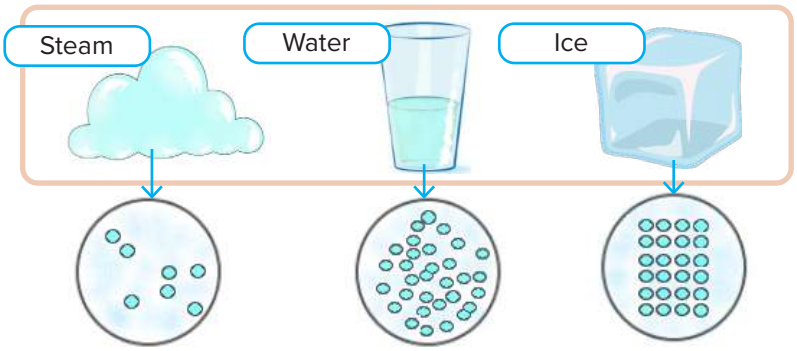
Isothermal & Adiabatic Humidification Fundamentals

What is humidification?

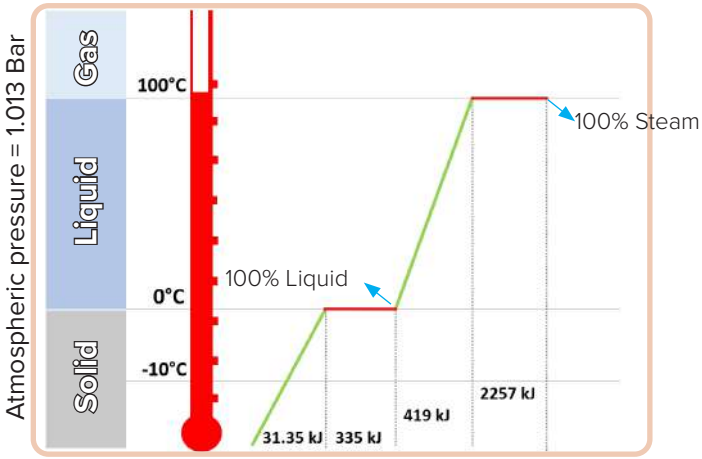
Humidification is the process of adding water vapour to the air.

Air: Air is a mixture of gases. It is normally colourless, invisible and odourless. The mixture consists of nitrogen (78%) and oxygen (21%) and other gases (1%), it also contains water vapour and is variable.

Water is the only component of air that can easily and naturally change phase: liquid, solid and gaseous.



In order for water to change state (or phase) it must absorb or release energy. One form of energy is called sensible because it allows the water temperature to increase or decrease (in any state) and another form is called latent energy because it allows the water to change state without any temperature variation.



In psychrometry, we also consider that air has two types of energy: sensible & latent energy.

Sensible energy: the supply of sensible energy to the air increases its temperature and can be measured by a dry bulb thermometer.

Latent energy: corresponds to the quantity of water in the air. We also remind you that water is the only element in the air able to change phase. Water vapour in the air is a sensible form of energy storage, measurable by a wet and dry bulb thermometer. Adding steam directly to air does not change its temperature.

Dry bulb thermometer

Dry & wet bulb thermometer

Total air energy (enthalpy) = sensible energy + latent energy

There are two types of humidification: isothermal & adiabatic

ISOTHERMAL

(*or steam injection*)

from Greek **ἴσος (iso)**
which means «equal»

➜ done at the same temperature

It is a humidification which is done by direct supply of steam from boiling water. Technically the air does not undergo any temperature variation (if there is no condensation factor of the water vapour).

The sensible energy has been theoretically kept equal, while the latent energy has increased, so the **total energy of the air has increased.**

In this process the air is passive, the supply of steam is forced (until saturation or even condensation), the air does not lose energy, on the contrary, it gains energy.

Steam is produced by boiling, caused by the direct supply of energy to a volume of water.

ADIABATIC

(*or evaporation*)

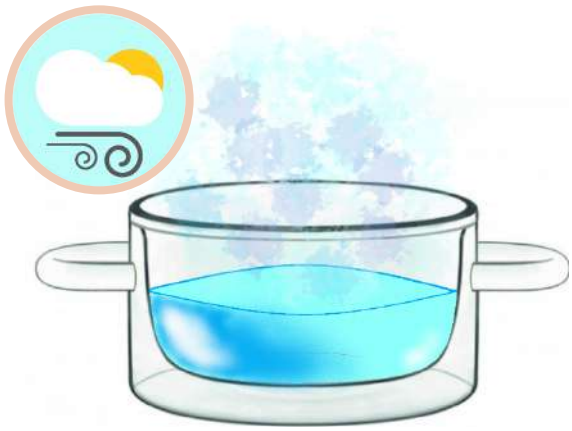
from Greek **ἀδιάβατος (adiabatos)**
which means «impassable»

➜ done without total energy loss or gain

It is a humidification which is done by evaporating the free water surface, by supplying sensible energy from the air.

The air is cooled and humidified: it has lost sensible energy and gained latent energy, the **total energy has remained equal.**

In this process, the air is active and exchanges its sensible energy with the water (usually saturation is never reached unless there is an aftercooling).



Steam is produced at the free surface of the water by the supply of sensible energy from the air.

Humidification on psychrometric diagram

STEAM INJECTION HUMIDIFICATION

Example 1

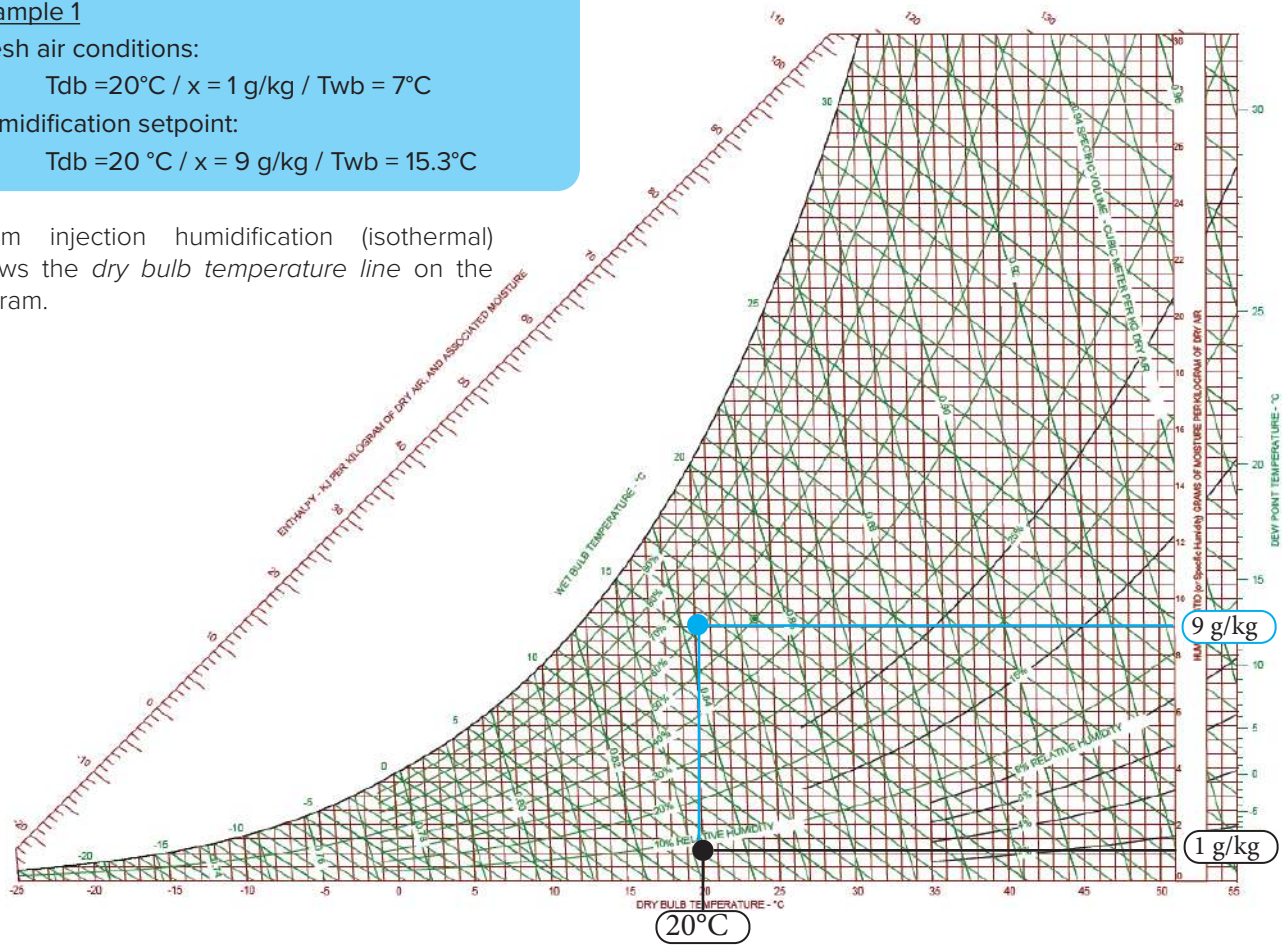
Fresh air conditions:

Tdb =20°C / x = 1 g/kg / Twb = 7°C

Humidification setpoint:

Tdb =20 °C / x = 9 g/kg / Twb = 15.3°C

Steam injection humidification (isothermal) follows the *dry bulb temperature line* on the diagram.



EVAPORATIVE HUMIDIFICATION

Example 2

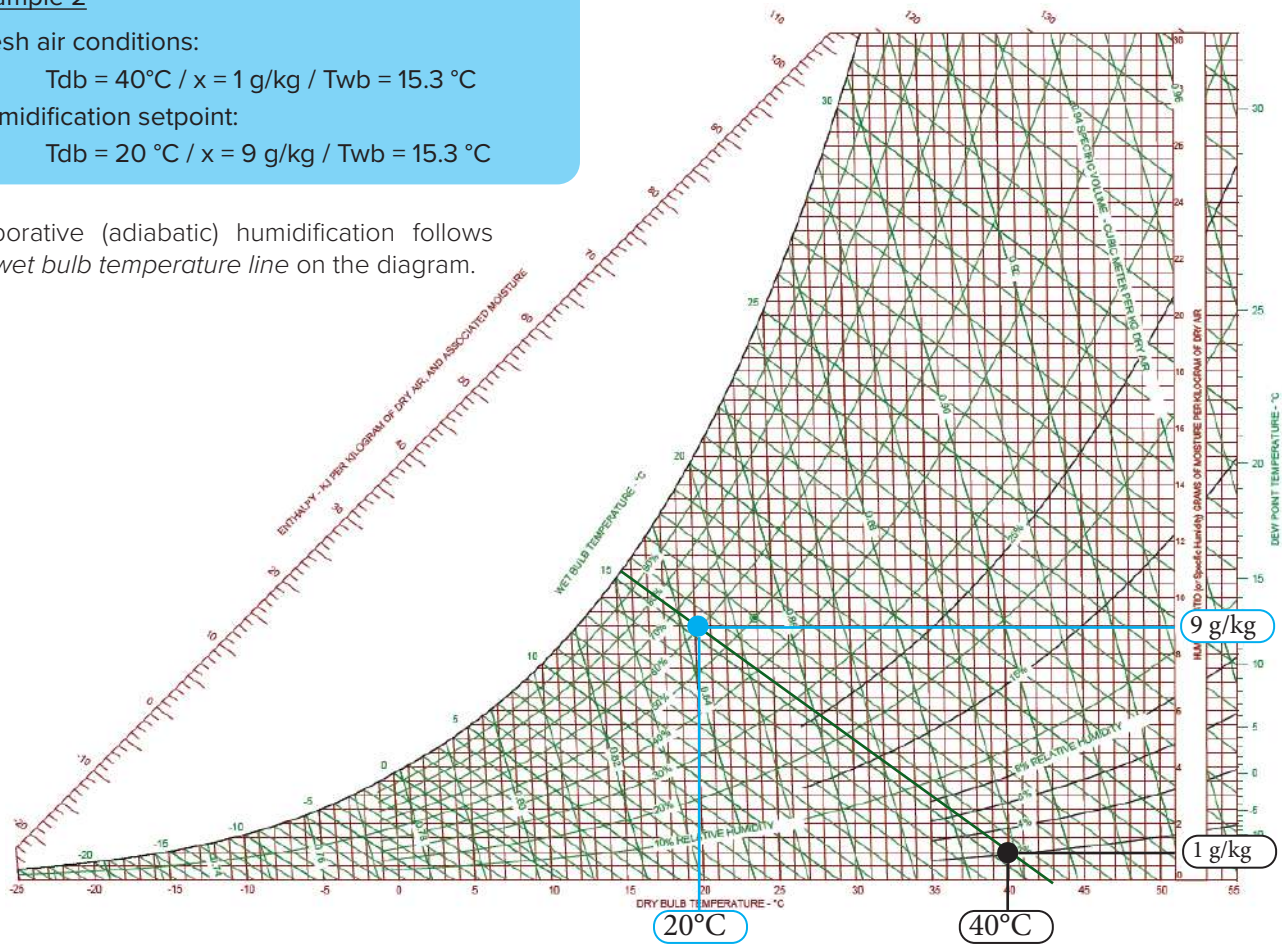
Fresh air conditions:

Tdb = 40°C / x = 1 g/kg / Twb = 15.3 °C

Humidification setpoint:

Tdb = 20 °C / x = 9 g/kg / Twb = 15.3 °C

Evaporative (adiabatic) humidification follows the *wet bulb temperature line* on the diagram.



Humidification : calculate humidity intake

In order to calculate this amount, we need to know the air flow rate and its humidity ratio variation.

The formula to be used is the following:

W (kg/h) = Q (m^3/h) ✖ 1.2 (kg/m^3) ✖ Δx (g/kg) / 1000

W = Amount of humidity added or removed from the air
Q = Air flow rate
Δx = Humidity ratio variation

Case Study :

Calculation of humidity ratio variation :

For the example 1 from Tdb = 20°C / x = 1g/kg to Tdb = 20 °C / x = 9 g/kg
Δx = 9-1 = 8 g/kg

For the example 2 from Tdb = 40°C / x = 1g/kg to Tdb = 20°C / x = 9 g/kg
Δx = 9-1 = 8 g/kg

If we take an air flow rate = 10 000 m^3 / h, for both examples, the humidity supply is therefore:
W = 10 000 x 1.2 x (9-1) / 1000 = 96 kg/h

Isothermal or adiabatic humidification ?

This choice depends on the energy sources available, their cost and environmental impact.

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