast Response Time

The sensor response time is the speed of response when the sensor is subjected to a step change in humidity. In addition to the sensor, factors such as temperature, airflow, and filter type all have an effect on response time. A blocked filter will give a slower response.

Optimal Measurement Range

The choice of humidity sensor depends on the application and operating temperature, especially at the extremes of humidity.

The majority of Vaisala's humidity sensors work over the full range from 0 to 100%RH. Vaisala HUMICAP® sensors are the optimal choice for applications with a relative humidity around 10–100%RH, whereas DRYCAP® sensors are designed for measurements in low humidities around 0–10%RH.

Good Chemical Tolerance

Aggressive chemicals can damage or contaminate sensors. The instrument manufacturer should know the effects of various chemicals on their sensors and be able to give advice related to acceptable chemical concentrations.

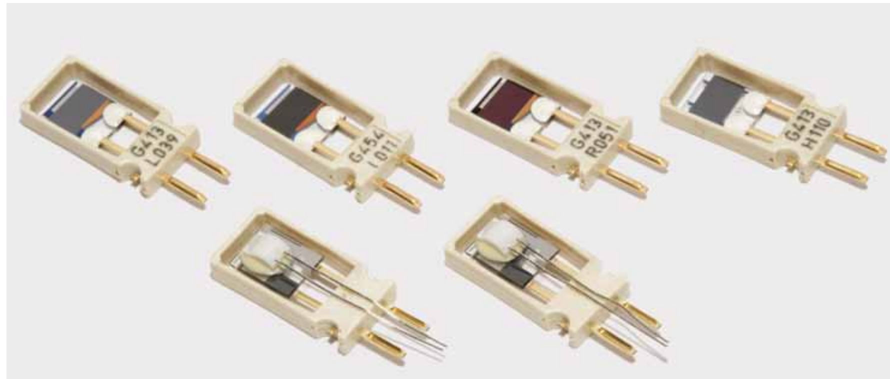
High Accuracy

Accuracy as a term is well established, but difficult to define. Each step in the calibration chain – from the primary standard in an internationally recognized calibration laboratory, to the actual product manufacture and the measurement on site – introduces measurement error. The sum of these potential errors is the uncertainty of the measurement.

When selecting a humidity sensor, consider the following factors associated with accuracy:

- Linearity over the working range
- Hysteresis and repeatability
- Stability over a period of time
- Temperature dependence of the sensor

During manufacture, Vaisala products are compared and adjusted against factory standards that are directly traceable to internationally recognized standards. The calibration chain is detailed in the certificates that are supplied with the majority of Vaisala products.



Humidity sensors from Vaisala.

The Right Humidity Instrument for the Job

Protective filters for Vaisala's humidity instruments.

No matter what the application, the total range of gas temperatures and expected water vapor levels must be known in order to decide the optimal humidity parameters and the optimal instrument for the environment. The process pressure must also be known when measuring humidity within the process. In addition, it must be decided whether to make the measurement at the process pressure or at some other pressure. For gases other than air, the gas composition must be known.

The terms probe, transmitter, and sensor describe products that measure humidity. The probe is the part of the product that contains the humidity sensor. The probe may be rigidly bound to the transmitter or connected with a flexible cable. The transmitter provides the output signal.

Vaisala designs and manufactures a range of products for measuring relative humidity, temperature, and dew point based on HUMICAP® and DRYCAP® sensors. All Vaisala humidity instruments feature built-in temperature compensation to minimize the errors caused by temperature variations and operation at extremes of temperature. Many of the products include built-in calculations for other humidity parameters.

Protect the Sensor and Electronics with the Right Filter

As well as screening the sensor from any stray electromagnetic fields, the filter protects the sensor from dust, dirt, and mechanical stress. A membrane or netting filter is a good alternative for the majority of applications. In temperatures above 80°C, in high pressure, or in rapidly moving air up to 75 m/sec, a sintered filter should be used.

A suitable protective enclosure protects the instrument electronics from dust, dirt, and excessive humidity. An enclosure with an IP65 or NEMA 4 classification gives good protection against dust and sprayed water. The cable entry points need to be sealed during installation.

When using the instrument outside, it should be mounted in a radiation shield or Stevenson screen to prevent solar radiation or extremes of weather from affecting the measurement.

Must the Instrument Tolerate Condensation?

Making good quality humidity measurements in near-condensing conditions is very challenging. Warmed probe technology ensures reliable measurements when measuring relative humidity close to saturation point. The humidity level of the warmed probe always stays below the ambient level, where condensation occurs.

Must the Instrument Withstand Exposure to Chemicals?

A chemical purge feature helps to maintain measurement accuracy in environments with a high concentration of chemicals or cleaning agents. The chemical purge heats the sensor at regular intervals to remove chemicals that may have accumulated over time.

The Importance of Electromagnetic Compatibility (EMC)

There are many standards defining the ability of products to withstand external electrical interference. In addition, the product must not generate emissions that can cause interference to sensitive equipment. Industrial applications have more demanding EMC requirements than HVAC installations – the CE marking used in Europe guarantees compliance.

Consider Wiring and Earthing

Except for short cable runs, a screened cable is recommended. Proximity to high-voltage cables or RF sources should be avoided. It is good practice to earth the connection cable screen at a common point and avoid multiple earth points. Galvanic isolation is also available on some Vaisala products.

Vaisala HUMICAP® Humidity and Temperature Transmitter Series HMT330 is a flexible product family designed for demanding industrial applications.

Which Power Supply and Output Signals are Needed?

The majority of measurement instruments are powered using a low voltage supply. If a low voltage AC supply is used, an isolated supply is recommended for each transmitter to avoid earth loops or interference from an inductive load.

Analog output instruments usually have an option for both voltage and current outputs. The choice depends on the length of the signal path and on the interfacing equipment. Some products have a 4–20mA loop power connection, which is a 2-wire system where the output signal current is measured in the supply line.

In addition to analog outputs, some Vaisala products feature digital communication via RS-232, RS-485, or LAN/WLAN interfaces. Selected commercial protocols (Modbus, BACnet) are also available.

Consider Calibration before Purchasing

Instruments typically need to be calibrated every year or every second year. Calibration requirements depend on the application and the stability of the instrument, with wide variations in how easy it is to carry out field checking and calibration. Some instruments need to be sent to a laboratory for calibration, for example. Understanding the calibration needs is therefore an important part of instrument selection.

Calibration Frequency

An individual calibration certificate for a particular instrument indicates the accuracy and linearity at the time of calibration. However, it does not reflect the stability of the instrument in the long run. Calibration at routine intervals is essential to understand the instrument's long-term stability.

Calibration frequency depends on the operating environment. A rule of thumb for Vaisala instruments is that yearly calibration is enough for HUMICAP® products, whereas in most applications a two-year calibration interval is suitable for DRYCAP® products. When measuring in constant high humidity (>85%RH), high temperature (>120°C), or chemically aggressive atmospheres, more frequent checks may be needed.

On-site calibration of a HMW90 humidity transmitter with a HM70 hand-held meter.

Humidity Instrument Calibration

In calibration, the humidity reading of an instrument is compared against a portable reference. The reference should be regularly calibrated and provided with a valid certificate. When selecting one of the many calibration methods, time, cost, technical requirements, expertise, and the unique needs of the organization must be balanced.

Portable meters and products that can be removed from the installation can be calibrated in an approved laboratory or returned to the instrument provider for calibration. Vaisala has four Service Centers around the world available for calibration.

Instruments installed in processes that operate within narrow boundaries can be calibrated using on-site one-point calibration that can be performed without disconnecting the instrument. One-point calibration can also be used to identify the need for further calibration and adjustment.

Some portables such as the Vaisala HUMICAP® Hand-Held Humidity and Temperature Meter HM70 or the Vaisala DRYCAP® Hand-Held Dewpoint Meter DM70 can be directly connected to the installed product and the readings compared to those on the portable meter's display.

In environments with large variations in humidity, multi-point calibration is recommended. Two-point or three-point calibrations can be accomplished in the field with the help of humidity-generating equipment, as long as the local environment is at a stable temperature. The advantage of multi-point calibration compared to one-point calibration is higher accuracy over the entire measurement range. Multiple humidity levels can be created with the Vaisala Humidity Calibrator HMK15, for example.

Vaisala Humidity Calibrator HMK15 for multi-point on-site calibrations.

Calibration of Dew Point Instruments

It is a demanding task to perform high-quality calibrations on low dew point instruments. For this reason, Vaisala doesn't recommend customers perform calibrations on Vaisala DRYCAP® products. Instead, they should be calibrated in professional calibration laboratories, such as Vaisala Service Centers. However, it is possible to perform a field check on a dew point instrument to identify whether adjustment is needed, using the Vaisala DRYCAP® Hand-Held Dewpoint Meter DM70.

To learn more about Vaisala's humidity instruments, visit www.vaisala.com/humidity.