Factsheet 9 mar. 2009

Evaporative cooling – two-stage

Evaporative cooling was already used in ancient Egypt. By using porous jugs and letting the water evaporate from the surface, the contents were cooled. Heat is needed to evaporate the liquid. This heat is taken from the jug surface, which in turn cools the contents.
Nowadays evaporative cooling is used, based on the same principle, to cool buildings. Clever “two stage” designs are introduced, to use the cold without increasing air humidity, and to cool below the wet bulb temperature limit.

A single stage (direct) evaporative cooler takes in dry air, evaporates water into the dry air, and discharges the moist air, which has dropped in temperature.
Theoretically, the wet bulb temperature is the lowest output temperature one can get from a direct evaporative cooler; it is reached when the air is saturated with water (relative humidity 100 %). In practice, heating by the fan (dissipation) and humidification below 100% will result in output temperatures above the wet bulb temperature.
More details on direct evaporative coolers can be found in *Factsheet Evaporative cooling – direct*.

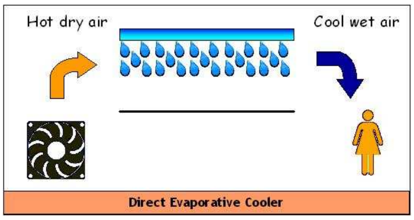

Figure 1. Direct evaporative cooler.

The advantage of direct evaporative coolers is that they operate at very low energy costs, and perform well in hot and dry climates. These coolers are called “swamp coolers” in the USA. A the big disadvantage of these direct evaporative coolers is the high humidity of the air that is discharged. At warm temperatures this becomes uncomfortable when the humidity is over 60%.

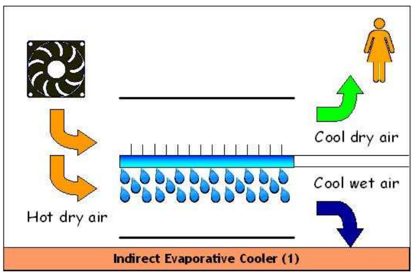

Figure 2. Indirect evaporative cooler (1).

The most obvious solution to the problem of high humidity in the cool air, is to use the moist, cool airstream for cooling a second airstream (which is not by itself moisturized). This principle is known as indirect evaporative cooling. There are a number of possible configurations for creating an indirect evaporative cooler, of which Figure 2 shows the simplest setup. Here, the “dry” side of the evaporating surface is formed as the heat exchanger surface.
Unfortunately, this is not a very effective setup, because a part of the produced “cold” is discharged to outdoors with the cool wet air stream. Nevertheless, these systems are on the market both in residential size and industrial size.

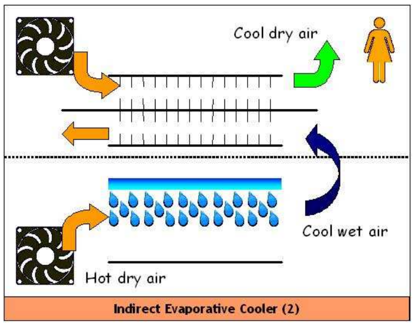

Figure 3. Indirect evaporative cooler (2).

A setup that doesn’t “waste” so much of the moisturized air is shown in Figure 3 where a heat exchanger is placed after the humidifier section. The amount of “cold” produced that is useable, now depends on the efficiency of the heat exchanger. The heat exchanger can be the same as in traditional, mass produced, Heat Recovery Units. The disadvantage is obvious: a second fan is needed to create the airflow in the “dry” channel. The lowest temperature that can be obtained with this setup is close to the wet bulb temperature – but never completely, since there will remain a temperature difference across the heat exchanger.

It is possible to reduce costs for the indirect evaporative cooler with separate heat exchanger - the setup (2) according to Figure 3 - by not using ambient air as input to the humidifier, but to use the return air instead. This air is pre-cooled, and thus needs less additional cooling to reach it’s wet bulb temperature. The humidifier section therefore can be smaller, saving costs. Refer to setup (3), Figure 4.

Note that, when the return air has taken up much heat, e.g. when the space to be cooled is infiltrated with outdoor air, the cooling effect of the small humidifier will small.

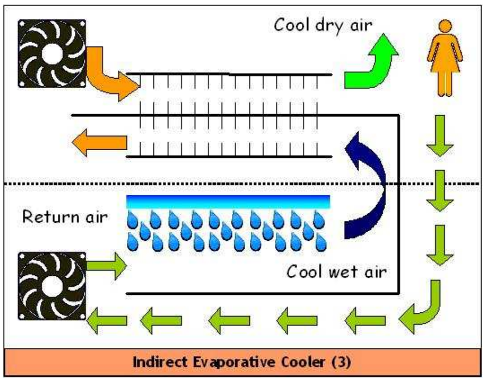

Figure 4. Indirect evaporative cooler (3).

More information on this type of indirect evaporative cooler is given in F*actsheet Indirect evaporative cooling*.

It is interesting to notice that with this setup, temperatures below the wet bulb temperature of the outdoor air can be reached, when the wet bulb temperature of the return air is lower than the wet bulb temperature of the outdoor air.

Two-stage evaporative cooler: dew point cooler

An interesting setup of the indirect evaporative cooler, known in the Netherlands as a "dew point cooler", is given in Figure 5. It is an efficient setup, which uses only one fan and where the humidifier and the heat exchanger have been combined - similar as in indirect evaporative cooler (1) (Figure 2).

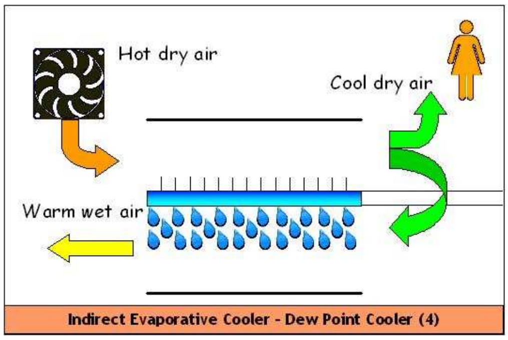

Figure 5. Indirect evaporative cooling - Dew point cooler.

In this setup too, it is possible to reach temperatures below the wet bulb temperature of the ambient air, as the incoming air is first cooled down at constant water content (and thus it's wet bulb temperature decreases). The (theoretical) limit of the temperature of the cool dry air is the dew point temperature of the incoming air.

All indirect evaporative coolers have the advantage that the cooling air is not humidified, which is not only an advantage in terms of comfort, but also in terms of hygiene: bacteria that can multiply in humid environments, cannot reach the climatized area.

Costs

Costs for an indirect evaporative unit of 400 m3/hr according to setup (3) are estimated at 1000 Euro (2008) excluding installation. Costs for a commercial sized dew point cooler, 7500 m^3/hr primary air and 5000 m^3/hr useful air, are estimated at 7500 Euro (2008) excluding installation costs.
Running costs include costs for electricity (fan & pump), water (and possibly water treatment chemicals) and maintenance.

Table: Specifications for a commercially sized dew point cooling unit. Unit size 7500 m^3/hr primary, 5000 m^3/hr useful

Coefficient of performance (COP) equals Cooling Capacity (kW) divided by electrical power input (kW).
Unit contains one fan (7500 m3/hr primary air, pressure 400 Pa, input power 1,6 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 is very close to dew point of outdoor air, and may not be reachable in practice

Desired Temperature	**Outdoor conditions**					
	25ºC / 50%		**15ºC / 50%**		**5ºC / 50%**	
	Capacity (kW)	COP	Capacity (kW)	COP	Capacity (kW)	COP
18 ºC	11,7	7,4	(free)	-	(free)	-
5 ºC	NA (under T_{dp})	-	17,2 (*)	10,9	(free)	-
0 ºC	NA (under T_{dp})	-	NA (under T_{dp})	-	9,0	5,7
-18 ºC	NA (under T_{dp})	-	NA (under T_{dp})	-	NA (under T_{dp})	-

Contact: *Sietze van der Sluis*, TNO, Phone +31.88.8662206 email Sietze.vanderSluis@tno.nl
Jan Broeze, AFSG Wageningen UR, phone +31.317.480147, e-mail jan.broeze@wur.nl
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