AIR CONDITIONING USING R718 (WATER) AS REFRIGERANT

P.G.H. Uges
StatiqCooling BV
Heliumstraat 8
NL-7463 PL Rijssen, The Netherlands
Fax.; +31 (0)548 545342
E-mail: info@statiqcooling.com

ABSTRACT

Static cooling is a development regarding an indirect operating air conditioning system based on the evaporation of only water (R718) and suitable for moderate (like in Europe) and warm climates. This system consumes very little energy (up to 75 % less). Temperatures below the wet bulb temperature can be achieved. It characterizes itself also by, no pollution and almost no maintenance costs . The only moving part is one fan. Static Cooling implies that no condensation will occur during the cooling process. The heat is taken “indirectly” from the air by means of a heat exchanger, made of only synthetic materials. The absolute humidity of the air-to-be-cooled remains unchanged during the cooling process. The air is cooled below the wet bulb temperature by means of a hygroscopic layer on the external cooler surface. The disengaged humidity does not enter the room to be conditioned, but disappears into the open air. From a micro-biological point of view, it is important to know, that there is no water collector filled with water, that no aerosols are formed and so no Legionella bacterium can be transported. Growth of algae will also not occur, because the hygroscopic layers are automatically dried when the cooling process stops.
Static cooling is an alternative to the use of F-gasses and an answer to the CO2-policy. It makes cooling possible where this would hardly be feasible because of insufficient supply of energy.

1. INTRODUCTION

Static Dew Point Cooling is a development regarding an indirect operating evaporative air conditioning system, based on the evaporation of water (R718) and still suitable for any capacity, used for larger systems. This system consumes very little energy (up to 75 % less). Temperatures can be reached below the Wet Bulb temperature. This type of cooling is only suitable to cool sensible heat.
Static Dew Point Cooling characterizes itself by almost no maintenance costs. This, and the low energy consumption, contributes greatly to the fact that the total running costs are considerably lower than those of a traditional air conditioning installation. The only moving part in the Static Dew Point Cooler is the fan at the air inlet. The system has been developed for moderate and warm climates, like in most European countries.

Using Static Dew Point Cooling is an answer to the proposed European F-gasses policy and the existing CO2-policy. It makes cooling possible where this would hardly be feasible because of insufficient supply of energy or using too much energy.

In 2004 we received, after a joint application, ”The Asercom Energy Efficiency Award 2004” for this development.

2. EVAPORATIVE COOLING

2.1. Direct Adiabatic (Wet Bulb) Cooling

Direct Adiabatic Cooling is an adiabatic process resulting in a Wet Bulb temperature to be found on the saturation line in the Mollier diagram for moist air (fig. 2.) according to h = constant. If water and air are in direct contact, the minimum attainable temperature is the Wet Bulb temperature.
Example (fig 2.): 28°C and 50% RH Wet Bulb is 20,3 °C.

Direct Adiabatic Cooling systems are also for sale under the names Desert Cooling and Wet Bulb Cooling. They consist of a wetted absorbent material, 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 evaporating is directly withdrawn from the air by cooling it. As can be seen in the Mollier diagram for moist air (fig. 2.), the discharge temperature depends on the temperature and relative humidity of the entering air.
Direct Adiabatic Cooling saves a lot of energy but unfortunately, these coolers add moisture to the air entering the conditioned room. Because of this the relative humidity increases greatly with, in moderate climates, the risk of mildew on walls and goods. It is therefore mostly used in dry (desert) climates and only in moderate climates if the high humidity is no problem. Systems like this require special cleaning/maintenance and care to prevent the growth of algae and the risk of Legionella.

2.2. Indirect Adiabatic Cooling

Because of this mildew and Legionella risk, a logical next step was the development of systems based on indirect adiabatic evaporative cooling, supplied with a spraying chamber and a cross-stream heat exchanger. In this system the humidified air disappears towards the ambient. The lowest possible achievable temperature is a few degrees C above the Wet Bulb temperature. These indirect adiabatic cooling systems have been on the market for some time, but are not widely used, because of their complexity and costs.

2.3. Indirect Static Dew Point Cooling

To increase the performance of the indirect adiabatic cooler and to reach lower temperatures (even below the Wet Bulb temperature), the Static Dew Point Cooler has been developed
It is a system mostly used for larger air quantities (4000m3/h and more), without a process fan, without a circulation pump, without a water collector and without a purging device; hence the name “Static Dew Point Cooler.” A system with almost no maintenance involved.

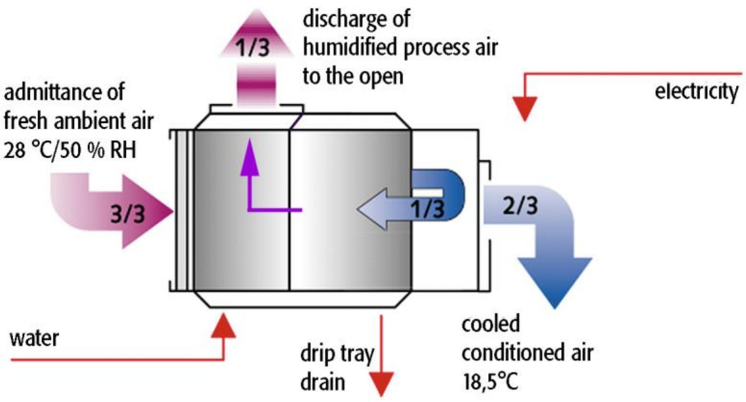

Figure 1. Principle diagram

3. CHARACTERISTICS

3.1. Circumstances

- When cooling air, without direct humidification, no condensation will occur until the Dew Point .
- In unsaturated air the Dew Point temperature is lower than the Wet Bulb temperature.
- The absolute humidity of the air-to-be-cooled remains unchanged during the process.

Indirect Dew Point Cooling implies that no condensation will appear during the whole cooling process. That means at temperatures above and below the Wet Bulb (between Wet Bulb and Dew Point).

3.2. Choice of material

Materials should not be susceptible to corrosion.
It is a known fact that air can be aggressive in combination with moisture in coastal areas, swimming pools, stables, near chemical plants, etc. Also the use of demineralised water can cause corrosion problems.
Because of that, only synthetic materials such as polypropylene are used.

3.3. Technical requirements and safety

- Ventilation energy is cooled away instantly, so the cool discharge temperature is almost equal to the air temperature entering the conditioned room.
- Special care is taken to keep the heat exchange surface properly moisturized with the right quantity of water at various cooling demands.
- Controlling the relation of the two separate air flows involved, at varying capacities.
- No humidity from the cooling process is entering the space-to-be-cooled.
- There is no Legionella risk.

4. THE COOLING PROCESS

4.1. Using water (R 718) as cooling medium

Dew Point Cooling is based on evaporation of water by means of an absorbent layer on the external surface of the heat exchanger plates (the process air side).
In this absorbent layer, a constant evaporating water film is maintained. Temperatures below Dew Point can only be reached as an indirect process and by using counter flow.

4.2. The process

The process (diagram: fig. 1.) takes place in a heat exchanger made of a synthetic material.
At the end of the heat exchanger, approximately one third of this cooled air is re-routed as process air. This in counter flow and along the external surface of the heat exchanger plates, covered with an absorbent (hygroscopic layer). Evaporation of the existing moist in this layer, indirectly takes place, using energy from the primary air, flowing on the other side of the plate wall.
As mentioned before, the absolute humidity of the air-to-be-cooled remains unchanged during the cooling process. If the air is cooled until the point where condensation will occur, the Dew Point temperature is reached. (Mollier diagram for moist air: fig. 2.).
Evaporation of the existing moisture in the absorbent layer cools the primary air ”indirectly” The amount of kJ taken from the primary air is equal to the amount of kJ necessary for evaporation of the moisture and warming the process air. The process air discharges the evaporated moisture towards the open air and can not enter the conditioned room.

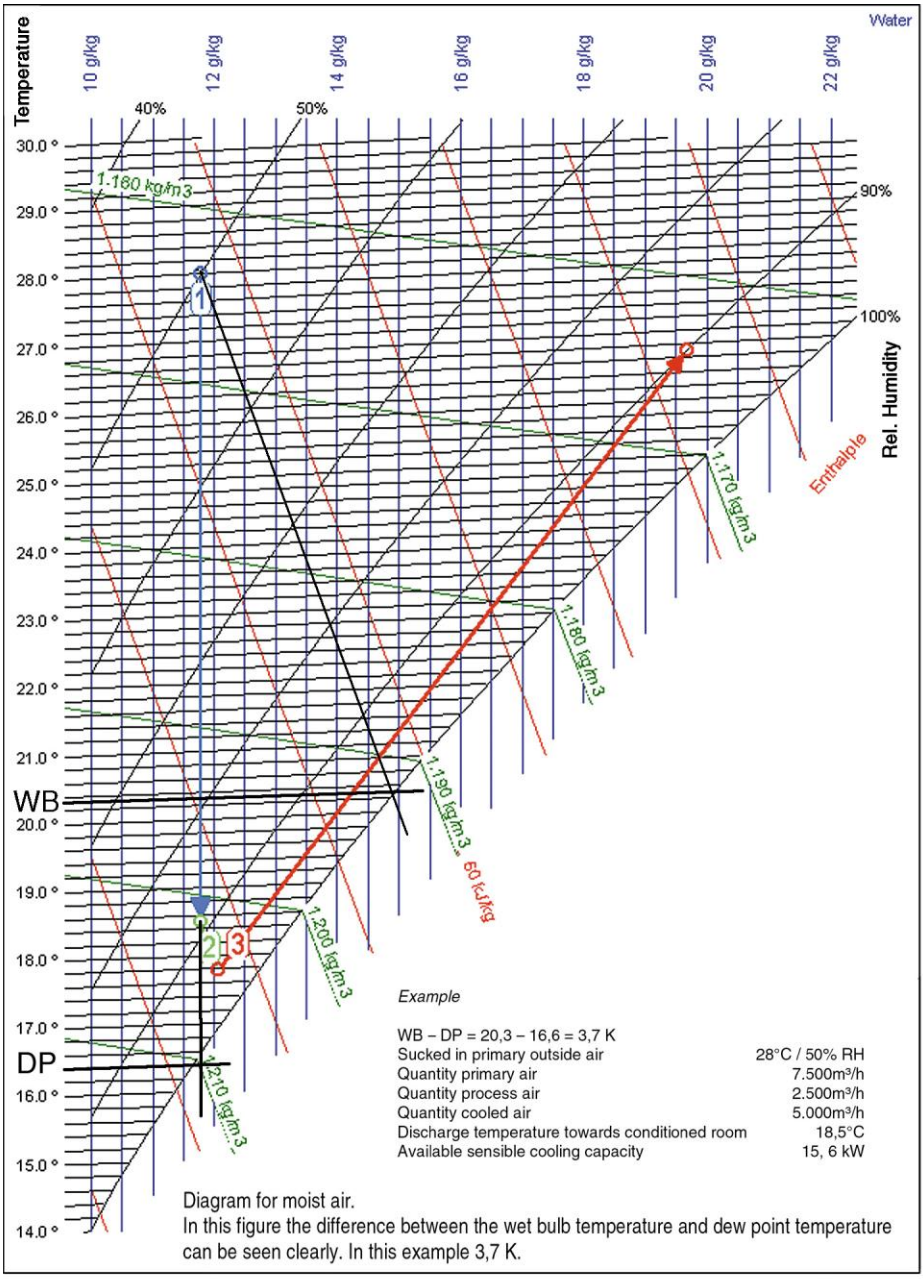

Figure 2. Mollier diagram for moist air

- In the explanatory Mollier diagram (fig. 2. point 1.), primary air of 28°C/50% R.H. (11,8 gr humidity /kg air) is admitted and cooled down to 18,5°C.
- At the end of the heat exchanger, approximately one third of this cooled air (fig. 2. point 2: 18,5°C/87%) is re-routed and becomes process air.
- At this point (fig. 2. point 2.) the process air enters the wetted process area.
This almost adiabatic (h = constant: 47 kJ/kg) picks up moisture until it reaches 95% (fig. 2. point 3: 17,8°C/95%).

- From there (fig. 2. point 3.) the process air stops reacting adiabatic and starts reacting diabatic by picking up moisture and heat along the wetted outer surface of the heat exchanger plates, until is leaves toward the ambient. (at 26.5°C/92%).

This diabatic process and the use of only one fan, makes this type of cooling so unique.

4.3. Example / kg air

Fresh air admittance (F kg)	Conditioned cooled air (C kg)	Process (discharged) air (P kg)
28,0°C / 50%: = 57 kJ/kg	28,0°C / 50% = 57 kJ/kg	18,5°C / 87% = 47,0 kJ/kg
18,5°C / 87%: = 47 kJ/kg	18,5°C / 87% = 47 kJ/kg	26,5°C / 92% = 77,3 kJ/kg
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Diff. = 10 kJ/kg	= 10 kJ/kg	= 30,3 kJ/kg

F = 1 kg air
10 kJ/kg = 30,3 kJ/kg x P kg ~ 3/3 air volume
P = 0,33 kg ~ 1/3 air volume
C = 1,00 – 0,33 = 0,67 kg ~ 2/3 air volume

These results are achieved depending on the application, with an energy consumption, which is approximately 75 % lower than in a conventional system.

4.4. Water consumption

The water consumption depends largely on the quantity of air to-be-cooled and the absolute humidity of the admitted air. It will use no more than approximately 5 litres per 1000m3 cooled air.

5. MICRO-BIOLOGICAL ASPECTS

5.1. Legionella

The conditioned air is not moisturized in the Dew Point Cooler. From a micro-biological point of view this is an advantage, because humidity is the prominent factor for micro-biological growth.
It is impossible for micro-biological contamination to occur, as humidification only takes place in the process air flow. This process air is discharged into the open air.
- Due to the fact that the process airspeed is low (< 2 m/s), no aerosols are formed, with which the Legionella bacterium could have been transported.
- Growth of algae will not occur, because the Static Cooler operates without re-used circulation water, has no water collector and the hygroscopic layers are automatically dried as soon as the cooling process stops.

5.2. Cleaning

The first Static Coolers were put in operation six years ago. To-day coolers with capacities from 5000m3/h to 20.000m3/h conditioned air, are in operation.
Until to-day no cooler has had to be cleaned, this owing to the fact that:
- The internal surface of the synthetic plates in contact with the primary air, is smooth and dry.
The air speed in the plates is 4 to 5m/s and therefore dust particles which are not removed by an air filter, do not settle as deposit;
- The used 30% process air, as part of the already cooled air, turns 180° to enter the cooler again in counter flow.

As a result of the centrifugal force, existing dust particles will not turn, but follow their way into the air duct, resulting in almost no pollution of the cooler surface.

A Static Dew Point Cooler was opened after four years running with no maintenance at all and found almost clean, thus proving that cleaning of the cooler is not needed.

Outside air temperature	Relative Humidity Outside Air 30%	40%	50%	60%	70%	
20 °C	10,5 °C	12,0 °C	13,5 °C	15,0 °C	16,5 °C	Indirect Dew Point Cooling*
20 °C	13,0 °C	14,5 °C	15,5 °C	16,5 °C	17,5 °C	Direct Adiabatic Cooling **
25 °C	13,0 °C	15,0 °C	16,5 °C	18,5 °C	20,5 °C	Indirect Dew Point Cooling*
25 °C	17,0 °C	18,5 °C	20,0 °C	21,0 °C	22,0 °C	Direct Adiabatic Cooling **
30 °C	16,0 °C	18,5 °C	20,0 °C	22,5 °C	25,0 °C	Indirect Dew Point Cooling*
30 °C	21,0 °C	22,5 °C	24,0 °C	25,0 °C	26,5 °C	Direct Adiabatic Cooling **

* Minimum discharge primary air temperatures, leaving the heat exchanger at point 2 fig. 2 and partly based on test results. Temperatures measured at fig. 2. point 2.

**Data from catalogue third party

Figure 3. Comparing discharge temperatures