5. Dew Point and Relative Humidity

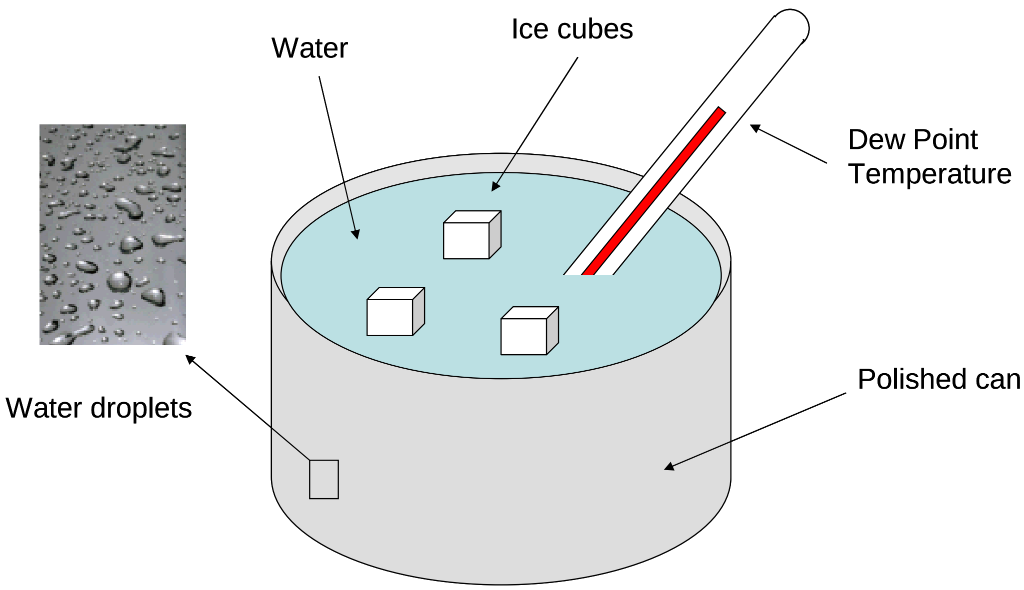
Dew Point Temperature (or, sometimes, just Dew Point) is the temperature at which the air becomes saturated with water vapor. At this temperature, any excess water vapor in the air precipitates as small droplets.

Many day-to-day phenomena are related to the Dew Point:

- The small droplets of water found in the morning on leaves;
- The fogged surface of a glass of cold beer;
- The night time fog, when the streets are wetted by a tiny drizzle, although no clouds are found in the sky; the warmer air in contact with the cold asphalt becomes chilled below its Dew Point, resulting in the condensation of water vapor as small droplets;
- The moistened windows, on the indoors side, in a cold day outside;
- Fogged car windows when it is cold outside and warm inside the car;
- The condensation on the surface of a mirror when one blows on it.
- Fogged mirrows and eyeglasses in the bathroom, when finishing taking a hot shower: the water vapor from the bathroom's warmer air condensate when reaching the colder glass surface.

The most accurate way to measure the relative humidity in the air ambient is by means of the Dew Point Temperature method, as indicated in Figure 1.

Measuring Dew Point Temperature



Start with water at ambient temperature. Add some ice cubes. Stir the water with a thermometer, until water droplets begin to appear on the can surface. Read the temperature: it is the dew point temperature of ambient air.

Figure 1: Precise Measurement of Dew Point Temperature

The Equations

When condensation begins, it means that the maximum mass of water vapor $\mathbf{m_{DEW}}$ that the air volume $\mathbf{V_{DEW}}$ can hold has been reached. If air temperature continues to decrease, the excess water is "extracted" from the air by means of condensation. This is the way air-conditioners reduce the ambient humidity.

According to the Ideal Gas Law (Annex A) at a given temperature $\mathbf{t_{DEW}}$ the maximum mass $\mathbf{m_{DEW}}$ is related to the saturation pressure of water vapor $\mathbf{p_S(t_{DEW})}$ (Annex C):

$$m_{DEW} = \frac{V_{DEW}\, M_W\, p_S(t_{DEW})}{R\, T_{DEW}} \qquad (1)$$

For example, in a volume $V_{DEW} = 1.0\ m^3$ at a temperature $t_{DEW} = 10^oC$:

$$m_{DEW} = \frac{1m^3\ 18\,(g/mol)\ 9.18\,(mmHg)}{0.06237\,(m^3\ mmHg/mol/^oK)\,(273.15+10)\,^oK} = 9.4\ grams$$

that is, one cubic meter can contain a maximum of 9.4 grams of water vapor at 10ºC.

If the volume $\mathbf{V_{DEW}}$ holding the mass $\mathbf{m_{DEW}}$ is <u>expanded</u> at constant pressure until an ambient temperature $\mathbf{t_{AMB}}$ and a volume **V** are reached (note that this is the exact situation in the ambient air: a water vapor density (m_{DEW} / V) at temperature t_{AMB}.), according to the Ideal Gas Law:

$$\frac{V_{DEW}}{T_{DEW}} = \frac{V}{T_{AMB}} \qquad (2)$$

and the maximum mass **m** of water vapor the volume **V** can hold is related to $\mathbf{p_S(t_{AMB})}$:

$$m = \frac{V\, M_W\, p_S(t_{AMB})}{R\, T_{AMB}} \qquad (3)$$

By definition, the relative humidity RH of the ambient is (m_{DEW} / m). Using expressions (1) to (3):

$$\boxed{RH\% = 100\ \frac{p_S(t_{DEW})}{p_S(t_{AMB})}} \qquad (3)$$

where $\mathbf{p_S(t)}$ is the saturation pressure (Annex C).

Note that if $\mathbf{t_{DEW}}$ and $\mathbf{t_{AMB}}$ are known, **the psychrometer is not needed** to compute the relative humidity of the air. On the other hand, the "can method" shown here may be used to check the accuracy of any humidity meter.

Example:

If ambient temperature is 20ºC and the dew point temperature is 10ºC, then the relative humidity will be 52.6%:

$$RH\% = 100 \left(\frac{9.18\,mmHg}{17.44\,mmHg} \right) = 52.6\%$$

Given RH, find t_{DEW}

Solving eq. (3) above for t_{DEW}

$$p_S(t) = K\ e^{\left(\frac{at}{b+t}\right)} \qquad \text{(Annex C)}$$

$$\boxed{parcel = (b + t_{AMB}) Log_e\left(\frac{RH\%}{100}\right)}$$

$$\boxed{t_{DEW} = b\left(\frac{a\,t_{AMB} + parcel}{a\,b - parcel}\right)}$$

where (Teten formula, Annex C):

a = 17.2694
b = 238.3 ºC

Example:

A psychrometer indicates that the relative humidity in a room is 52.6%, and the temperature is 20ºC. What should be the windows temperature for the windows to start getting fogged ?

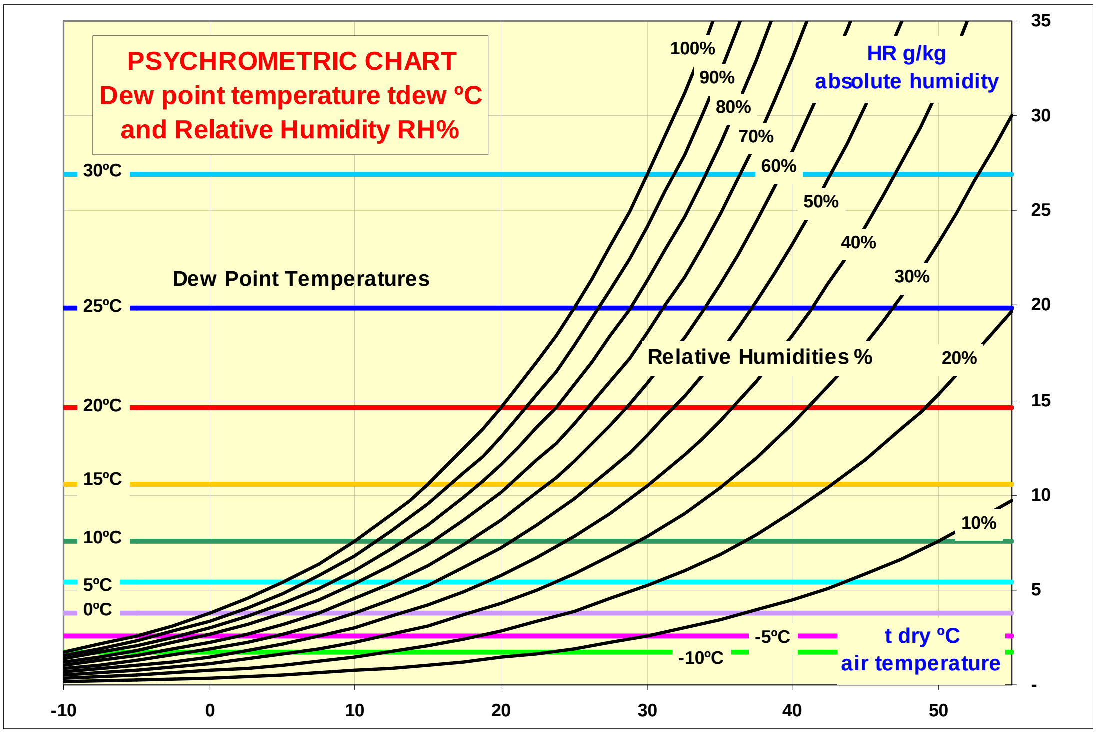
$$parcel = (238.3 + 20)\ Log_e(52.6/100) = -165.95\,^oC$$

$$t_{DEW} = 238.3\ \frac{17.2694 * 20 - 165.95}{17.2694 * 238.3 + 165.95} = 10^o\,C$$

Therefore, the windows will start getting fogged when they reach 10ºC or less. Since the room temperature is 20ºC, this implies that the outside temperature should be even lower than 10ºC (heat transfer).

Putting all together

The graph that follows shows how Dew Point and Relative Humidity are related to Ambient Temperature and to Absolute Humidity. It is included in the Excel spreadsheet "Psy-Chart-XLS.xls", which is part of this paper.


PSYCHROMETRIC CHART
Dew point temperature tdew ºC
and Relative Humidity RH%
Dew Point Temperatures
Relative Humidities %
HR g/kg
absolute humidity
t dry ºC
air temperature
100%
90%
80%
70%
60%
50%
40%
30%
20%
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