“Inert” evaporative cooling using a minimum of water

“Inert cooling” is a new development based on indirect dew point cooling, using evaporating water as a refrigerant and 100% fresh air. The water supply has been developed in accordance with a recent invention, which helps to lower the so-called water surface-tension and minimize the use of water by absorption. It can also utilise evaporating seawater.

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Air handling in combination with evaporative cooling using water (R718) as a refrigerant is an answer to the F-gas- and CO2-policy. However, there is a lot of misunderstanding regarding the various types of evaporative cooling, like Direct or Indirect, Adiabatic or Diabatic, and Wet bulb or Dew-point cooling. They all discharge only the sensible heat. In general, evaporative cooling brings down the energy consumption for air conditioning systems by between 70% and 85%, and COP‘s above 20 are no exception. Besides the need for a very low energy consumption, there is now an increasing demand for the system to operate with low water consumption. Legionella and corrosion must also be points of attention.

Design criteria

- The choice: direct/ indirect.
- Adiabatic (wet bulb cooling) or diabatic (dew-point cooling).
- Evaporating water as refrigerant:
  - (potable) mains water (should be minimized as much as possible);
  - spring water;
  - salt (sea)water.
- Water distribution:
  - gravity without a pump;
  - (re)circulation with a pump;
  - sprinkle (nozzles);
  - absorption.
- Free from Legionella, bacteria and algae:
  - with or without water treatment?
  - descaling
  - demi-water
  - surface tension
- Materials:
  - not be susceptible to corrosion.
  - preferably the use of synthetic materials.

Adiabatic and Diabatic

Linguistically the word Adiabatic means Non-Diabatic.

During an adiabatic process, the heat itself is taken from the air and not supplied or taken via the cooler surface (in a Mollier diagram this process is drawn with lines of constant enthalpy = h). Theoretically the lowest temperature that can be achieved is the wet bulb temperature, hence the use of the term Wet Bulb Cooling.

During a diabatic process however, there is an exchange of heat between cooler surface and air. In this case the lowest temperature theoretically possible is the dew-point temperature, hence the use of the term Dew-point Cooling. (in **Figure 1** (Mollier diagram) this process is drawn with lines of constant absolute moisture = gr/kg)

Direct cooling systems

Only available as adiabatic (wet bulb) Cooling

Direct adiabatic cooling makes use of a wetted absorbent, an air filter and fan. The air to be cooled is blown through the absorbent, evaporating a part of the water. The energy needed for evaporation is directly withdrawn from the air by cooling it. The discharge temperature depends on the temperature and relative humidity of the air entering the process. These systems mostly use a water circulation pump and means to prevent legionella and bacteria growth.

- These coolers add moisture to the air entering the cooled room, resulting in both a lower room temperature and also an increasing relative humidity (%RH). **Note the contrasting effect**: A lower temperature will be more comfortable, but a higher RH will be experienced as uncomfortable. The latter is especially

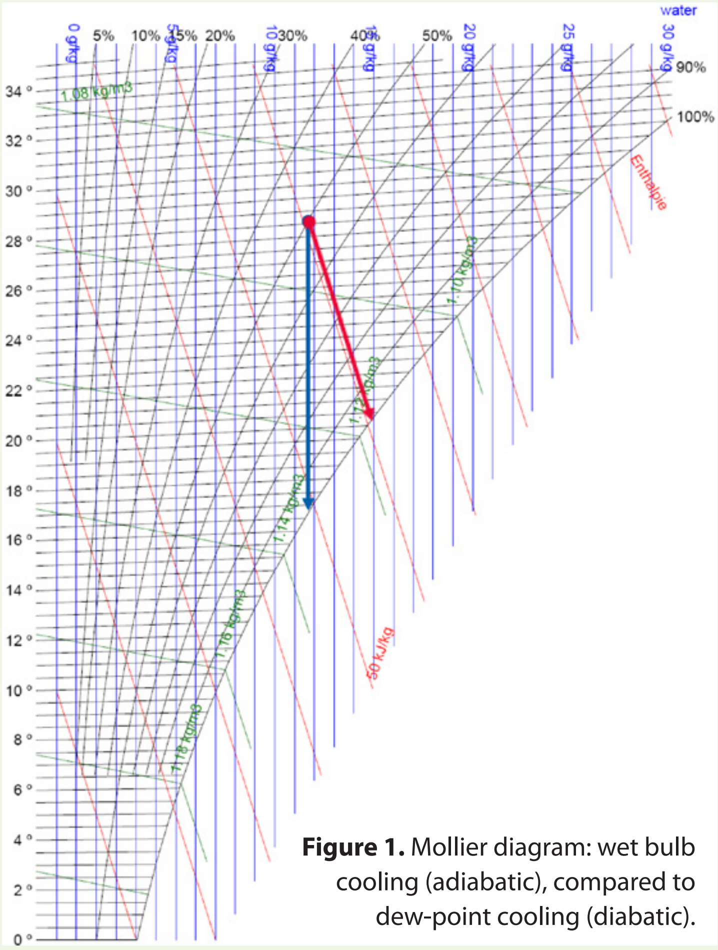


Figure 1. Mollier diagram: wet bulb cooling (adiabatic), compared to dew-point cooling (diabatic).

Example:

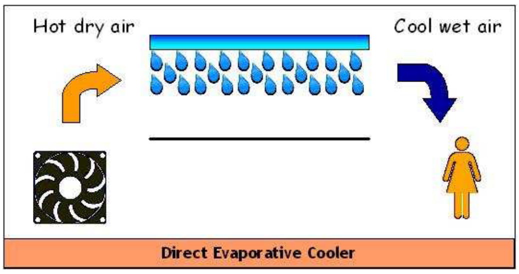
Temperature..28°C
Absolute humidity...11.9 g/kg
RH...50 %
Dew-point (blue) ....16.6°C
Wet bulb temperature (red)..19.4°C
Difference... 19.4°C – 16.6°C = 2.8°K

this will differ from case to case.

If the temperature of the sucked-in ambient air is higher, this causes a higher wet bulb temperature and so a higher outgoing temperature. This is in contrast with the dew-point temperature, which will not change if the temperature rises. Minimum temperature achievable is a few degrees K (Kelvin) above the wet bulb temperature.

the case when we are dealing with gyms, workshops or other places where physical exertion is taking place, as it is more difficult to perspire in a high RH environment.

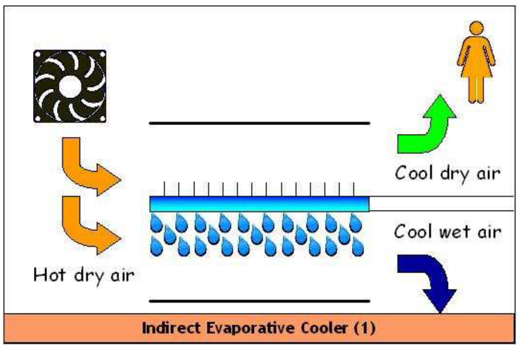
- Direct cooling also might give problems to stored goods and electronics. It is therefore mostly used in dry (desert) climates or in moderate climates only for industrial purposes.
- The minimum discharge temperature of cooled air is a couple of degrees Kelvin above the wet bulb temperature. However, if during the daytime the ambient temperatures rises because of the sun and the absolute humidity (gr/kg) remains the same, the wet bulb temperature will also rise, resulting in a higher outgoing (cooled) air temperature.



Indirect cooling systems

Available as adiabatic (wet bulb) and diabatic (dew-point) cooling

- The vaporized water as a result of the cooling process, will be discharged to the ambient and will not influence the % RH in the room to be cooled.
- Indirect systems are available either as wet bulb cooling or as dew-point cooling each with its own characteristics.



Indirect wet bulb cooling (adiabatic)

- The minimum discharge temperature is a couple of degrees K above the wet bulb temperature. Another outcome, if the ambient temperatures rises during the day, is that the wet bulb temperature will rise, resulting in a higher outgoing (cooled) air temperature.

Indirect dew-point cooling (diabatic)

- The minimum discharge temperature is a couple of degrees Kelvin above the dew-point temperature.
- Comparted with wet bulb cooling, and depending on the temperature and humidity, both the dew-point temperature and cooled air temperature will be between 2 K and 4 K lower.
- If during the daytime the ambient temperature rises, and at the same time the absolute humidity (gr/kg) remains the same, the wet bulb temperature will stay the same and consequently the outgoing (cooled) air temperature will not change. It will, in fact, stay almost the same for the whole day.

Inert cooling

Inert cooling is a new development based on dew-point cooling, an extreme low energy consumption, and suitable to operate in an aggressive polluted ambient with almost any quality of evaporating water. A couple units are now in operation.

This type of dew-point cooling uses only one fan for both the primary air and the process air, resulting in a minimum of moving parts. The outside of the heat exchange plates is covered with a wetted hygroscopic foil.

At the end of the heat exchanger, 33% of the cooled air leaving the cooler becomes process air. This is caused by turning the air 180° and returning it in counter flow along the outside of the heat exchanger plates by using the available extern pressure drop (in ducts and grilles of the building to be cooled) as the driving force. Due to this turning process and a forced air flow (no suction), a centrifugal force is developed and, as a consequence, dirt particles will not be taken into the process air stream. As the dirt particles aren't able to contaminate the cooler surface, there is no pollution and less maintenance costs. Cooling is a natural process existing of a water supply by the combination of falling film, adhesion (foil to plate) and hygroscopic operation of vapor. The amount of heat (kJ) taken from the primary air is equal to the amount of kJ necessary for evaporation of the moisture. The process air discharges the evaporated moisture towards the open air and cannot enter the conditioned room (**Figure 2**).

It is a commonly acknowledged that air can be aggressive in combination with moisture in coastal areas, swimming pools, cattle and poultry, near chemical plants, etc. The use of demineralised water, with $NH4^+$, or salt can also cause corrosion problems. This explains why inert cooling systems are entirely made of synthetic materials.

The use of fresh water can be a problem in certain areas and has to be limited as far as possible, but salt (sea)water is always largely available. The system was successful when tested using sea water for a 6-month period. The use of saltwater is only possible if the whole unit (housing and cooling surface) is made of synthetic material. It is possible to prevent salt crystals by using indirect dew-point cooling with absorption wetting and combined with an overflow of seawater, instead of with nozzles.

Water consumption

In general, the water consumption depends first of all on the amount of air to be cooled, the temperature and humidity of the admitted air. Besides that, also the system as well as the way of wetting has influence.

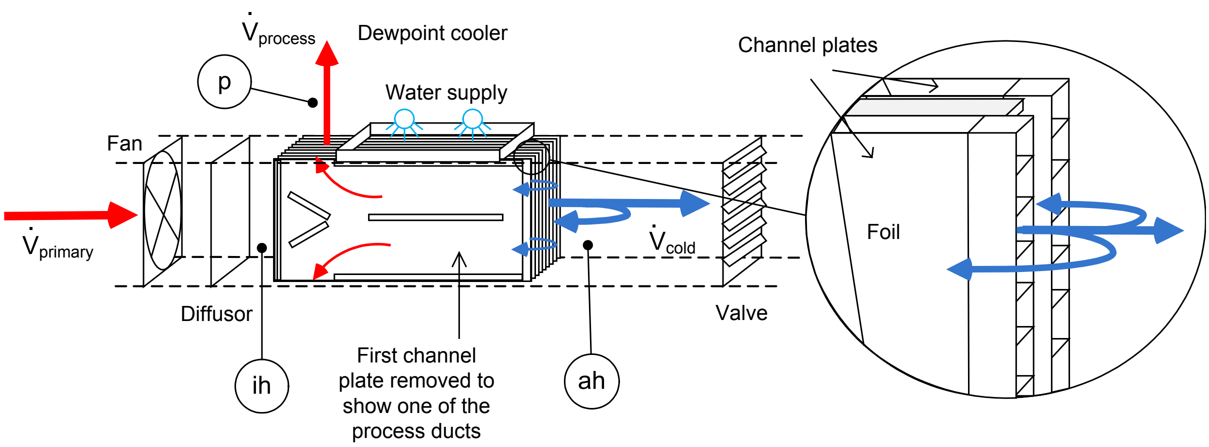


Figure 2. Principle layout of the dew-point cooler.

Based on evaporating, the water supply temperature has practically zero influence on the cooling capacity.

Various methods of water supply

- Constant pump recirculation in combination with a water container
- Without a (re)circulation pump, so using the pressure of mains water supply.
- The use of nozzles for the water distribution. Disadvantage: nozzles can -depending on the water quality- clog, so requires maintenance.
- The water supply can be controlled by periodical opening and closing a solenoid valve in the water supply.

Using Inert cooling:

- A new development water supply is based on absorption, without pump circulation and without the use of nozzles, using the mains water pressure. It takes care of a very constant water flow, with little waste of water and brings down the water surface tension (patent pending).
- Inert cooling is also suitable for evaporating salt (sea) water

Micro-biological aspects of inert cooling

- The cooled air keeps the same absolute humidity during the whole cooling process without any condensation, so stays dry.
- The humidified process air is discharged towards the outside ambient and due to the use of a wetted hygroscopic foil on the process plate surface, as well as a low process air velocity (< 2 m/s), no aerosols will be formed.
- Growth of algae will not occur, because the cooler operates without re-used water circulation, has no water collector and the hygroscopic layers are automatically dried once a day and as soon as the cooling stops. ■

Test

The test data below was recorded last year (2015) in a sports hall, situated close in the seacoast and a blast furnace, so a polluted area, using absorption water supply, so without nozzles.

Primary ambiant air intake:

Air flow .... 4 500 m^3/h

Dry bulb .... 22.0 °C

Wet bulb .... 16.0 °C

% Humidity .... 54.0 %

Dew point .... 12.3 °C

Abs. moisture .... 8.9 gram/kg

Process air:

Air flow .... 1 485 m^3/h

V = 33 % process air leaving .... 96% to 98%

Cooled air:

Air flow .... 3 015 m^3/h

Dew point .... 12.3 °C

Abs. moisture .... 8.9 gram/kg

V cold = cooled air leaving at: .... 14.3 °C

Results:

- According to a simulation program which is based on using water supply by nozzles, the cooled air should be 16.2 °C, however the now reached temperature is 14.3°C.
- 16.2 – 14.3 = 1.9 K lower than according to the simulation program (in this case 33% increase and average 25%). Reason: an optimal and constant water distribution compared with the use of nozzles.
- In this case: 1.7 K below the wet bulb temperature (16 – 14.3) and 2 K above dew-point (14.3 – 12.3).

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