

Improving the Energy Performance of Air-Cooled Chillers with Water-Spray Mist Pre-Cooling: An Application

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The Main Objectives

- Introduce a new **Water-Spray Mist Pre-Cooling System** with a **Tor (mesh material)** / **WSMCST**
- Assess its performance,
 - which is based on pre-cooling the ambient air entering the condensers to decrease compressor power consumption while increase system capacity.
- Energetically compare with the conventional systems.

Why the study was needed

- Chillers consumes 25-40% of the total electricity energy in a commercial buildings.
- COP of water-cooled chillers is much higher than that of widely used air-cooled chillers.
- Air-cooled chillers are popular due to;
 - Ease of installation
 - Simplicity of operation and maintenance
 - Lower installation and maintenance costs

Why the study was needed

- “Evaporative cooling system” used to improve COP of widely used air-cooled chillers.
 - Lowers the temperature of the air before it enters the condenser
 - Refrigeration capacity is increased
 - Power consumption is reduced

Water-Spray Mist Pre-Cooling System with a Tor (mesh material) / WSMCST

- Special electronic controller to monitor and decide the adiabatic cooling amount in real-time
- Mesh material
- Water pipe work, atomization nozzles, filter assembly and high pressure pump

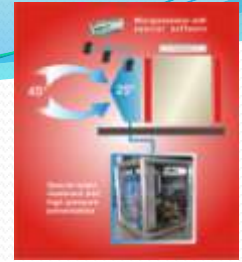


Water-Spray Mist Pre-Cooling System with a Tor (mesh material) / WSMCST



- Designed and tested within scope of a project supported by the Scientific and Technological Research Council of Turkey (TUBITAK)
- Differs from the previously installed and operated ones due to the fact that it is monitored in real-time and electronically controlled

Water-Spray Mist Pre-Cooling System with a Tor (mesh material) / WSMCST



- Variable flow rate maintained by the different quantity of nozzles (managed by solenoid valves)
- Constant pressure (60-70 bar) maintained by variable speed reciprocating pump.
- Very fine droplets obtained by the nozzles
- Small droplets easily vaporized by the ambient air before entering the condenser
- Cooled air distributed uniformly on the exchanger by the tor (mesh material)

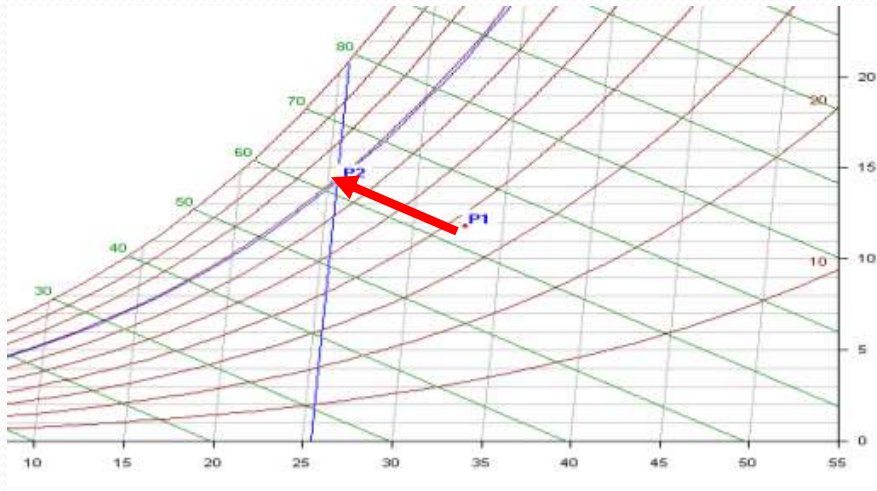
Water-Spray Mist Pre-Cooling System with a Tor (mesh material) / WSMCST



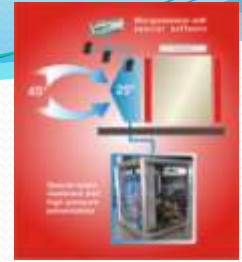
As a result of vaporization;

5 – 20 K reduction

in the temperature of that air follows the adiabatic cooling process with constant specific enthalpy



Water-Spray Mist Pre-Cooling System with a Tor (mesh material) / WSMCST



- ▶ The energy consumption of the system is relatively low comparing other evaporative cooling systems
- ▶ Water consumption is lower than the water cooled and other evaporative cooling systems
- ▶ Pressure drop on mesh material is about 20 Pa, so no additional power for maintain desired air-flow rate

Analysis and Data

$$\dot{Q}_{cool} = \dot{m}_w \cdot C_p \cdot (T_r - T_f)$$

where \dot{m}_w

is the mass flow rate of the water,

C_p is the specific heat of water

T_f and T_r are the flow (or supply) and return temperatures of the water

$$\dot{m}_w = C \cdot E \cdot A \sqrt{2 \cdot \Delta P \cdot \rho}$$

where ;

C is the discharge coefficient,

E is the velocity of approach factor,

A is the cross-sectional area and

ρ is the density of the water

Analysis and Data

$$COP = \frac{\dot{Q}_{cool}}{\dot{W}_{elec,total}}$$

where ;

$\dot{W}_{elec,total}$ is the total power consumption of the chiller unit, which is based on the measurements.

Analysis and Data

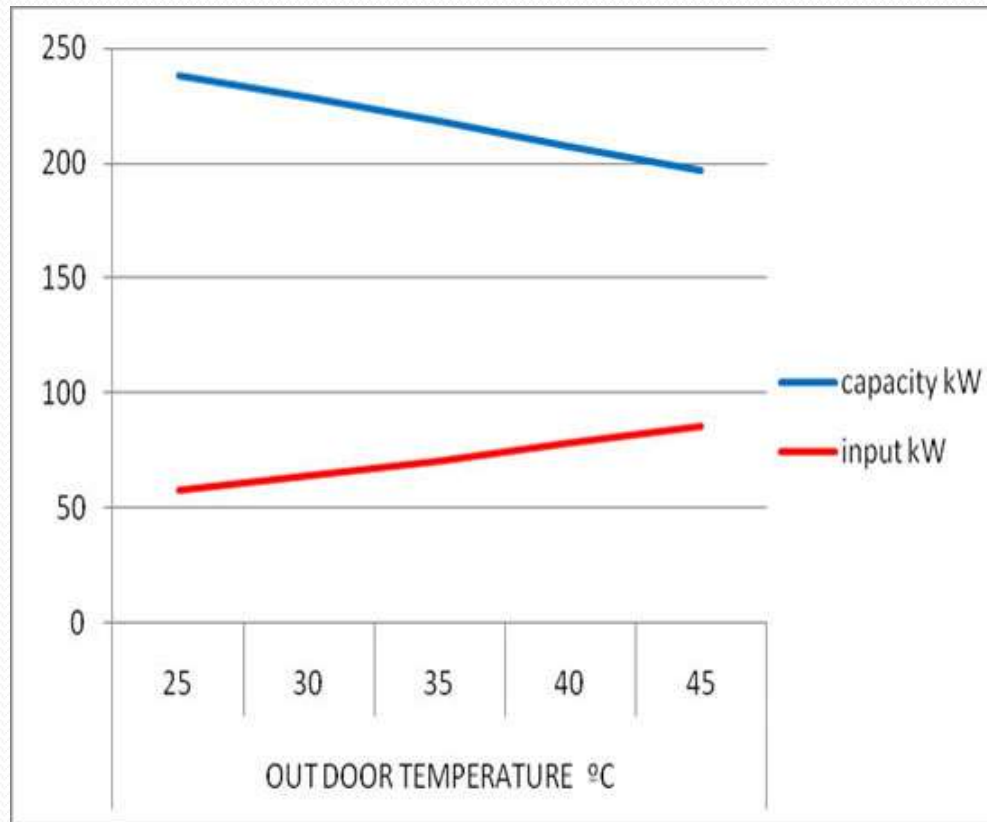
Maximum adiabatic cooling temperature values to be realized (K)	Cities in TURKEY
> 15	BATMAN, ŞANLIURFA, MARDİN, ELAZIĞ, DİYARBAKIR, ADIYAMAN, SİVAS, KİLİS
15-12	IĞDIR, BURDUR, BİNGÖL, KARAMAN, BAYBURT, AKSARAY, MALATYA, VAN, MARMARİS, GAZİNATEP, AMASYA, MUŞ, UŞAK, HAKKÂRİ, FETHİYE, KIRIKKALE, ERZİNCAN, KAHRAMANMARAŞ, GÜMÜŞHANE, MUĞLA, MANİSA, BİTLİS, KIRŞEHİR, ISPARTA, ARDAHAN, BODRUM, BLECİK, ANKARA
12-10	ADANA, TOKAT, AYDIN, DENİZLİ, ÇORUM, KASTAMONU, KÜTAHYA, KONYA, KAYSERİ, AĞRI, İZMİR, BALIKESİR, BURSA, AYVALIK, BOLU, ARTVİN, KUŞADASI, ANTALYA, ÇANKIRI, ESKİŞEHİR, ZONGULDAK
10-7	BARTIN, , EDİRNE, KIRKLARELİ, , KOCAELİ, YALOVA, HATAY, AFYON, SAKARYA
7-5	İSTANBUL, ÇANAKKALE, , İSKENDERUN, RİZE

Analysis and Data

Different Climatic Cities	Duration [h]	Average DB temp. [°C]	Average WB temp. [°C]	Average pre-cooling temp.* [K]	Seasonal pre-cooling [Kh]
Ankara	663	26.3	16.3	8.3	5503
Antalya	1872	28.0	18.6	7.7	14414
Diyarbakır	2306	30.0	14.7	12	27672
İstanbul	611	25.6	19.7	4.2	2556
İzmir	1749	27.3	19.8	7.5	13117

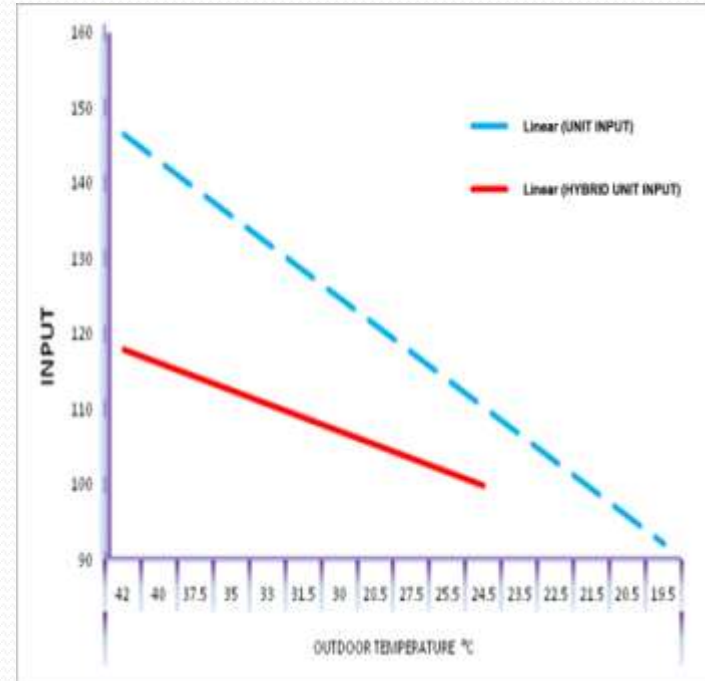
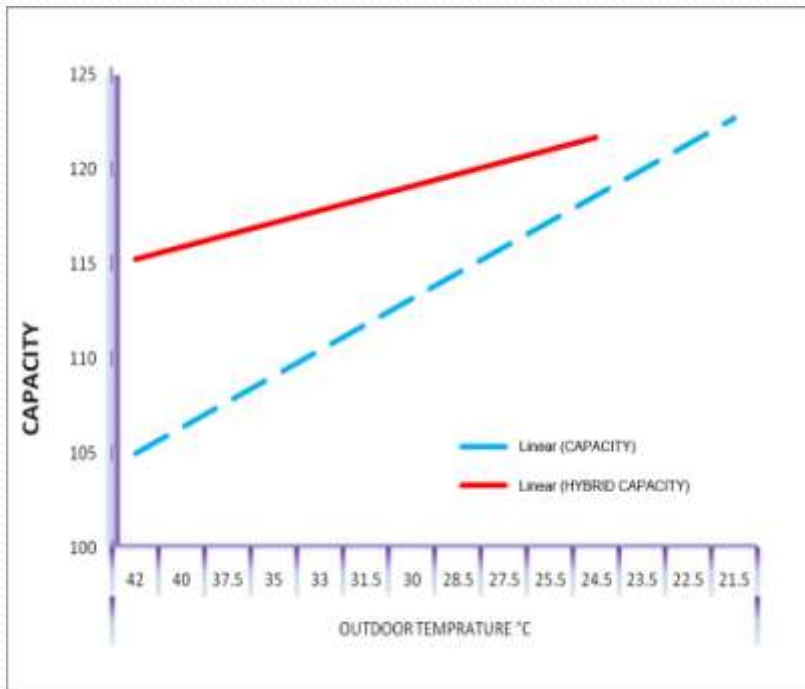
*These indicate the cooling temperature values of above 18 °C, at which air-cooled chillers could be operated without any trouble.

Analysis and Data



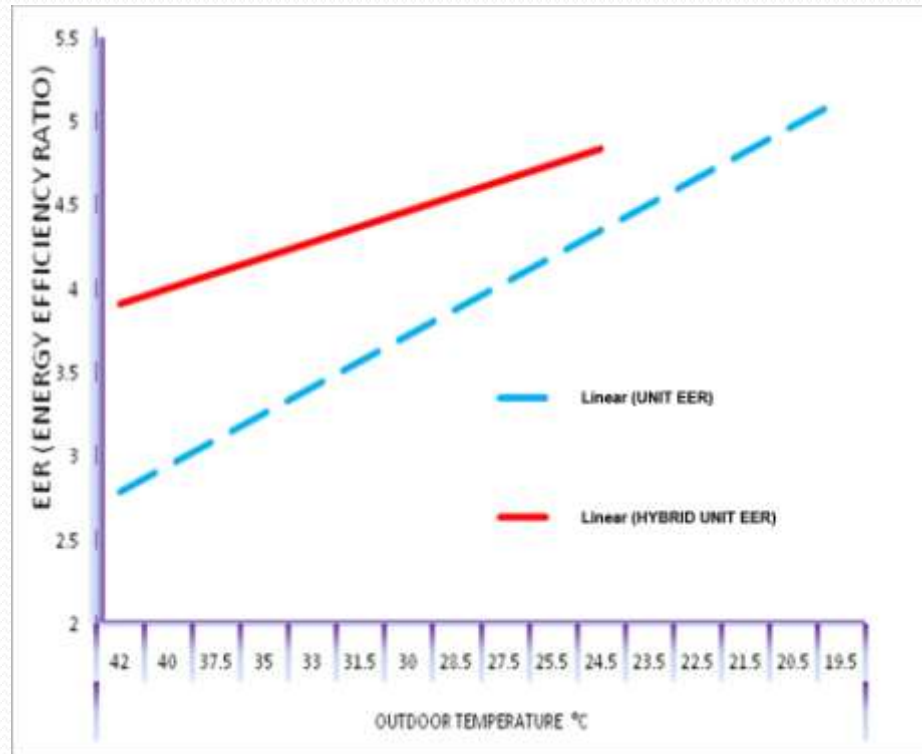
Variation of capacity values for a package type air-conditioner depending on different outdoor air temperatures

Analysis and Data



Variation of capacity and power input values for cooling systems utilizing an adiabatic cooling process depending different outdoor air temperatures

Analysis and Data



Variation of EER Energy Efficiency Ratio values for cooling systems utilizing an adiabatic cooling process depending different outdoor air temperatures

An Illustrative Example

- The WSMCST was applied to air-cooled chiller in a textile factory, located in Izmir.



An Illustrative Example

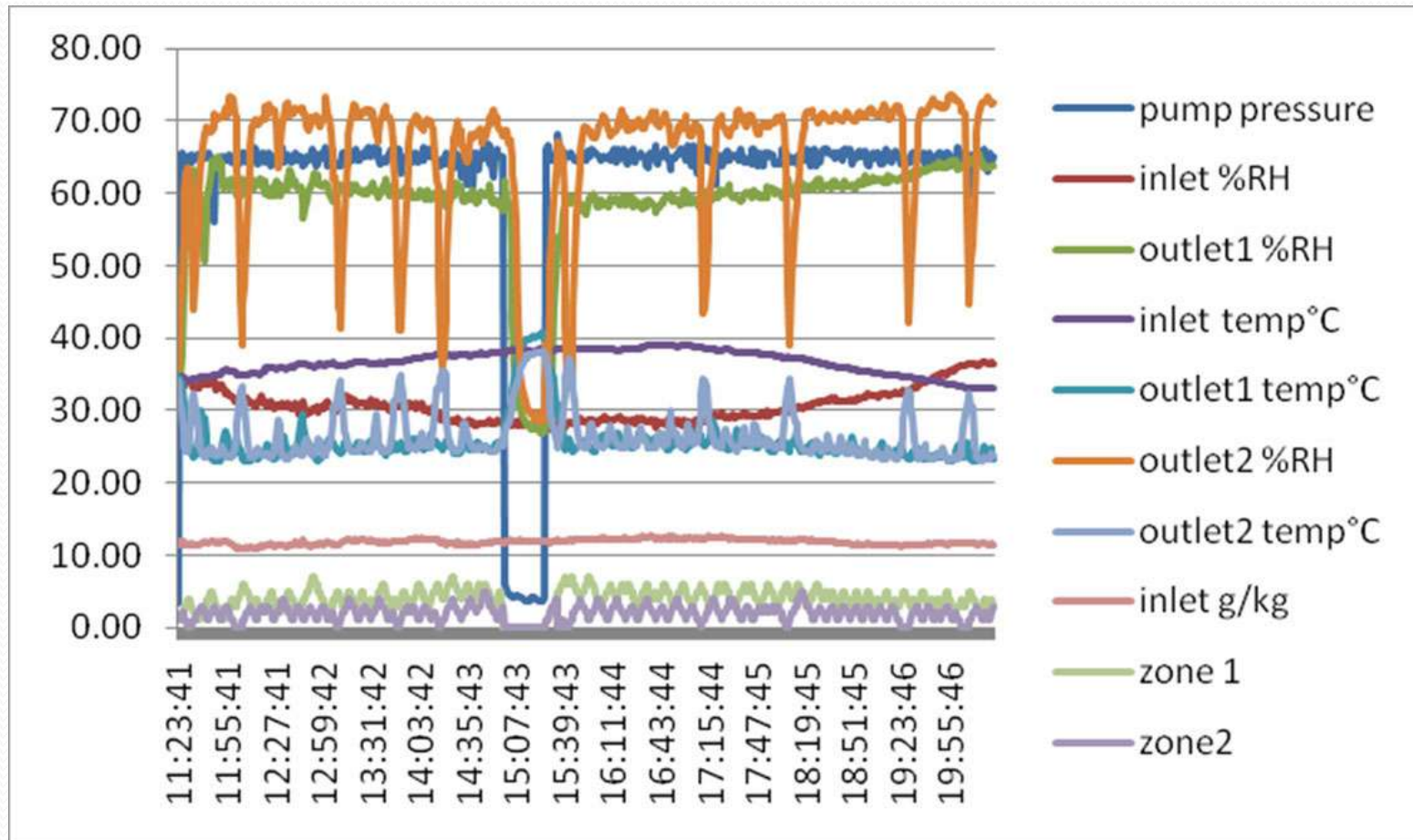
- One air-cooled chiller with cooling pad application
 - Water consumption 100% (reference value)
 - Problem on heat exchanger (accumulation of scale)
 - Due to increase of pressure loss on the pad, decrease in condenser airflow-rate.
- One air-cooled chiller with time based WSMCST
 - Water consumption 60-70% (compare to pad appl.)
 - Problem on heat exchanger (accumulation of scale)
 - 20 Pa pressure loss on the mesh material, decrease on condenser airflow-rate is not significant
- Two air-cooled chiller with smart control WSMCST
 - Water consumption 5-10% (compare to pad appl.)
 - No problem on heat exchanger (accumulation of scale)
 - 20 Pa pressure loss on the mesh material, decrease on condenser airflow-rate is not significant

An Illustrative Example / Smart Control WSMCST

Data used for design of Air-cooled chiller with smart control
WSMCST

Data used for design	Value
Dry-bulb (DB) temperature	36 °C
Wet-bulb (DB) temperature	24 °C
Condenser volumetric air flow rate	180000 m ³ /h
Maximum pre-cooling to be realized	10.6 K
Water content of the air	4.1 g/kg
The maximum water requirement of the system	14 L/min
Number of spray mist nozzles	208
Total water volumetric flow rate of spray mist nozzles	16 L/min

An Illustrative Example / Smart Control WSMCST



Some operational data of the Air-cooled chiller with smart control WSMCST

An Illustrative Example / Smart Control WSMCST

Description	Value
Outdoor air temperature	33.1 °C
Outdoor air relative humidity	31.8%
Inlet absolute (specific) humidity	10.1 g/kg
Target absolute humidity	14.4 g/kg
Target adiabatic cooling outlet temperature	22.3 °C
1 st circuit absolute humidity	12.8 g/kg
2 nd circuit absolute humidity	13.2 g/kg
1 st circuit stage	3/7
2 nd circuit stage	2/7
Pump pressure	65.6 bar

Some instantaneously operational data of the Air-cooled chiller with smart control WSMCST

An Illustrative Example / Smart Control WSMCST

- For monitoring the cooling temperature realized in front of the coils, **14000 data** were collected over a period of **250 hours** in the months of **June** through **August 2009**

OUTDOOR TEMPERATURE (average)

DB [°C] 32.8

WB [°C] 21.5

ADIABATIC COOLING OUTLET (average)

DB [°C] 25.5

WB [°C] 21,2

TEMPERATURE DROP [K] 7.3

An Illustrative Example / Smart Control WSMCST

OUTDOOR

TEMPERATURE (average)

DB [°C] 32.8

WB [°C] 21.5

ADIABATIC COOLING

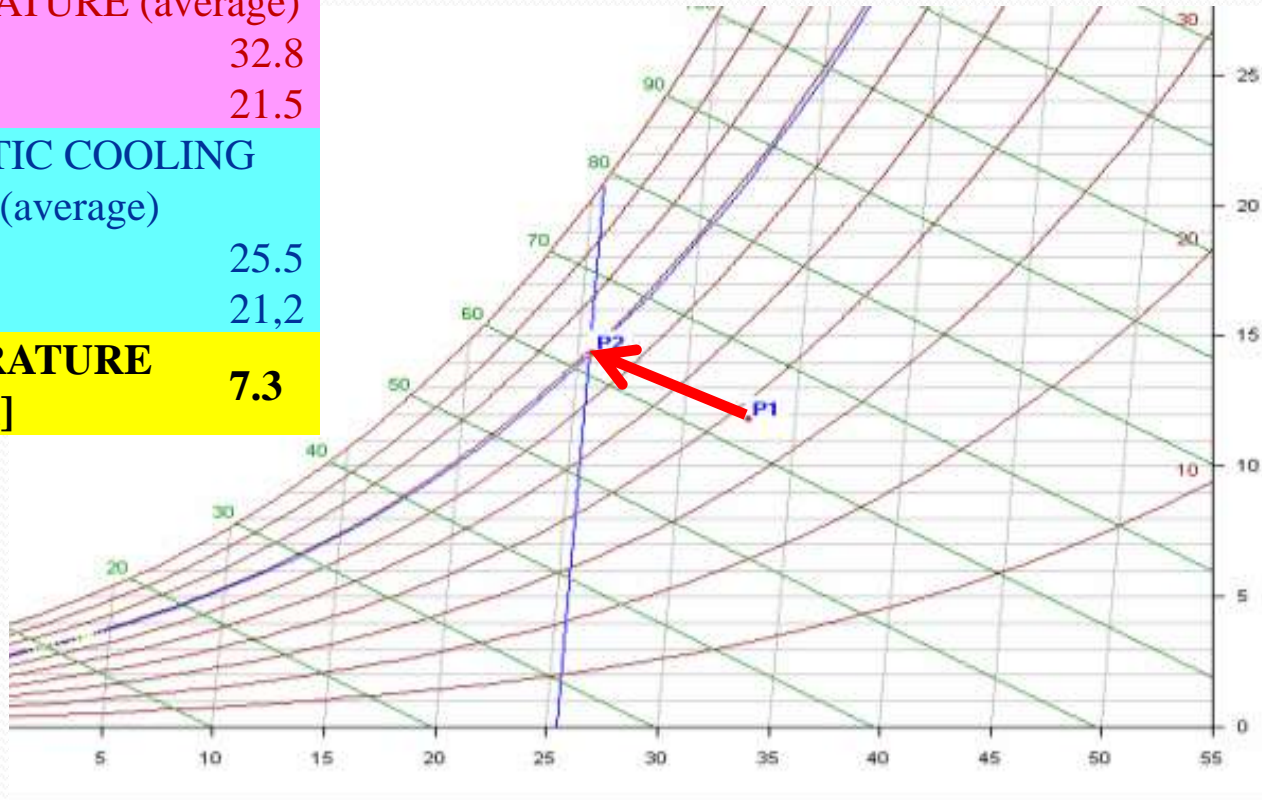
OUTLET (average)

DB [°C] 25.5

WB [°C] 21,2

TEMPERATURE

DROP [K] 7.3



Result on the psychrometric diagram of average of
14000 data

An Illustrative Example / Smart Control WSMCST

CHILLER UNIT	
Condenser inlet temperature	32.8 °C
Cooling capacity	659 kW
Inlet power	223 kW
EER	2.96
CHILLER UNIT WITH ADIABATIC COOLING	
Condenser inlet temperature	25.5 °C
Cooling capacity	698 kW
Inlet power	208 kW
EER	3.36
Increase in EER	13.5%
Increase in the cooling capacity	5.9%

Conclusion

- Based on the measurements obtained from the evaporative pre-cooling applied to air-cooled chillers in a textile factory, located in Izmir, Turkey,
 - Increase the EER in various temperatures by up to about 14% in the months of June through August 2009
 - No high pressure defect in refrigerant circuit
 - No scale problems on heat exchanger
- 7-10 K average pre-cooling temperature could be obtained in Izmir.

Conclusion

- It is simple and easy to apply a WSMCST with a real time monitoring system to any given air-cooled exchanger
 - Air-cooled chillers to improve energy efficiency ratio.
 - Gas turbine thermal power plants,
 - Cogeneration systems and
 - Geothermal power plants in order to improve their energy utilization efficiency values.
- It was determined that the installation of the WSMCST with a real time monitoring system enables its investment cost to recover in **one season**.

Thank you...

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