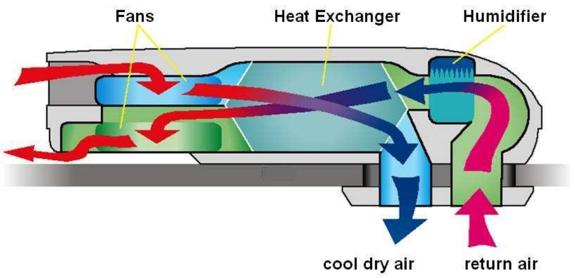
Factsheet

9 mar. 2009

Indirect evaporative cooling

When water evaporates from a surface, the surface is cooled down. The “other side” of the surface can then be used as for cooling down an air-stream, without adding water to that air stream. This is the principle of indirect evaporative cooling.
Another possibility is to use one airstream that is directly evaporative cooled (see *Factsheet Evaporative cooling – direct*) and thus becomes humid, and to provide the “cold” of this airstream to a second dry airstream by means of a heat exchanger.

An indirect evaporative cooler uses a humidifier to cool down one airstream by means of direct evaporative cooling (see *Factsheet Direct evaporative cooling*). This cooled down humid airstream is led through an air to air heat exchanger, where it cools down a second airstream without adding moisture to the second airstream. The heat exchanger is of the same type as those found in “heat recovery units” (HRU’s). A water pump is needed to circulate the water, this circulation of water is necessary to prevent any water soluble substances from depositing on the evaporative surfaces. Water must be drained from the reservoir to prevent building up of too high concentrations of soluble materials. Sometimes chemicals are added to the water to prevent microbiological growth (e.g. legionella pneumophila bacteria).



Evaporative coolers can be found in applications for cooling homes or for mobile cooling (caravans, campers).

Capacity

The amount of water that can be evaporated into ambient air (Δx in kg water / kg air) depends on the initial and final conditions of the air that is humidified, especially the relative humidity (φ in %) and saturated water vapour pressure (P_{sat} in Pascal). In this case the air that is humidified is the return air from the space that is cooled.

$$\Delta x = 0{,}622 \cdot P_{sat} \cdot \{ \varphi_{final} / (P_{ambient} - P_{sat} \cdot \varphi_{final}) - \varphi_{return\ air} / (P_{ambient} - P_{sat} \cdot \varphi_{return\ air}) \} \quad [kg/kg]$$

In this formula $P_{ambient}$ is the ambient pressure, which is normally 101325 Pascal (1 atm). The saturated vapour pressure (P_{sat} in Pascal) is highly dependent on temperature. The amount of “cold” generated – or better, amount of heat absorbed – Q is equal to the amount of evaporated water per time interval (*time* in seconds), multiplied with the heat of evaporation (2500,6 kJ/kg):

$$Q = 2500{,}6 \cdot \Delta x / time \quad [kW]$$

The absolute humidity of the cooled air that enters the room to be climatized, is equal to the absolute humidity of the outdoor air. It’s relative humidity is higher, as the temperature is lower. The temperature of the cooled air depends on the size and efficiency of the evaporating surface, with values from 95 % to almost 100 % and on the efficiency of the heat exchanger (typically 95 – 98 %). The final temperature of the outgoing air is in between the initial temperature and the wet bulb temperature. When the outgoing air would be fully saturated (φ_{final} = 100 %) the temperature would be equal to the wet bulb temperature T_{wb}.

$$T_{final} = T_{initial} - \{ \text{efficiency}_{heat\ exchanger} \cdot \text{efficiency}_{evaporation} \cdot (T_{return\ air} - T_{wb}) \}$$

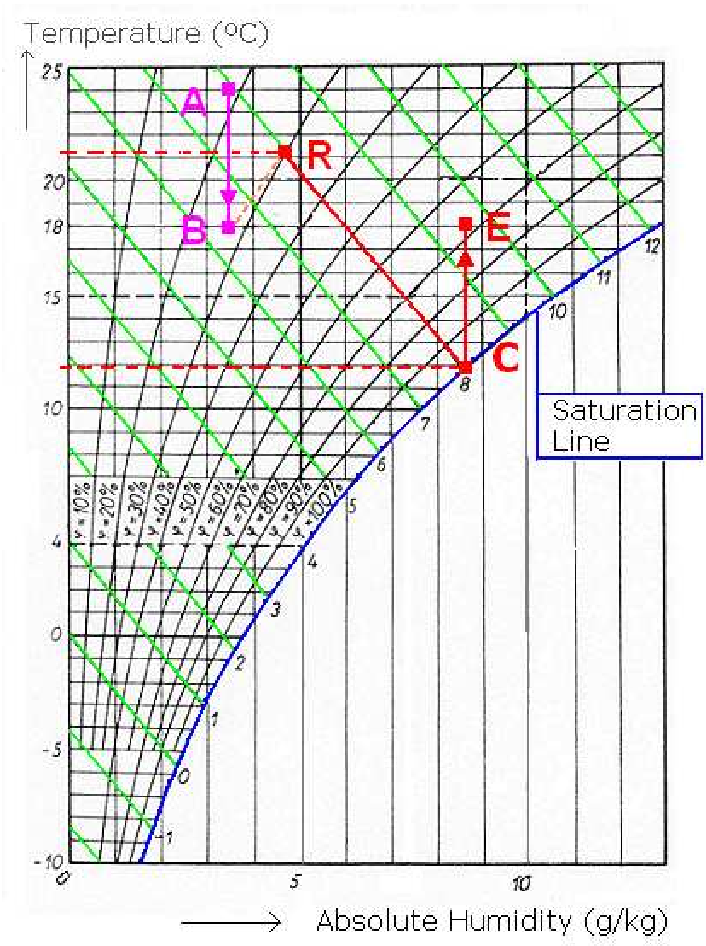


Figure 1. Mollier Diagram

The Mollier Diagram presents conditions of moist air. In the example points indicated in this figure, the initial condition of air at a temperature of 24 ºC and a relative humidity of 19% is marked “A” (Ambient).

This air is cooled down in the heat exchanger, while keeping the same (absolute) water content. This is depicted by a line going straight down in the graph, from “A” to “B”.

A second line of the same length, going straight up from “C” to “E” (Exhaust) depicts what happens on the other side of the heat exchanger: here the air is heated up without changing water content.

The line from point “R” (return air) to point “C” depicts the adiabatic cooling in the humidifier. In practice, point “C” will not be on the saturation line, which is only the case when the humidification is perfect.

Finally, the dotted line between points “B” and “R” represents the take-up of heat and moisture in the room that is climatized. When no moisture is added in this room, the line would go straight up (constant water content). When more heat is added, point “R” will be higher in the graph. This also shows that the behaviour of the system changes when the heat load in the room to be climatized changes. For when point “R” is moved, all other points (excluding the outdoor condition “A”) will also change.

caravan cooler 400 m3/hr

Costs

Costs for a direct evaporative unit of 400 m3/hr are estimated at 1000 Euro (2008) excluding installation. Running costs include costs for electricity (fan & pump), water (and possibly water treatment chemicals) and maintenance.

Table: Specifications for a small indirect evaporative cooling unit. Unit size 400 m3/hr.
Coefficient of performance (COP) equals Cooling Capacity (kW) divided by electrical power input (kW).
Unit contains one fan (full power 0,11 kW) and one water pump (0,02 kW).
Where the desired temperature is higher than or equal to the outdoor condition, cooling is “free”
Where the desired temperature is lower than the wet bulb temperature, direct evaporative cooling is not possible (NA).

Desired Temperature	**Outdoor conditions**					
	25ºC / 50%		**15ºC / 50%**		**5ºC / 50%**	
	Capacity (kW)	COP	Capacity (kW)	COP	Capacity (kW)	COP
18 ºC	0,85	3.7	(free)	-	(free)	-
5 ºC	NA (under T_{wb})	-	NA (under T_{wb})	-	(free)	-
0 ºC	NA (under T_{wb})	-	NA (under T_{wb})	-	NA (under T_{wb})	-
-18 ºC	NA (under T_{wb})	-	NA (under T_{wb})	-	NA (under T_{wb})	-

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This renewable cooling research is executed with practical input by NVKL and financial support by the Dutch Ministry of Economic Affairs; program *Energie Onderzoek Subsidie: lange termijn (EOS-LT)*.