IS INDIRECT EVAPORATIVE COOLING (IEC) AN ALTERNATIVE OR A COMPLEMENT TO MECHANICAL COOLING IN COMMERCIAL BUILDINGS IN BELGIUM?

The history of evaporative cooling and the situation of the IEC in Belgium

22 april 2021

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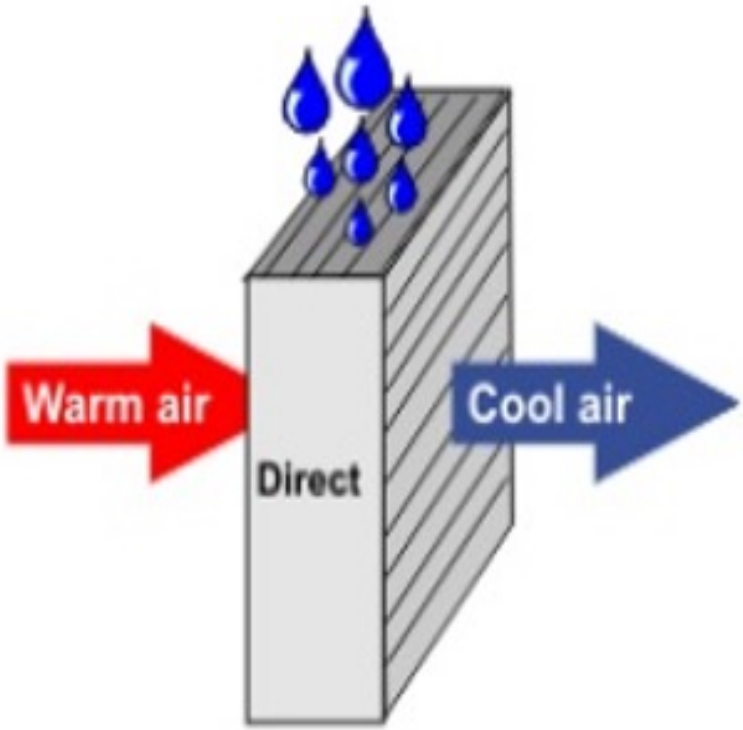
DIRECT EVAPORATIVE AIR COOLING.



- The water is sprayed or flows by gravity along a run-off surface through the air stream
- The heat of vaporisation of water is drawn from the air stream, which is thus cooled and humidified
- The process DEC or Direct Evaporative Cooling is mainly known and used for humidification and more rarely to cool the air in buildings

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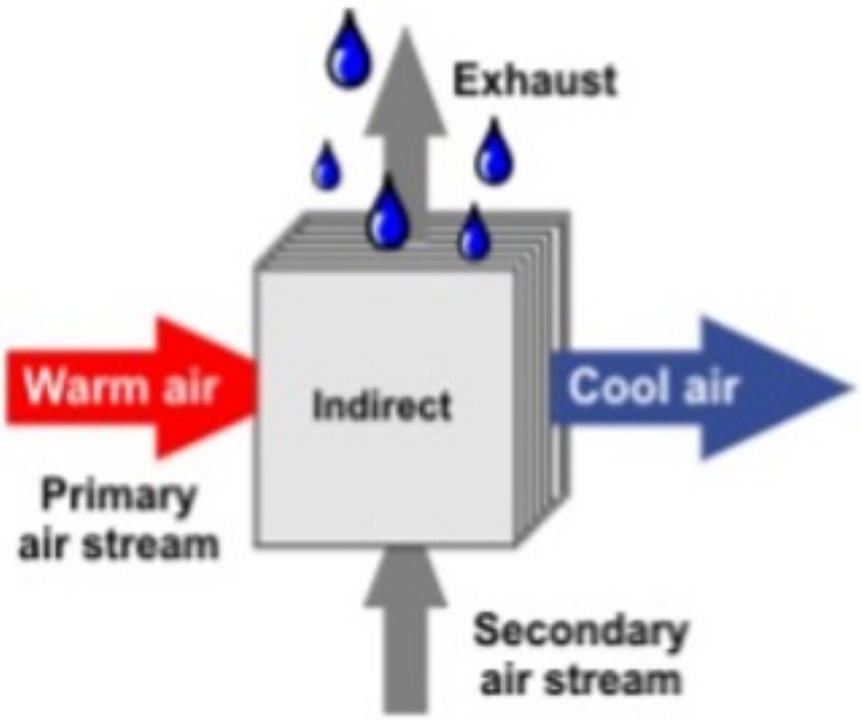
INDIRECT EVAPORATIVE AIR COOLING.



- The primary air is cooled sensibly by a heat exchanger, thanks to the secondary air which absorbs the thermal energy, necessary for the evaporation of water, in the primary air.

- The process IEC or Indirect Evaporative Cooling appeared in AHU (air handling unit) in the 1990s. The objective is the cooling of air

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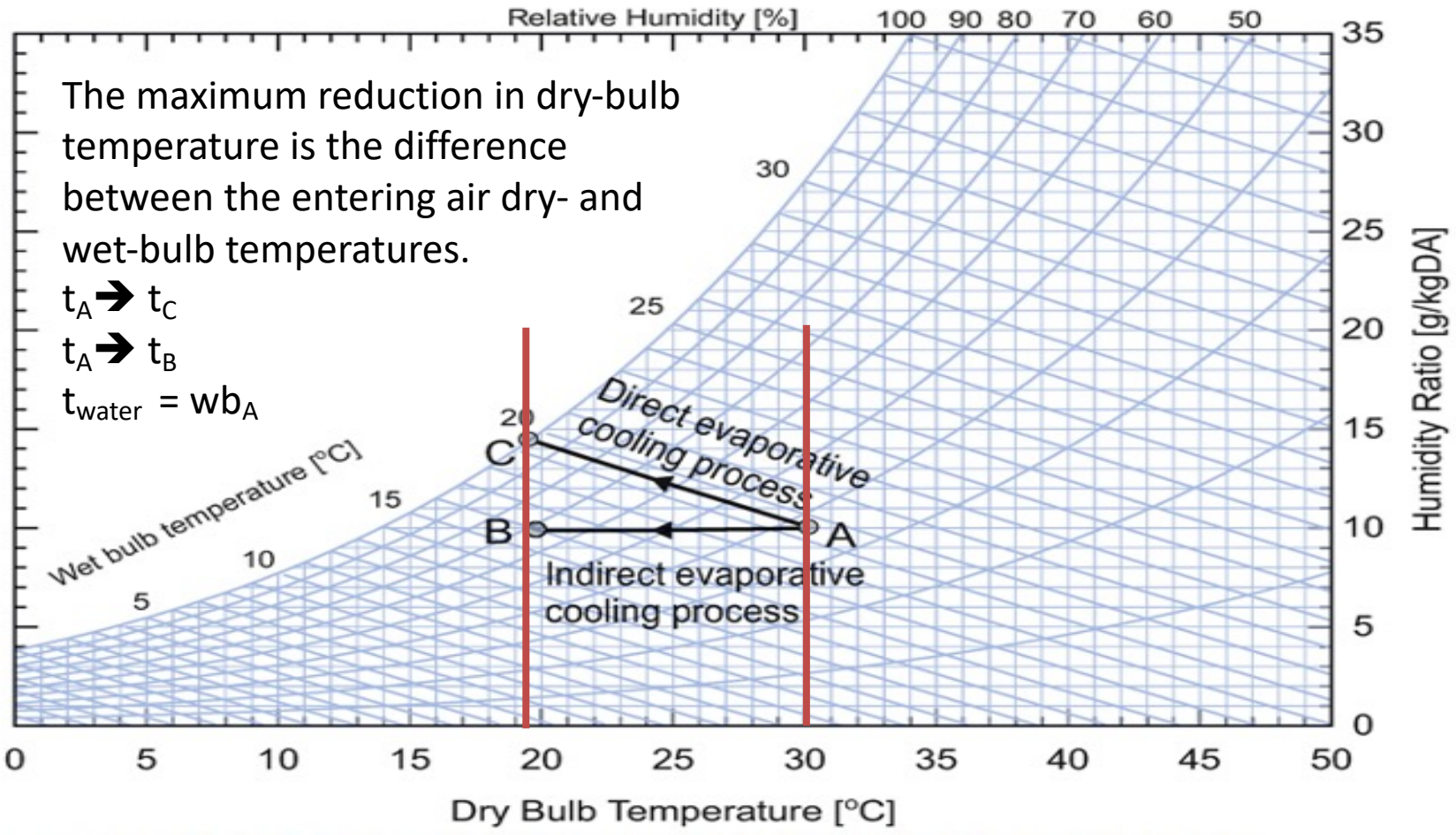
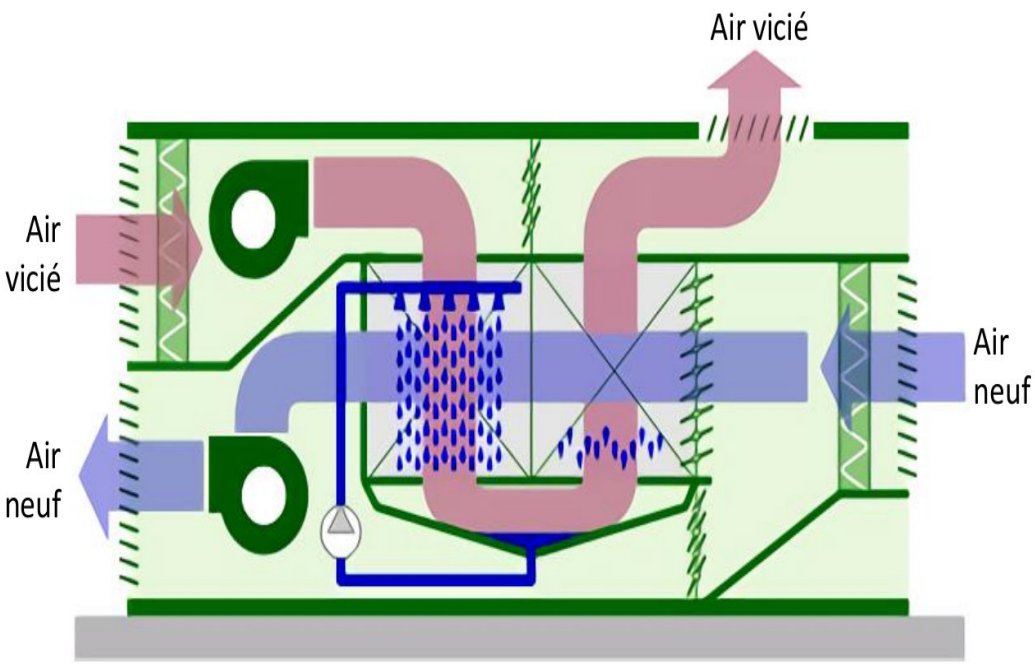
PSYCHROMETRIC CHART



IEC IN AHU



- Basic process
- IEC = humidifier + cross-flow exchanger
- Primary air = outdoor air
- Secondary air = extract air
- IEC to cool air in AHU is largely used in Belgium.
- The main air handling unit manufacturers use this technology.
- Can be used in rooms with high occupancy, where the airflow is high and can absorb the thermal load

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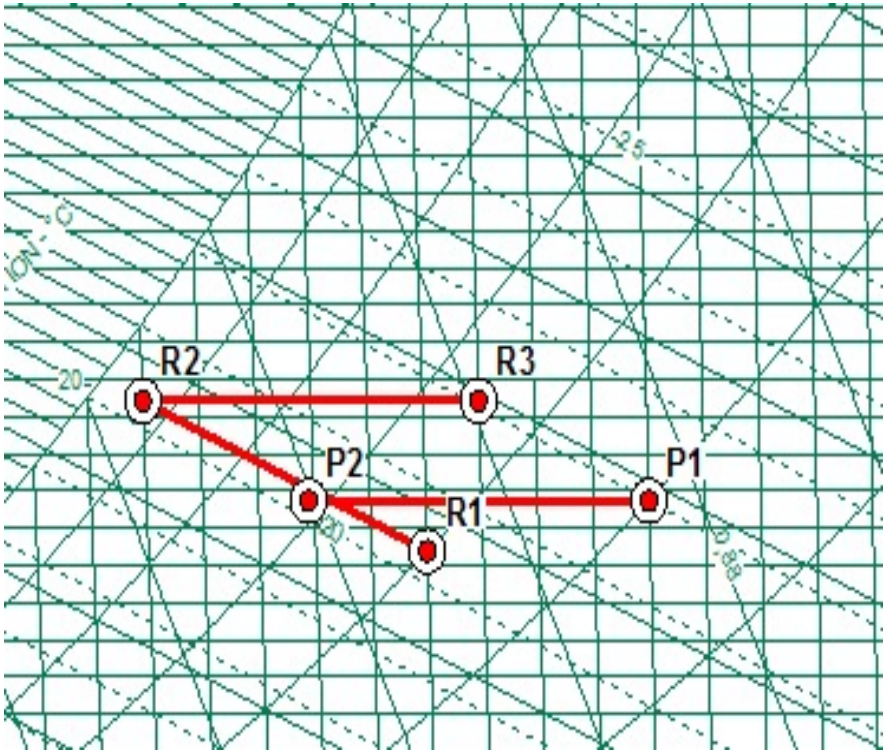
IEC - AIR COOLING



Basic process

Air evolution on the psychrometric chart

Here, humidification is carried out first, followed by recovery in the counter current exchanger.

With a HRV plate recuperator, which has an efficiency of about 60%, and with a high-efficiency adiabatic humidifier, which achieves an RH of 90%.

What temperature P2 can be achieved for different extract air conditions R1 of the room ?

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IEC - AIR COOLING

ε_{HRV} = 0,6 [-] h_{P1} = 70,95 [J/kg] ω_{P1} = 0,01516 [kg/kg] p_{atm} = 100 [kPa] rh_{hu} = 0,9 [-]

rh_{P1} = 0,5 [-] t_{P1} = 32 [C] wb_{P1} = 23,62 [C]

1 $t_{R1;i}$ [C]	2 $rh_{R1;i}$ [-]	3 $wb_{R1;i}$ [C]	4 $wb_{R2;i}$ [C]	5 $t_{P2;i}$ [C]
25	0,6	19,45	19,45	25,03
25	0,5	17,85	17,85	24,04
25	0,4	16,16	16,16	22,99
24	0,4	15,39	15,39	22,54

Temperature $t_{P2,i}$ reached for different inlet air conditions R1,i. in the process

We can see in the table that $t_{P2,i}$ decreases when the wet bulb temperature $wb_{RI,i}$ of the inlet air also decreases, so that the air in R1 is drier.

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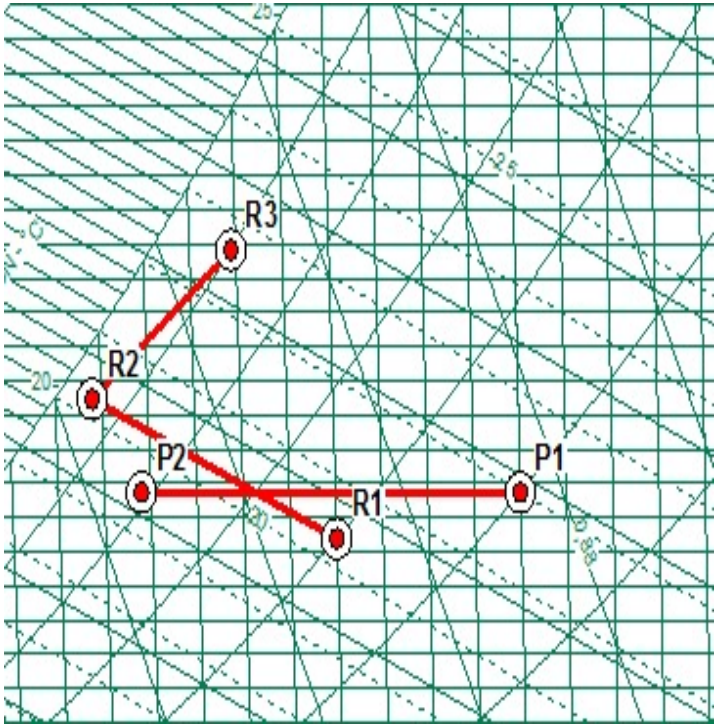
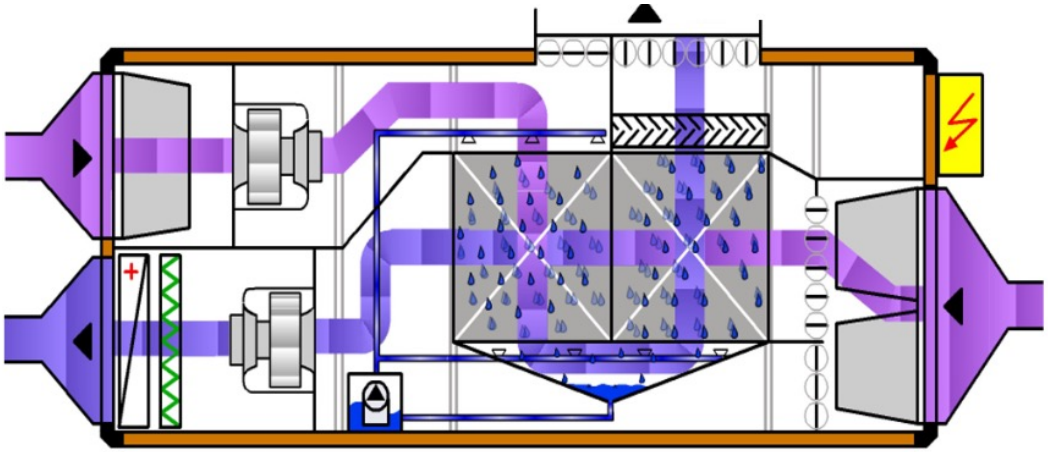
IEC - AIR COOLING



Improved process

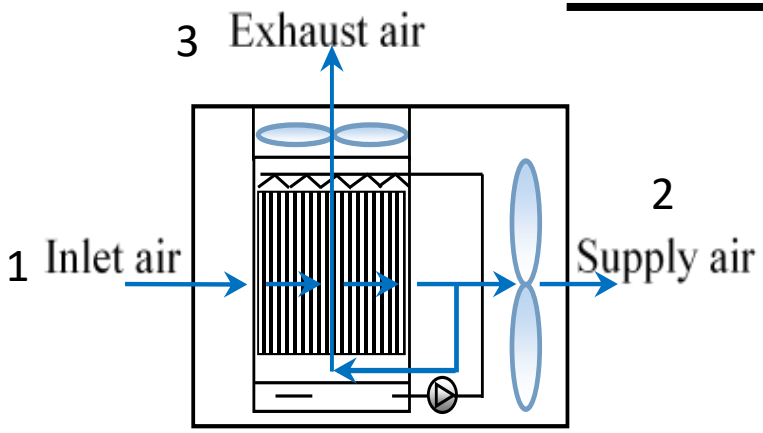
humidification and recovery take place in the heat exchanger

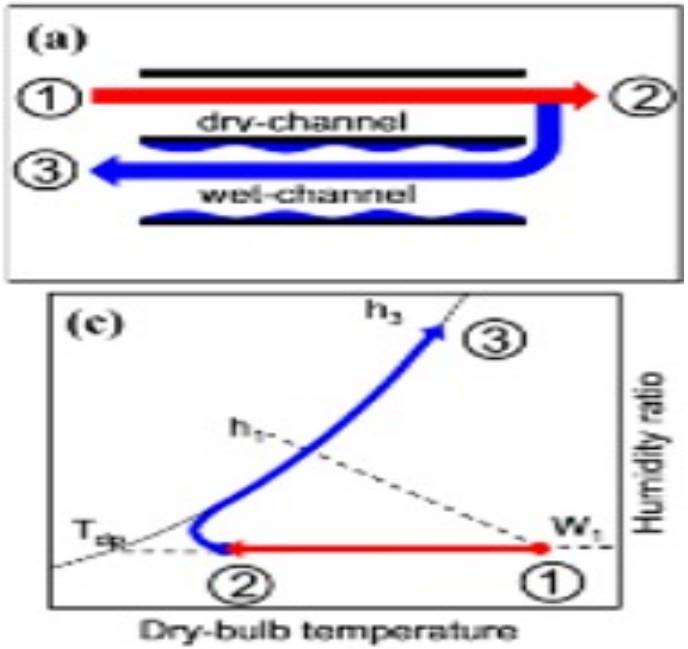


By humidifying the plates, the recovery efficiency is improved ($\varepsilon = 0{,}75$) and a lower outlet temperature in P2 can be achieved.

Manufacturers advertise an Δ cooling of about 10K

IEC –AIR COOLER





Innovative process

Internal IEC air cooler

As it was explained to you before by Mrs Xie, we can see that the most important point is to use a part of the cooled air as inlet air in the evaporative exchanger for cooling the outdoor air (1)➔(2)

With this configuration we can see that the cooling limit temperature of point 2 is now the dew point which is lower than the wet bulb

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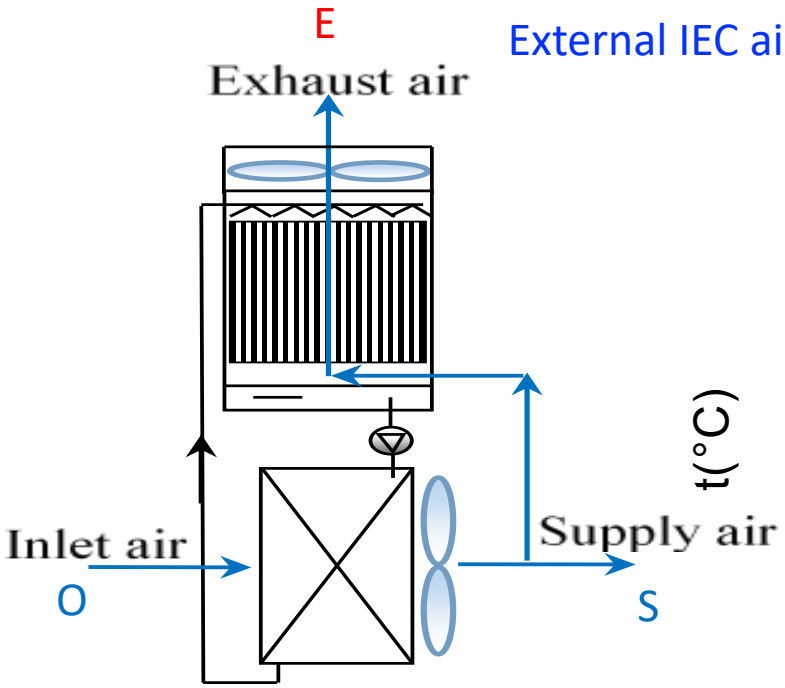
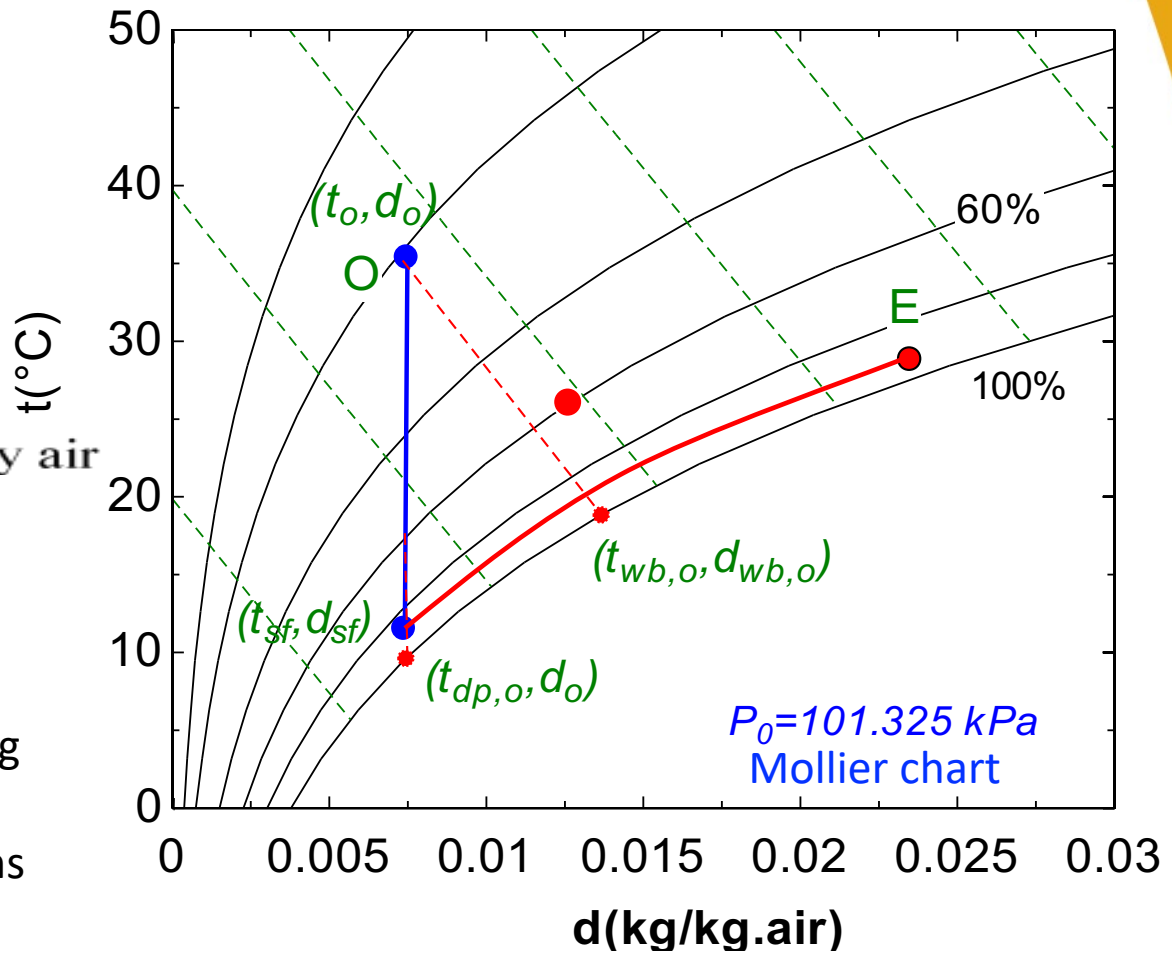
IEC - AIR COOLER



External IEC air cooler



The supply temperature is close to the dew point of the incoming air, in this case about 10C
For comparison in this conditions wet bulb is about 19C

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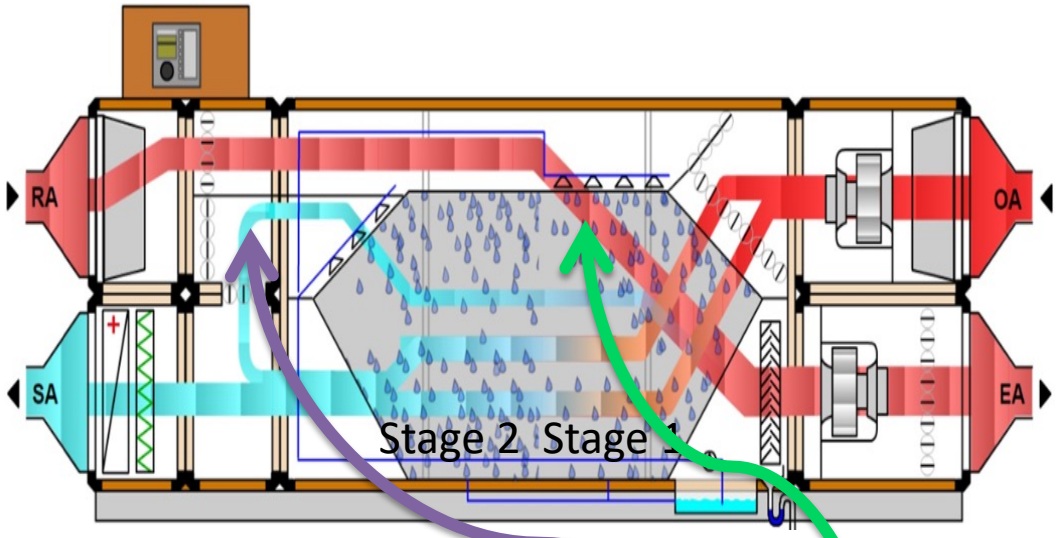
IEC - AIR COOLER



- Innovative process
- In AHU
- Two stage with secondary air precooled
- Outdoor Air OA = 32C
- Supply Air SA ≈ 18 to 20C
- Return Air from room : RA
- Exhaust Air : EA

- 1st stage the primary air is cooled a first time by humidifying the air extracted from the room (secondary air)
- 2nd stage the primary air is cooled a second time by humidifying the cooled primary air (secondary air)

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PERFORMANCE OF IEC AIR COOLER

If we compare the supply air temperature at the outlet of the air cooler processes, without and with precooled secondary air

Dry bulb OA	RH OA	Wet bulb OA	Dew point OA	Air supply without secondary air not cooled	Air supply with secondary air cooled
30	50%	22°	18,5°	21,5	20,5
32	40%	21,6°	16,7°	22	19,5
32	30%	19,4°	12,3°	22	17

IEC Air cooler with precooled secondary air is more efficient, a lower supply temperature is achieved

The efficiency increases with the temperature, but mainly with the reduction of the dew point or humidity ratio in the outside air.

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WATER COOLING

- The previous processes were used to cool the air. We will now look at processes whose objective is to cool water. Which are more efficient in terms of energy transfer.

- Cooling towers have been used for a very long time to cool the water. There are different types as we'll see below.
- Open and close Cooling Tower to cool water are present in Belgium, in the office buildings and industry.

- Maintenance and risks associated with legionella may have led to a reduction (?) in the use of cooling towers in the tertiary sector

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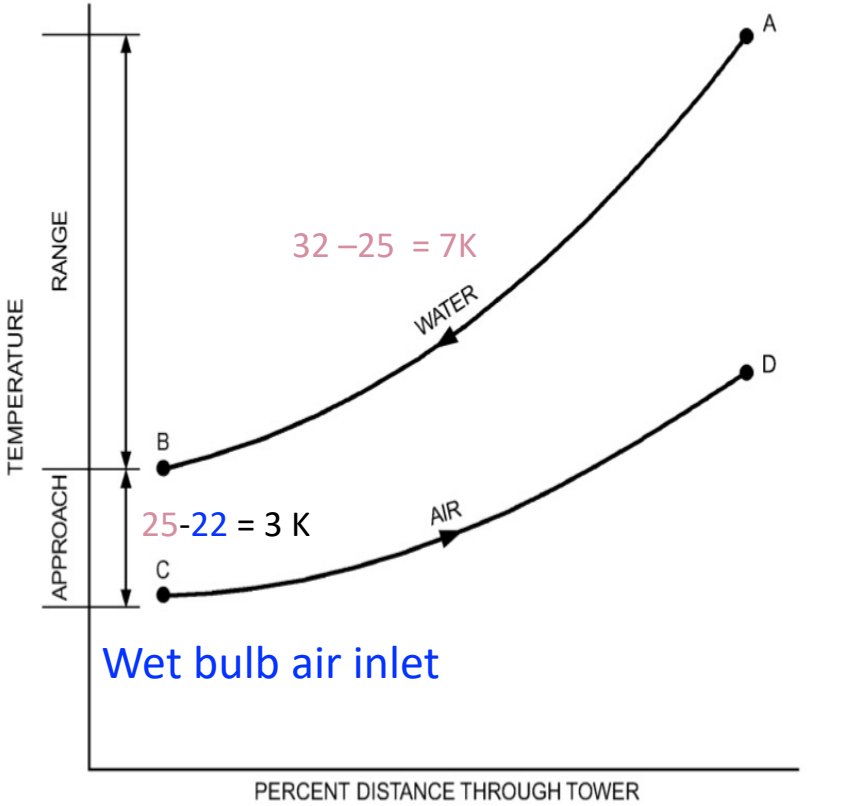
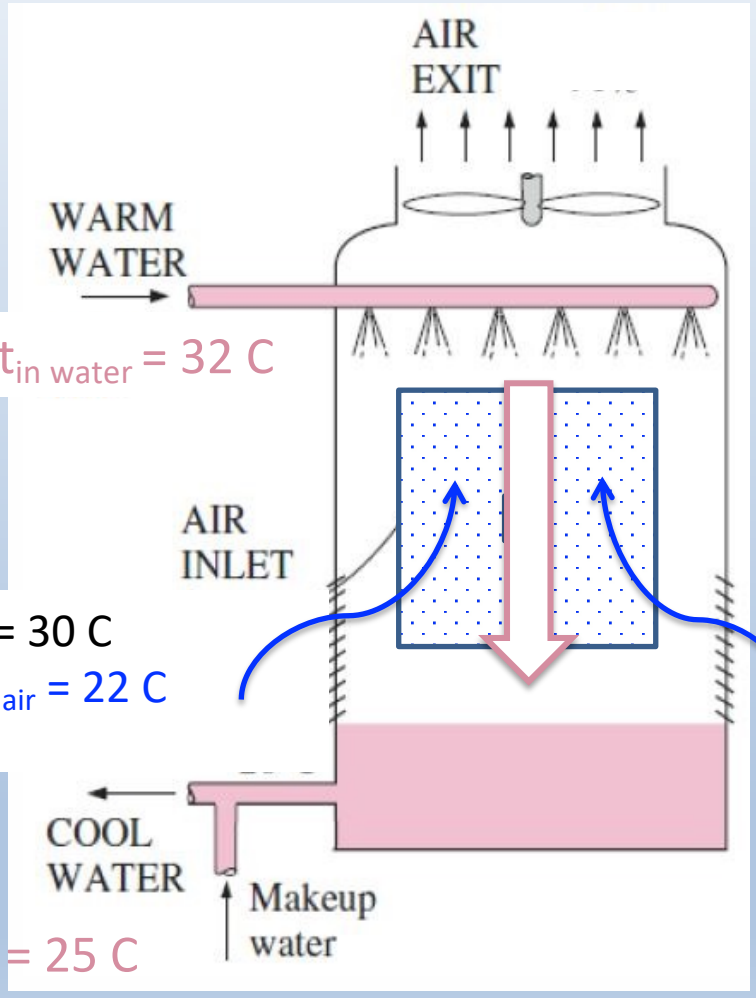
A REMINDER OF THE PRINCIPLES



Wet bulb air inlet

Fig. 1 Temperature Relationship Between Water and Air in Counterflow Cooling Tower



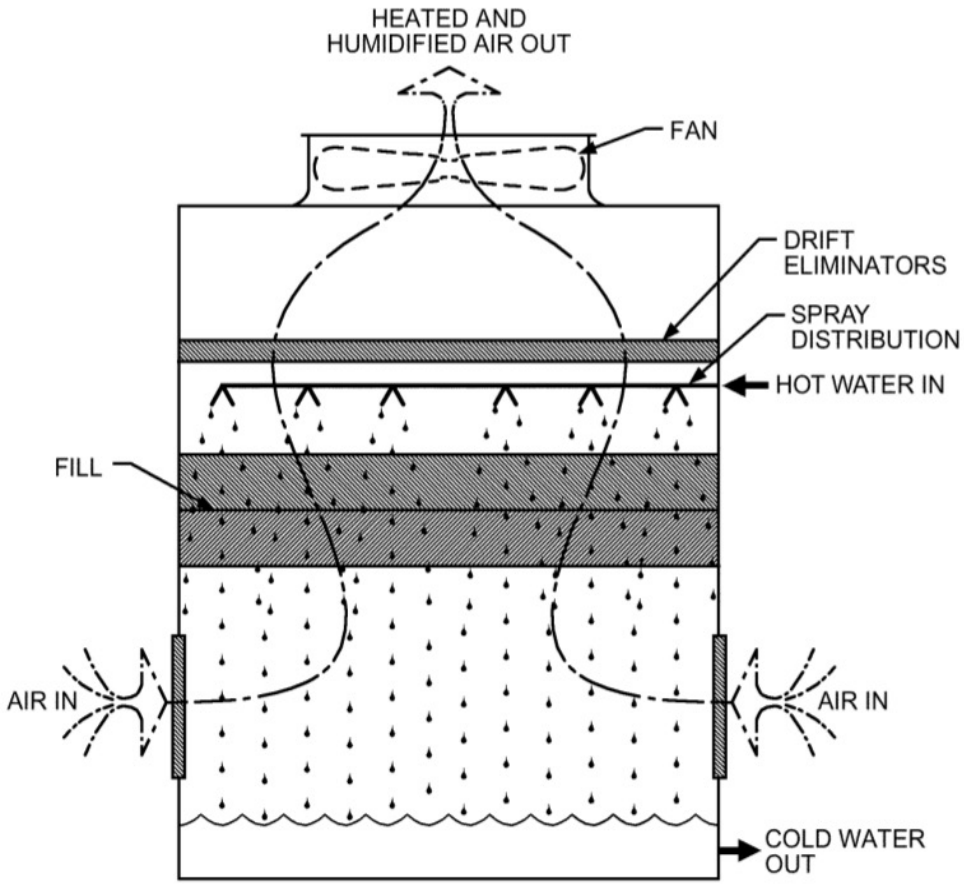
$t_{in\ water}$ = 32 C

t_{air} = 30 C

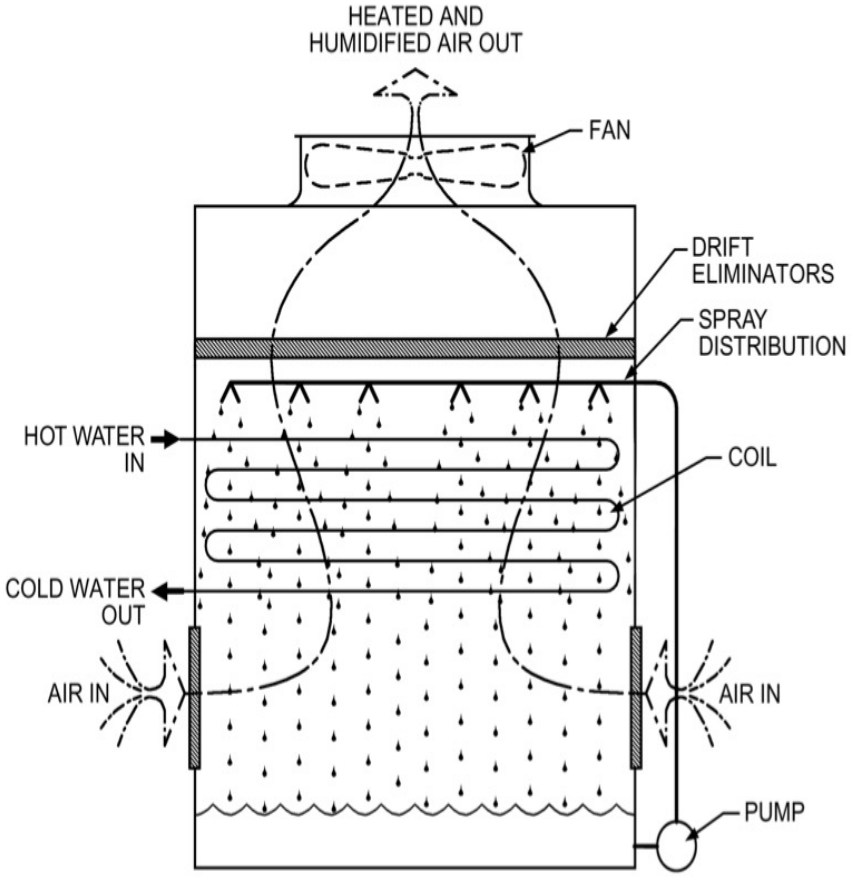
wb_{air} = 22 C

$t_{out\ water}$ = 25 C

COOLING TOWER



Direct-Contact or Open Evaporative Cooling Tower



Indirect-Contact or Closed-Circuit Evaporative Cooling Towers

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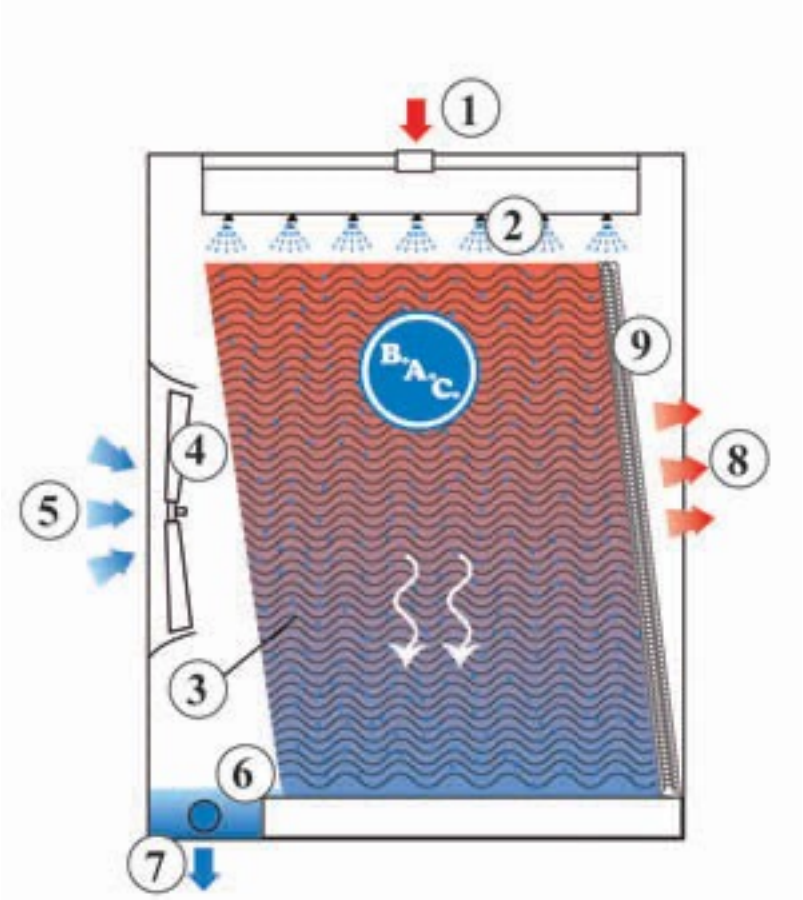
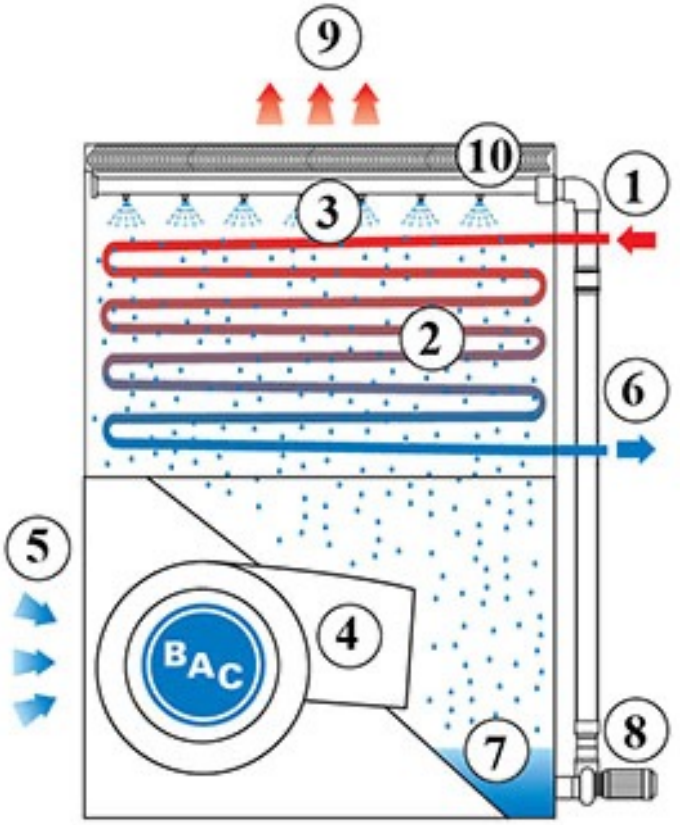
COOLING TOWER



Direct-Contact or Open Evaporative Cooling Tower



Indirect-Contact or Closed-Circuit Evaporative Cooling Towers

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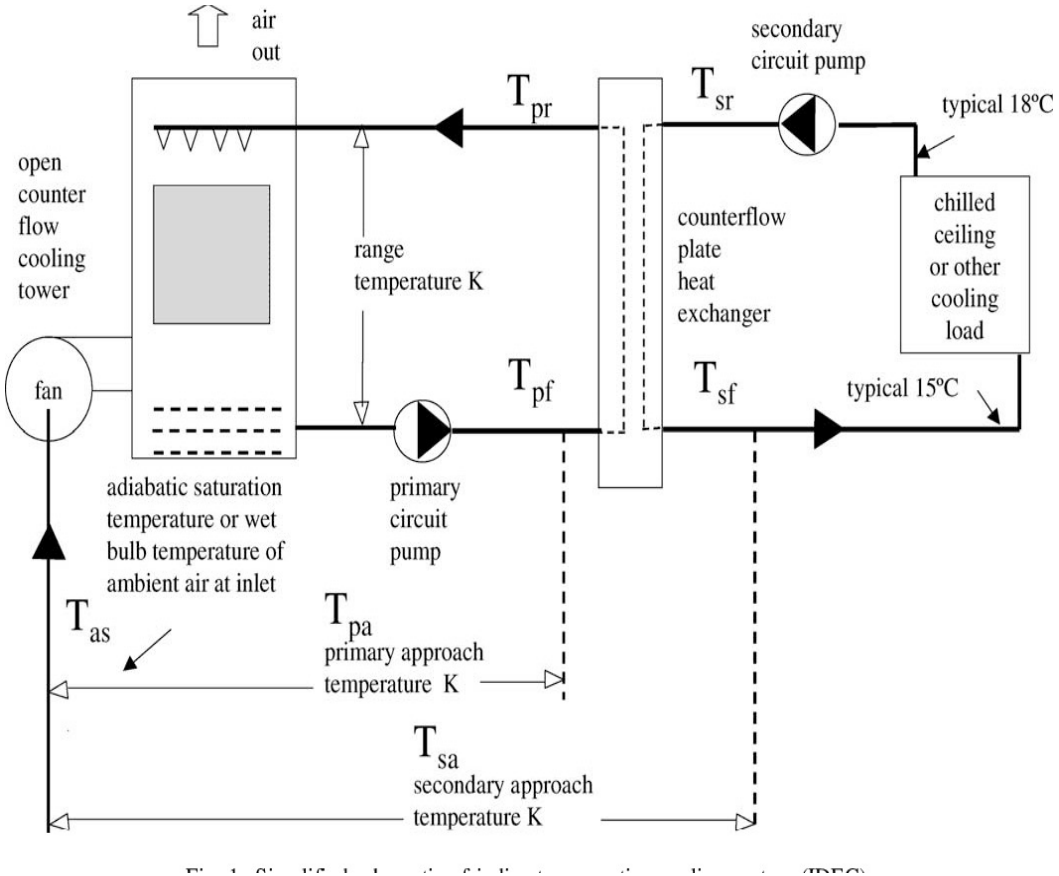
« FREE » CHILLING



- Towers are used to cool the condensed water from mechanical chillers.
- But also, to produce cold water when weather conditions are allowed, this is called “free” chilling.
- The “free” chilling is effective up to outdoor temperatures of around 19C maximum or wb= 13C, which allows the production of water at 15C compatible with terminal units such as chilled ceilings

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COOLING TOWER

- The processes in counterflow evaporative cooling “padding or fill” of the open tower are type DEC (direct evaporative cooling) technology
- The lowest water temperature of the produced cold water is the wet bulb temperature of the outdoor air, and in most of the time, the actual output water temperature of practical devices is around 3K to 5K (approach) higher than the outdoor wet bulb temperature.

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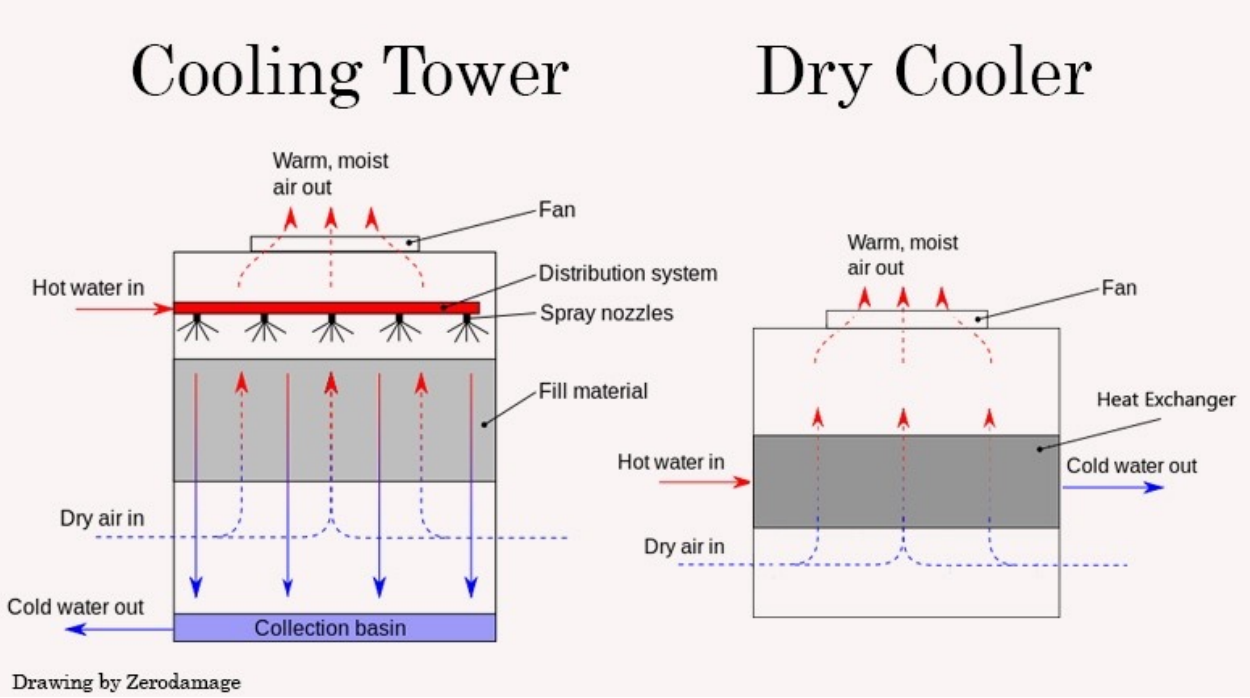
HYBRID COOLING



- Hybrid Cooling is the combination of dry and wet exchanges.

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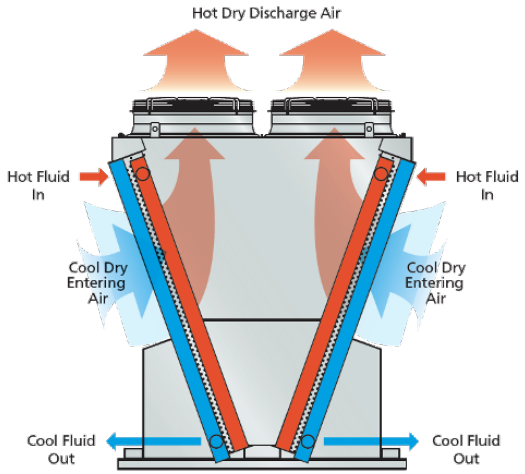
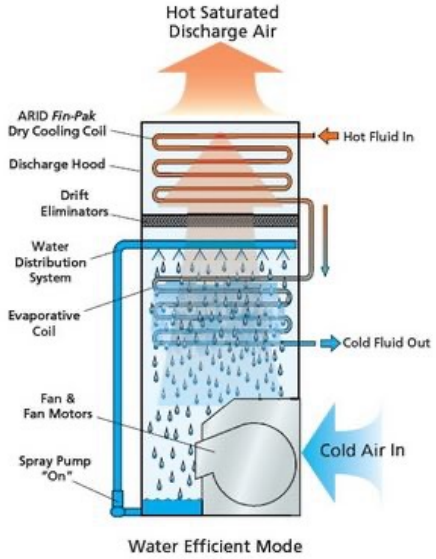
HYBRID COOLING TOWER





Water Efficient Mode

- Works in dry and wet operations
- Water saving
- No plume formation

- IEC chiller process where the dry and evaporative cooling exchangers are in serial

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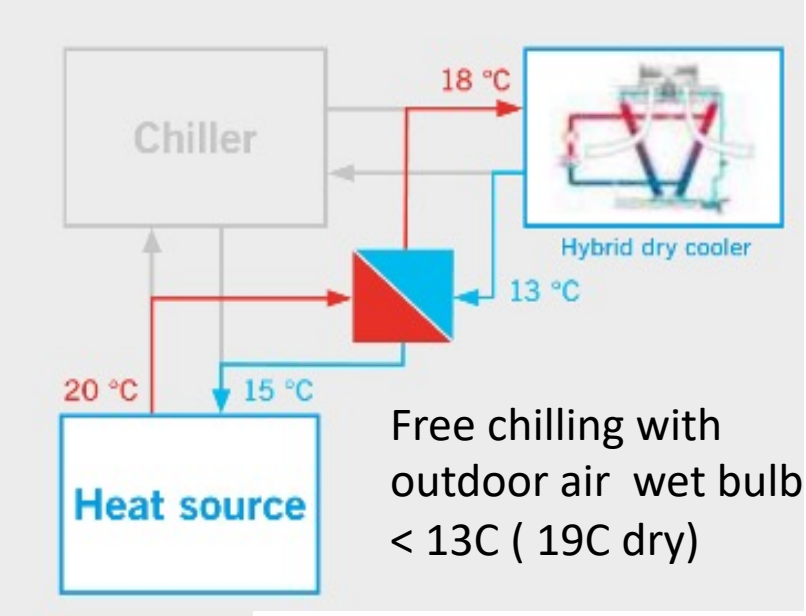
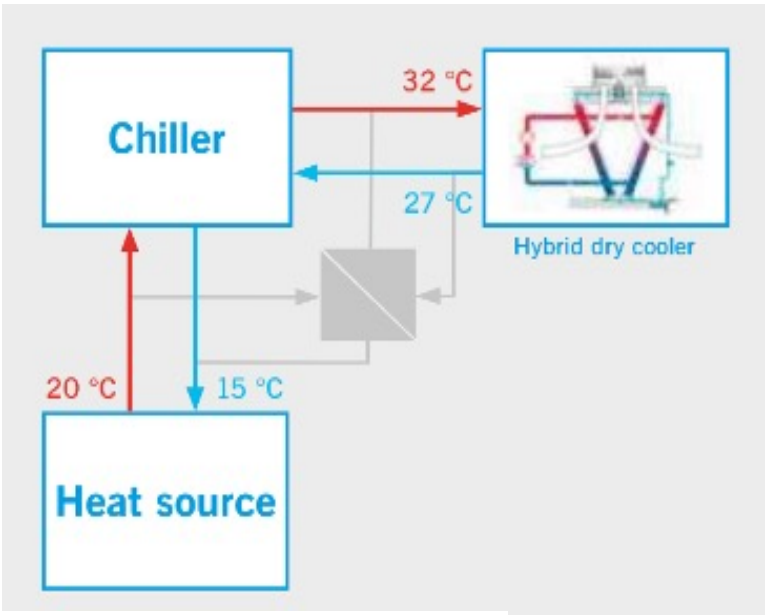
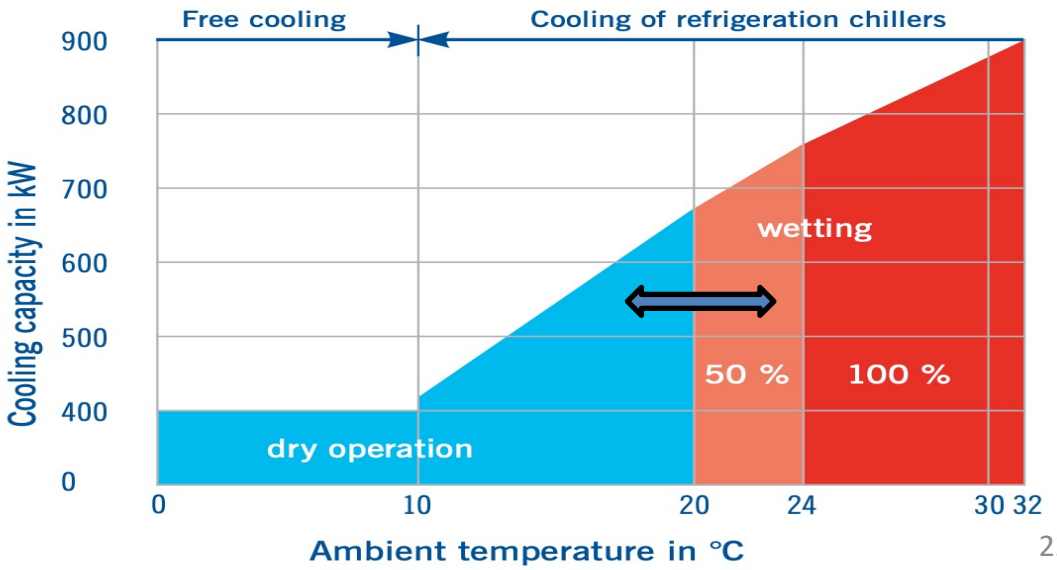
HYBRID COOLING TOWER



Free chilling with outdoor air wet bulb < 13C (19C dry)





IEC CHILLER

Innovative process

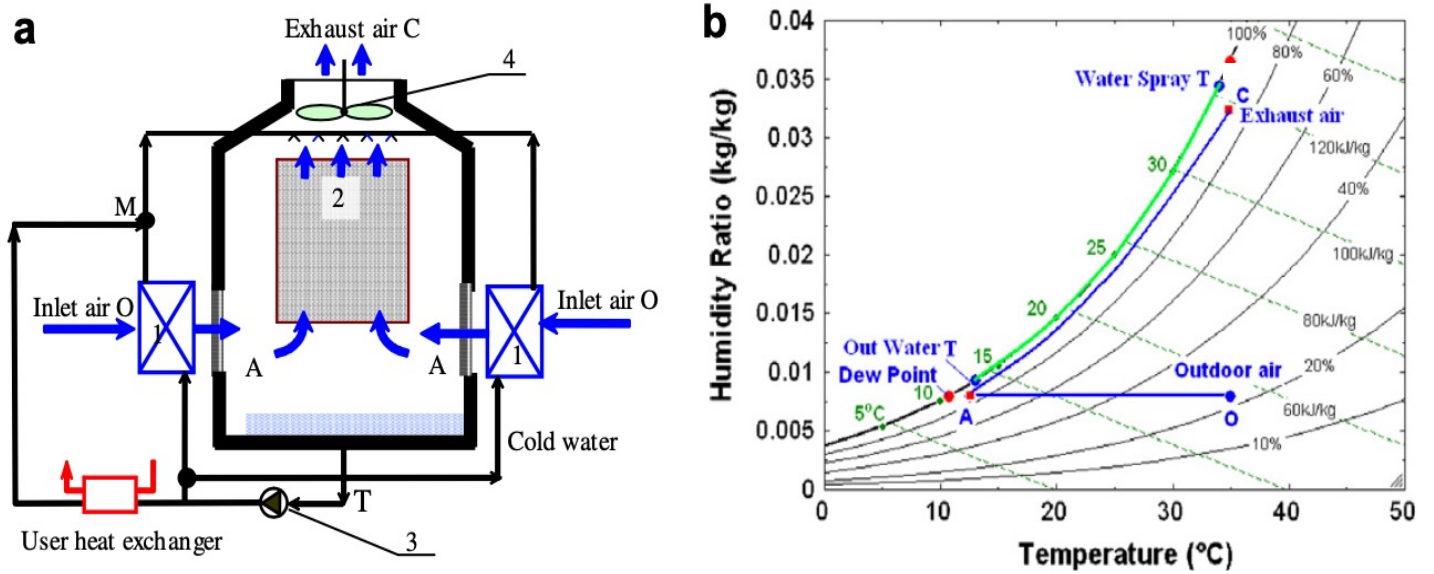
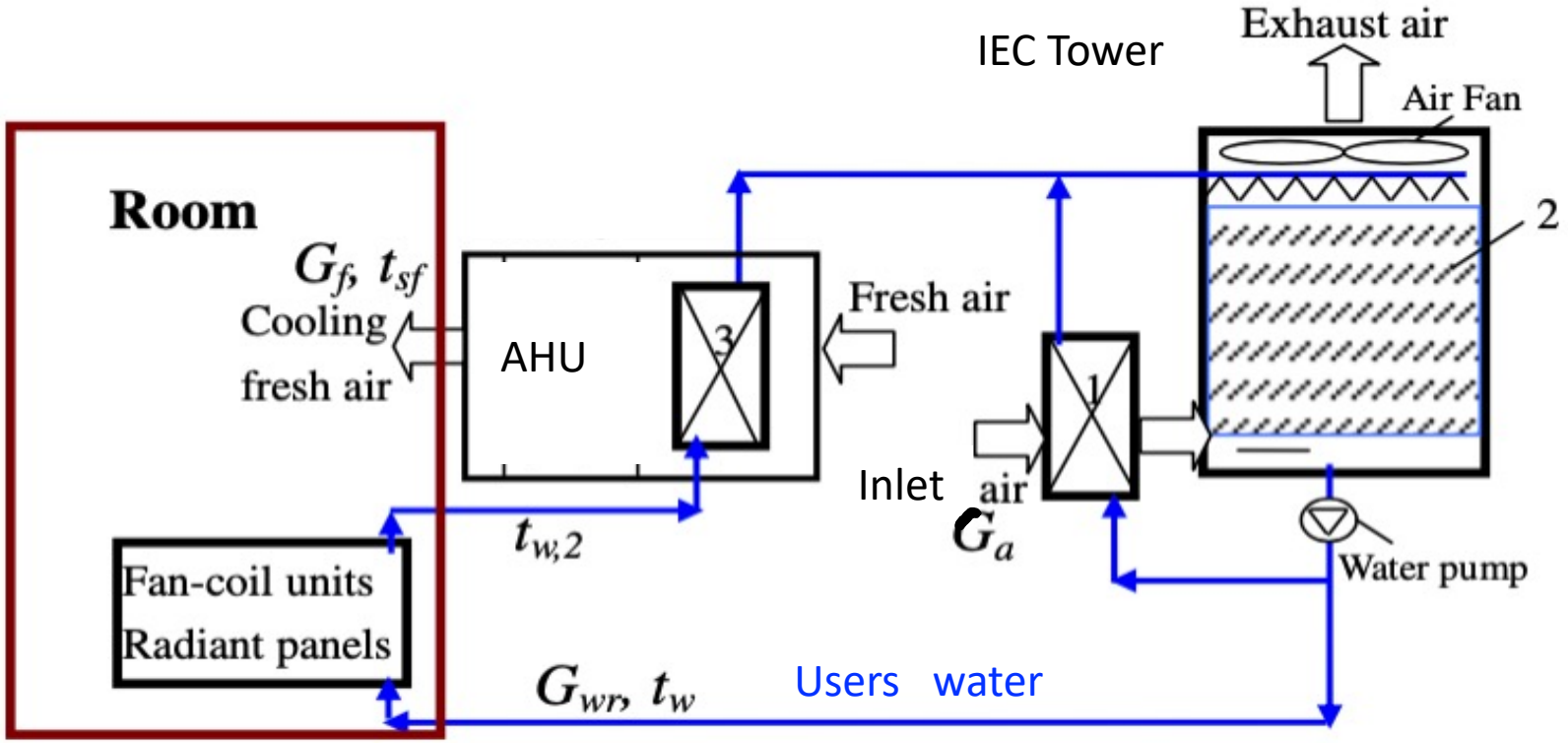


Fig. 1. Principle of the indirect evaporative chiller: (a) structure of the indirect evaporative chiller, (b) process to produce cold water. (1) Air–water countercurrent heat exchanger; (2) air–water countercurrent padding tower; (3) water pump; (4) fan.

On the diagram the evolution of the air is in blue and the water in green

Thanks to the pre-cooling of the air from O to A, the temperature at point A is close to the saturation curve and therefore the wet bulb at point A is close to the dew point of point A

IEC CHILLER



1. air-water countercurrent heat exchanger
2. air-water countercurrent padding tower
3. countercurrent fresh air cooler

IEC CHILLER

The constant output water temperature lines in the psychrometric chart.

For IEC chiller under the designed conditions, from which for different outdoor conditions we can estimate the output water temperature of the indirect evaporative chiller.

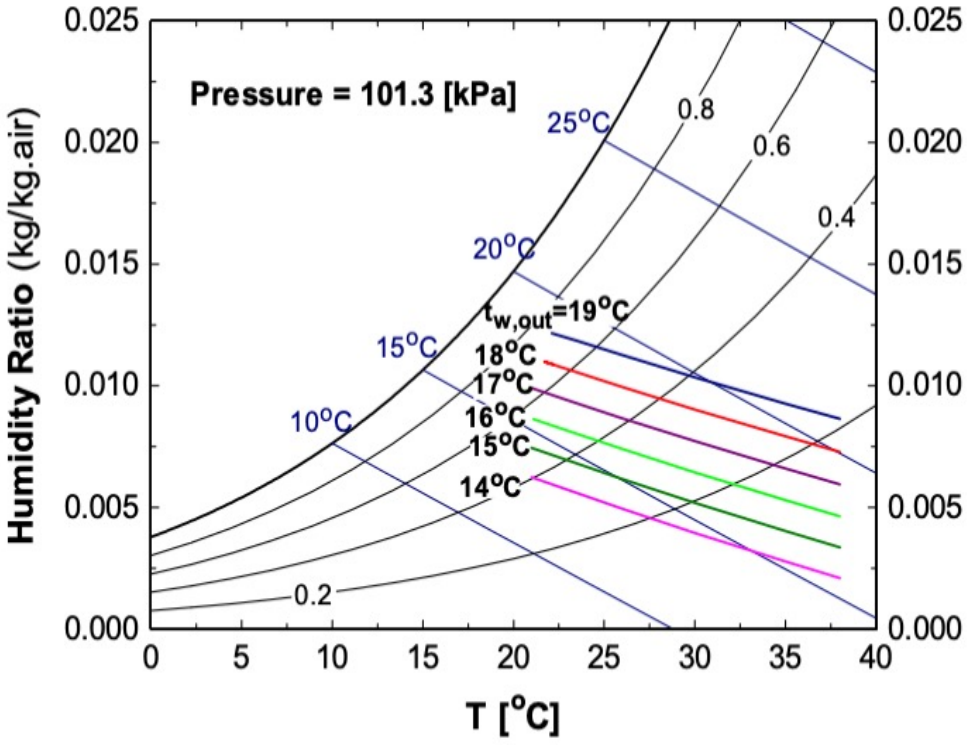
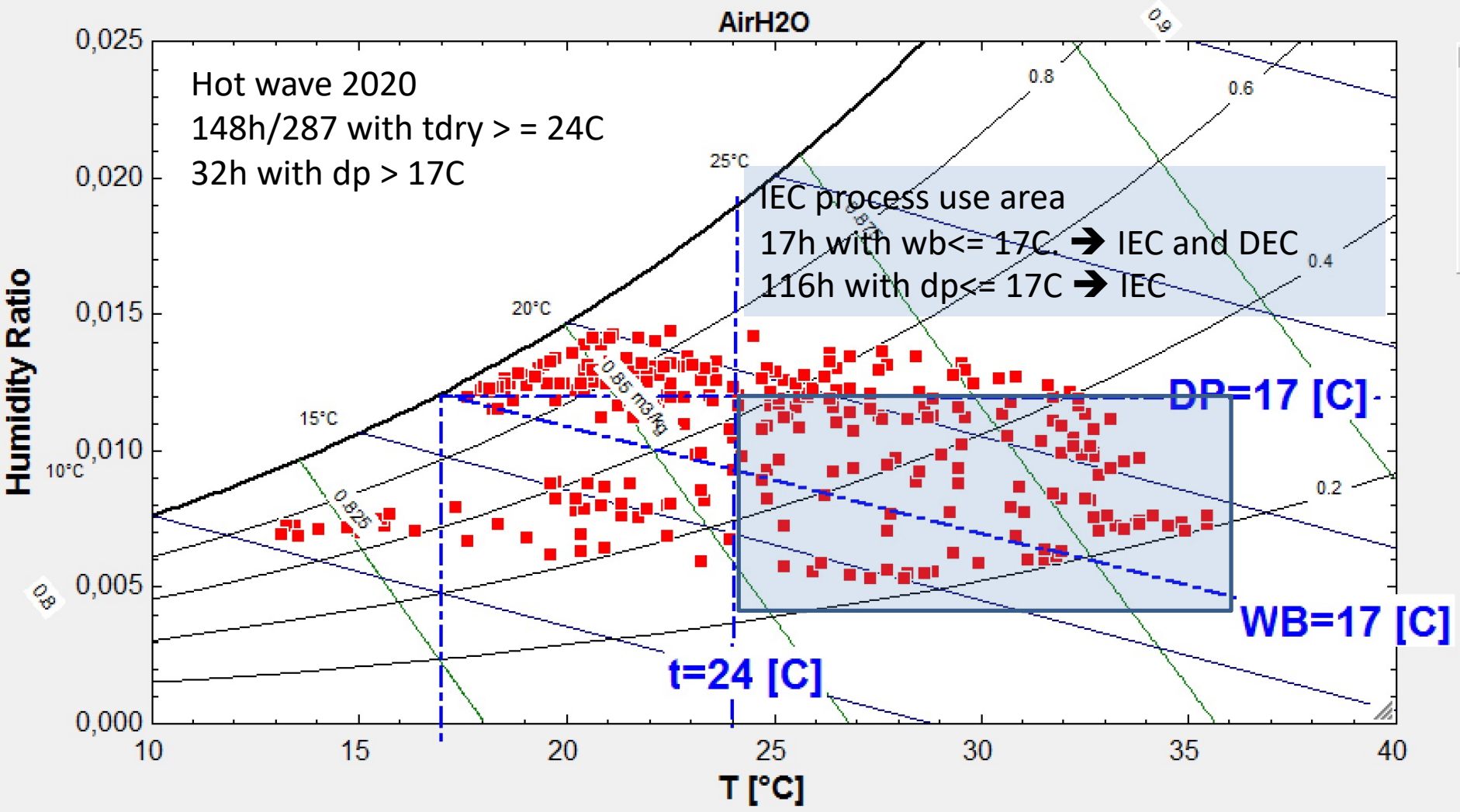


Fig. 10. Constant out water temperature lines.

Designed conditions of the indirect evaporative chiller.

Atmospheric pressure (kPa)	Inlet air flow rate (kg/s)	User water flow rate (kg/s)	Fresh air flow rate (kg/s)	Air coolers KA_1 (kW/°C)	Cooling tower K_sA (kW/°C)	Indoor fan-coil units KA_r (kW/°C)	Fresh air pre-cooler KA_f (kW/°C)
101.325	1	0.6	0.6	2.99	3.52	2.5	1

IEC CHILLER


AirH2O
Hot wave 2020
148h/287 with tdry > = 24C
32h with dp > 17C
IEC process use area
17h with wb<= 17C. ➔ IEC and DEC
116h with dp<= 17C ➔ IEC
DP=17 [C]
WB=17 [C]
t=24 [C]
Humidity Ratio
T [°C]
0,025
0,020
0,015
0,010
0,005
0,000
10
15
20
25
30
35
40
25°C
20°C
15°C
10°C
0.85 m3/kg
0.825
0.8
0.6
0.4
0.2
0.9

IEC CHILLER

- The IEC CHILLER should be able to produce sufficiently cold water, compatible with the treatment of office buildings.

- Professor Lebrun's simulation showed us that a feed water temperature of 16C can be achieved under warm outdoor conditions (t=34C wb=19C dp=10C)
- It can therefore be assumed that in Belgium it should be possible to have supply water for users in the range of 15C to 20C depending on outdoor conditions and also of efficiency of HX exchanger and cooling tower.
- Global warming tends to dry out the outdoor air and as shown by M. Marbaix earlier, we have 213h out of 248h that are appropriate with tdry >= 24C and dp <=17C. TMY 2004-2018

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IEC TECHNOLOGY

- The IEC technology is covered by Annex 85 of the IEA and is therefore undergoing certification of key parameters to determine its effectiveness and cost efficiency.

- To complete this first day, on 29 April, three of the main manufacturers active on the Belgian market as well as the KUL University where an IEC system has been installed and is being monitored, will bring their experience on this innovative technology.

- In view of the possibilities offered by this technology, IEA call on the HVAC actors in Belgium to join this approach and to participate in the work of this Annex 85.

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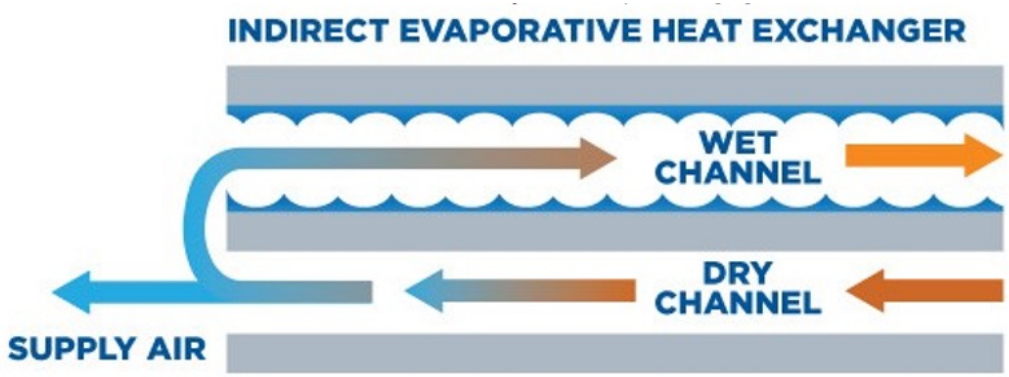

Thank you very much for your attention,
I now hand over to our President
Joris Manpaey