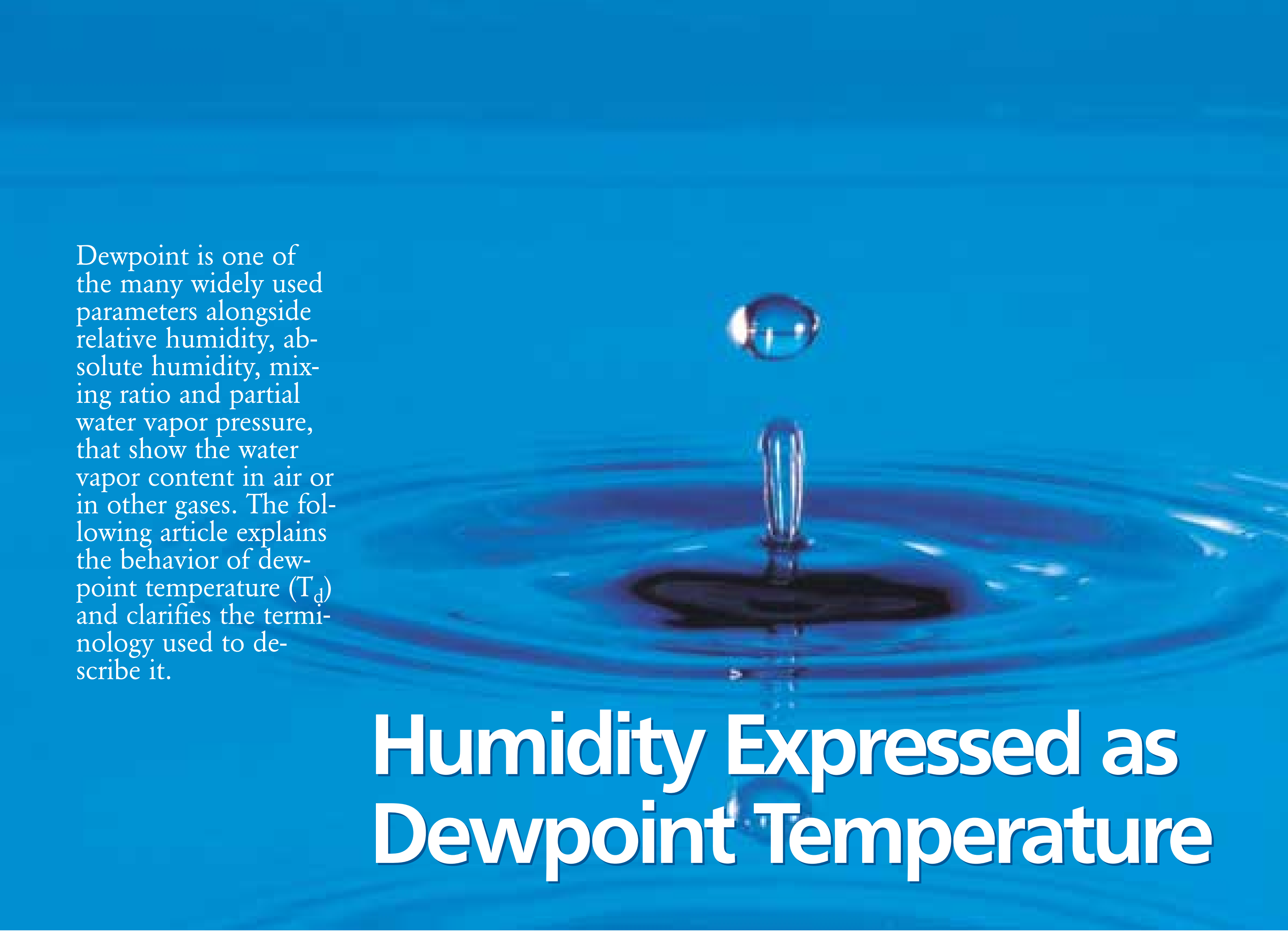

Dewpoint is one of the many widely used parameters alongside relative humidity, absolute humidity, mixing ratio and partial water vapor pressure, that show the water vapor content in air or in other gases. The following article explains the behavior of dewpoint temperature (T_d) and clarifies the terminology used to describe it.

Humidity Expressed as Dewpoint Temperature

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Dewpoint is defined as the temperature (°C or °F) to which air must be cooled for water condensation to begin, i.e. for air to become saturated with water vapor. At dewpoint temperature, the amount of water vapor present in the air is equal to the maximum amount of vapor air can hold at that specific temperature.

The capacity of air to hold water vapor is strongly dependant on temperature; warmer air can hold more vapor. This phenomenon is usually illustrated with a curve with water vapor saturation pressure as a function of temperature (Figure 1). At dewpoint, the partial water vapor pressure (P_w) in air equals the water vapor saturation pressure (P_{ws}). In this state, condensation and evaporation are in equilibrium and take place at the same rate.

Since the correlation between water vapor saturation pressure and temperature is known, the dewpoint can be calculated from the measured temperature and the relative humidity (Figure 1). This principle is used by some instruments with capacitive sensors to measure dewpoint in a gas.

A practical example of dewpoint is a glass of cold liquid on a warm summer day. If the temperature of the drink is equal to, or below, the dewpoint of ambient air, the air close to the glass surface cools down and becomes saturated with water vapor that condenses on the surface, forming water droplets called 'dew'.

Temperature changes

According to its definition, dewpoint is related to the amount of water vapor, i.e. the partial water vapor pressure, and is thus not dependant on temperature. This means that the dewpoint of a process with high temperature is equal to the dewpoint measured from a cooled sample of that process gas. However, if the gas sample is taken from the process to an environment where the temperature is below the process dewpoint, a dew formation appears, and this results in an inapplicable measurement.

Pressure changes

Dewpoint is a pressure sensitive parameter, because variation in total pressure changes the partial water vapor pressure according to Dalton's law:

$$P_{total}=P_w+P_{dry\ air},$$

Where the total pressure is the sum of the partial pressures of the gas components present: water vapor and dry air.

Pressurized air provides a practical example of what happens if the air at +20 °C is compressed from atmospheric pressure to a pressure of six bar (6000 hPa). We assume that the dewpoint of ambient air is +6°C (P_w=9.35 hPa), and that the temperature remains constant during compression. As the air is compressed, the partial water vapor pressure (P_w) is increased sixfold to P_w=56.1 hPa. The calculated dewpoint would then be +34.9 °C. However, dewpoint is always less than, or equal to am-

bient air temperature. Thus, dew formation would take place until the partial water vapor pressure is equal to the water saturation pressure at that temperature (23.4 hPa) i.e., dewpoint is the same as the actual air temperature, +20 °C.

Conversely, if a sample was taken from pressurized air (6000 hPa) with dewpoint of +3 °C to an atmospheric pressure of 1000 hPa, the dewpoint would then be –20 °C.

When using a measurement technology that cannot be installed in the pressurized process, but a sampling system is needed, the dewpoint in the process, which is sometimes called pressure dewpoint, has to be calculated from the measured value. However, new technologies have enabled measurements straight from the pressurized processes, thus obviating the troublesome logarithmic calculations.

Dewpoint or frostpoint

If dewpoint is below zero (0 °C), the term frostpoint (T_f) is often used. The water vapor saturation pressure over ice is slightly lower than that over supercooled water, i.e. ice gives off water vapor at lower rate (Figure 2). This must be taken into account when using a measurement technology in which the dew/frostpoint is a calculated parameter derived from relative humidity or from the partial water vapor pressure. As frost forms, it always occurs at a frostpoint that is different to dewpoint.

As in the case of dewpoint, the frostpoint can also be seen in practice by taking a package from a freezer to room temperature. In this case, the air close to the package cools down and becomes saturated with water vapor, which forms frost instead of dew, on the package surface.

Why dewpoint?

Dewpoint is a commonly used parameter to represent the amount of water vapor in dry applications such as pressurized air systems. In dry conditions, changes in dewpoint values are much larger compared to very small changes in relative humidity values, which gives dewpoint measurements an advantage in process control. For example, at room temperature, change in dewpoint from –40 °C to –45 °C corresponds to relative humidity from 0.81 % RH to 0.48 % RH.

In applications where gas pipes are installed outdoors, dewpoint is a useful parameter, because of wide variations in ambient air temperature. The gas should be dried to such a high degree that dew formation is avoided regardless of the temperature in the pipe, which means that dewpoint of the gas should be below the gas temperature in all conditions.

Chilled mirrors

One traditional method to measure dewpoint is a chilled mirror instrument where the mirror is cooled down until dew forms on it. The dew formation causes light to be scattered on the surface, and this is detected with optics. At the start of dew formation, the temperature of the mirror denoting dewpoint is read by a thermometer.

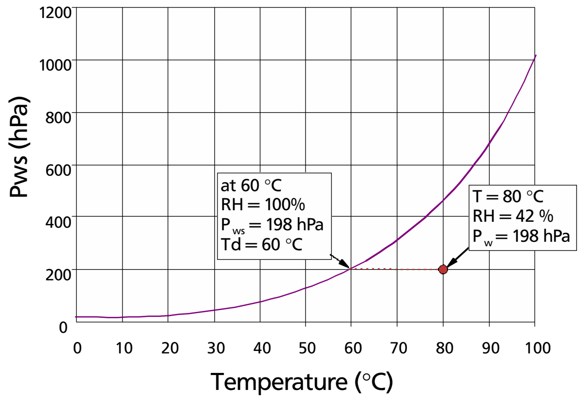

Figure 1. Water vapor saturation pressure P_{ws} as a function of temperature. Dewpoint of a gas at 80 °C and 42 % RH.

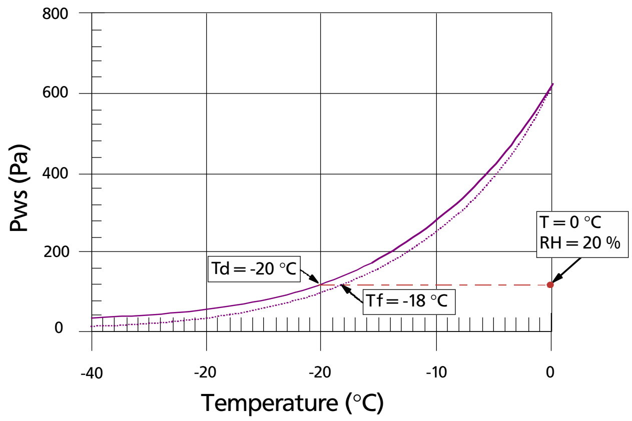

Figure 2. Water vapor saturation pressure P_{ws} over water (—) and ice (- - -). Dewpoint and frostpoint of a gas at 0 °C and 20 % RH.

This fundamental measuring technology is widely used as a calibration reference in laboratories because it gives very accurate results over a wide range of dewpoints. However, it cannot tolerate dusty environments due to its sensitive optics, and thus it is less commonly used for process control purposes.

With a chilled mirror instrument, dew, rather than frost, may also occur below freezing point, even down to –20 °C. Before frost, dew forms due to a lack of impurities on a very clean surface initializing the crystallization. This must be noted when comparing the readings of instruments using different technologies such as capacitive instruments, in which relative humidity or the partial water vapor pressure are the variables measured initially. The differences in the readings of the instruments may be due to the fact that one actually shows dewpoint and the other, frostpoint.

Capacitive instruments

Metal oxide sensors have been widely used in industrial processes for the past three decades. They have proved to be suitable for on-line measurement and tolerate dusty environments better than chilled mirrors. However, their poor long-term stability means there is a need for frequent calibration, which increases maintenance costs. Moreover, relatively high humidity may destroy the sensor e.g. if there is a drier malfunction in the process, or even during a system ramp up.

Recently, polymer sensors have also been introduced to dewpoint applications. Their advantages over the metal oxide sensors are that they tolerate condensing water and have far better long-term stability. The accuracy of polymer sensors has recently been improved to such a degree that they are reliable in applications with low dewpoints, even down to –70 °C. ■