IEA-EBC Annex 85

EBC
Energy in Buildings and Communities Programme

Comparison of IEC air cooler system and IEC water chiller system

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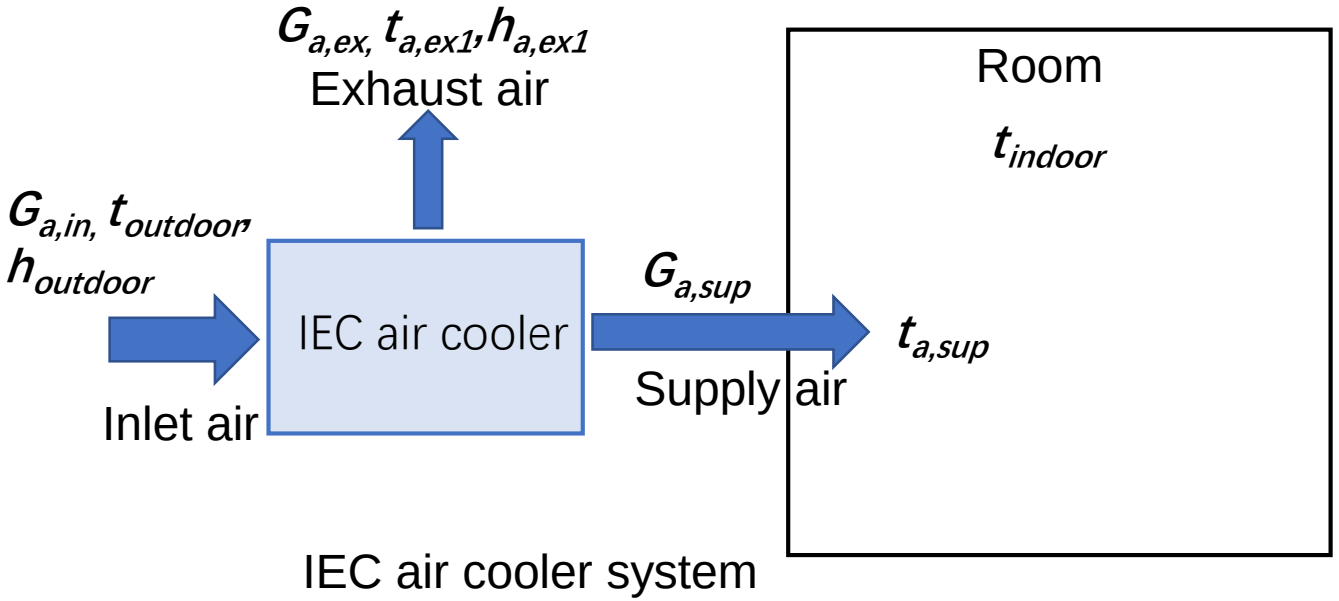
Main Problem

- For the IEC cooling system to remove indoor sensible heat, choose the IEC cooling air system or IEC water chiller system, which one is better?

IEC air cooler system and IEC water chiller system



For removing indoor sensible heat:

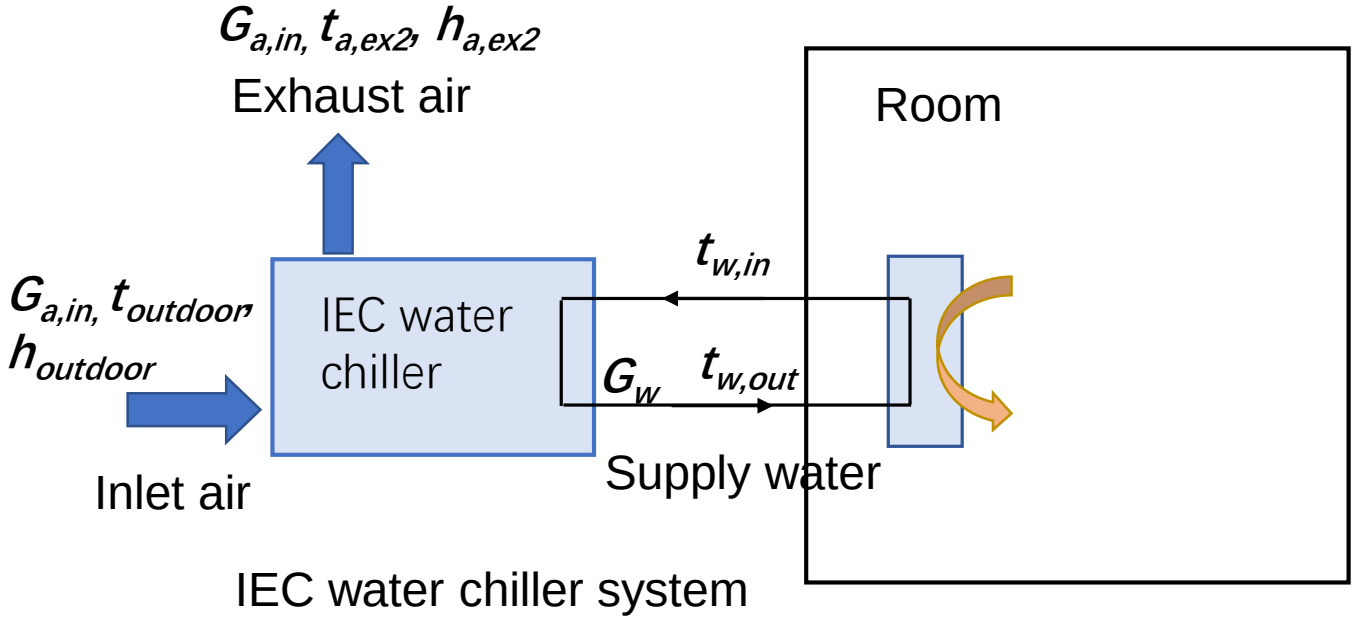
For IEC air cooler system:

$$Q_{indoor} = G_{a,sup}\, c_{pa}(t_{indoor} - t_{a,sup})$$

$$Q_{process} = G_{a,sup} c_{pa}(t_{outdoor} - t_{a,sup}) = G_{a,ex}(h_{a,ex1} - h_{outdoor})$$

$$Q_{process} \neq Q_{indoor}$$

Always $Q_{process} > Q_{indoor}$



For IEC water chiller system:

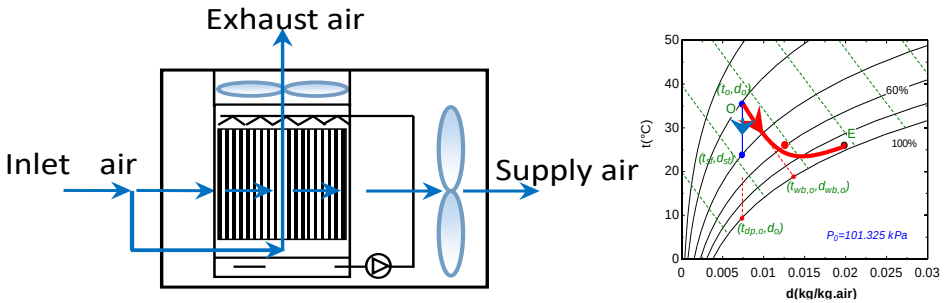
$$Q_{indoor} = G_w\, c_{pw}(t_{w,in} - t_{w,out})$$

$$Q_{process} = G_w\, c_{pw}(t_{w,in} - t_{w,out}) = G_{a,in}(h_{a,ex2} - h_{outdoor})$$

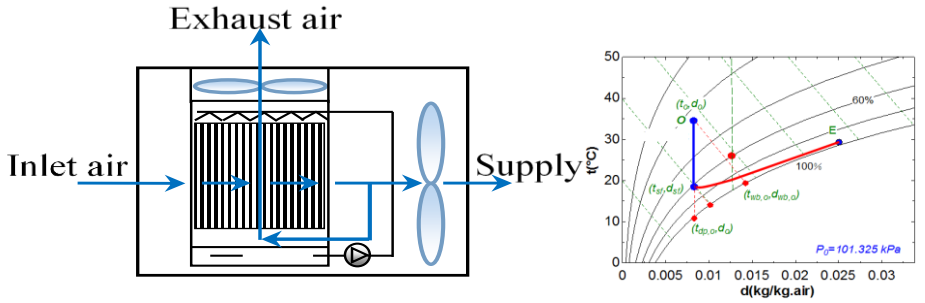
$$Q_{process} = Q_{indoor}$$

IEC air coolers

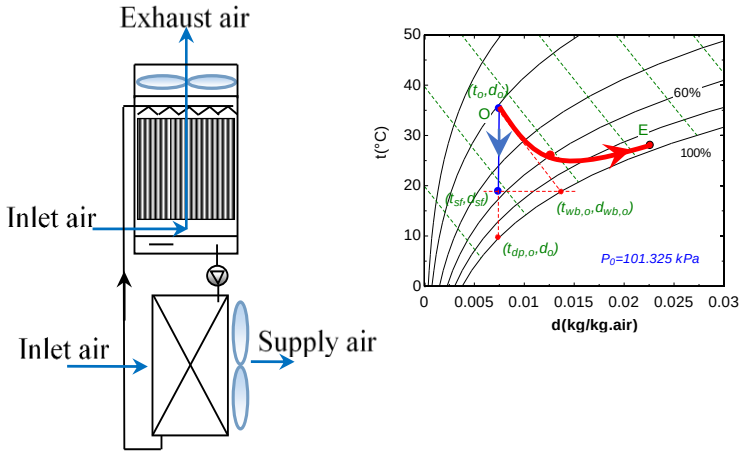
- **Various kinds of process structures**



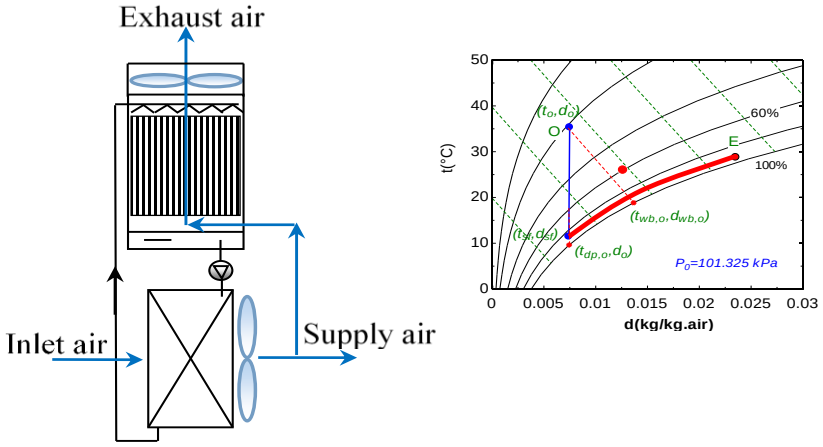
Internal IEC *air coolers with inlet air as secondary air*



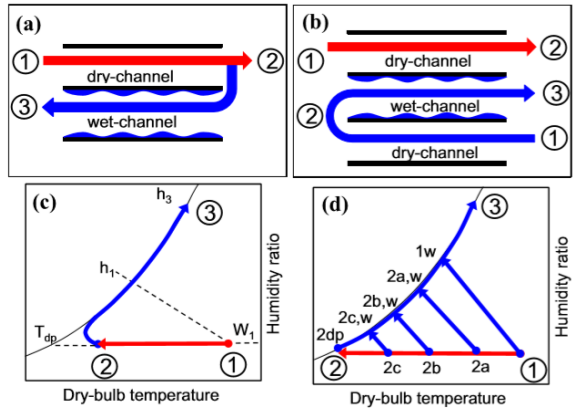
Internal IEC *coolers with one part of outlet air as secondary air*



External IEC *coolers with inlet air as secondary air*



External IEC *coolers with one part of supply air as secondary air*



M-Cycle IEC air coolers

IEC air coolers

Different IEC air coolers	Supply air temperature limit	Ability to remove indoor heat	Cooling medium
Internal cooling IEC coolers, using outdoor air as the secondary air, Fig.1.	$t_s > t_{wb,o}$	The lowest	air
Internal cooling IEC coolers, using one part of the supply air as the secondary air, Fig. 2.	$t_{dp,o} < t_s < t_{wb,o}$	Higher	air
External cooling IEC coolers, using outdoor air as the secondary air, Fig. 3.	$t_s = t_{wb,o}$	Lower	water and air
External cooling IEC coolers, using one part of the supply air as the secondary air, Fig. 4.	$t_s = t_{dp,o}$	The highest	air

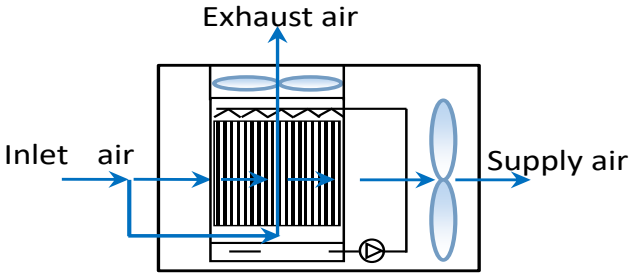


Fig. 1

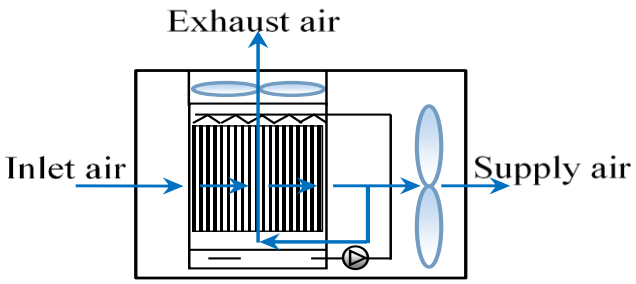


Fig. 2

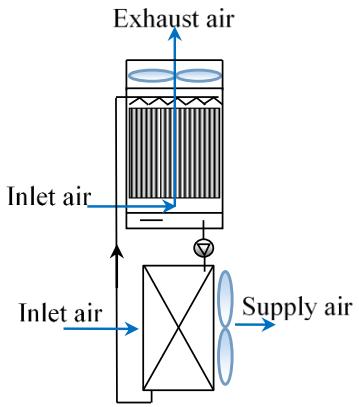


Fig. 3

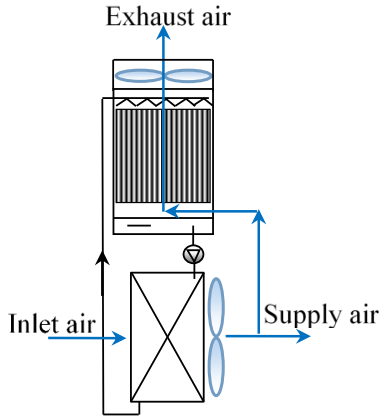
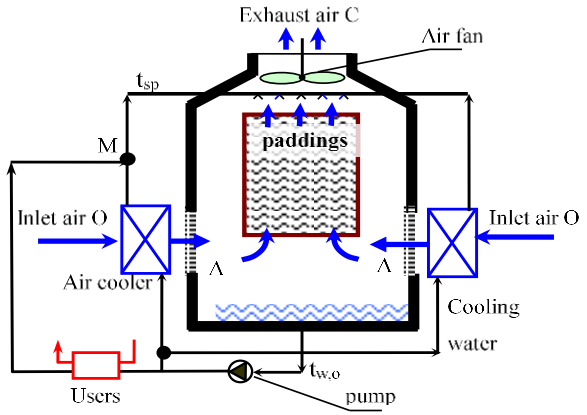


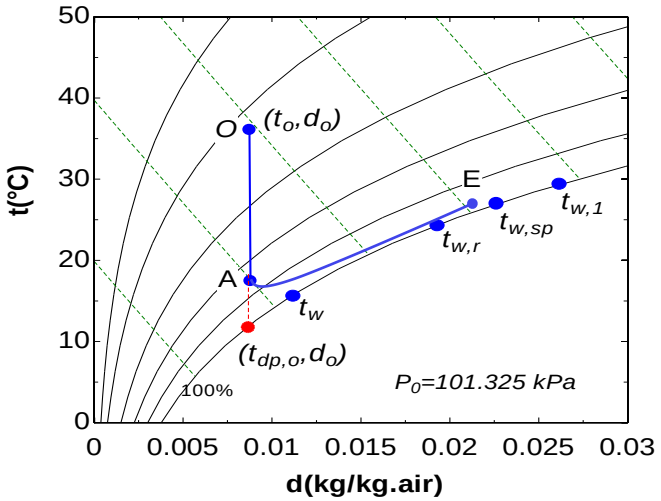
Fig. 4

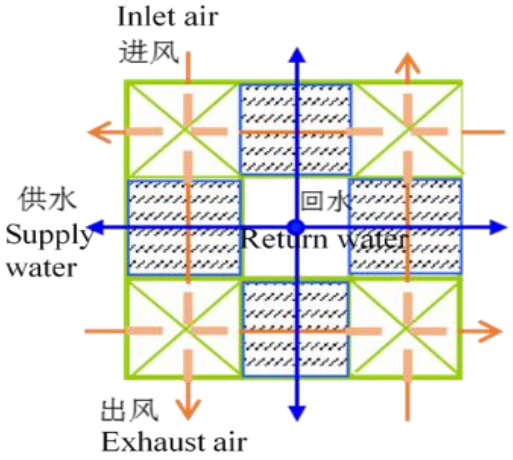
IEC water chillers

- **Different structures of IEC water chillers**

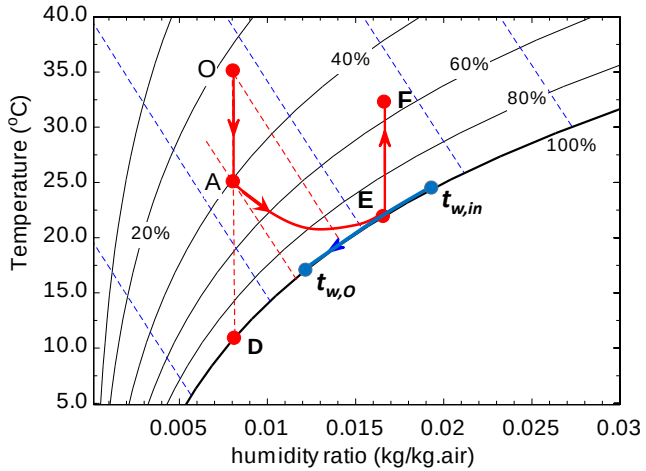


IEC chiller I



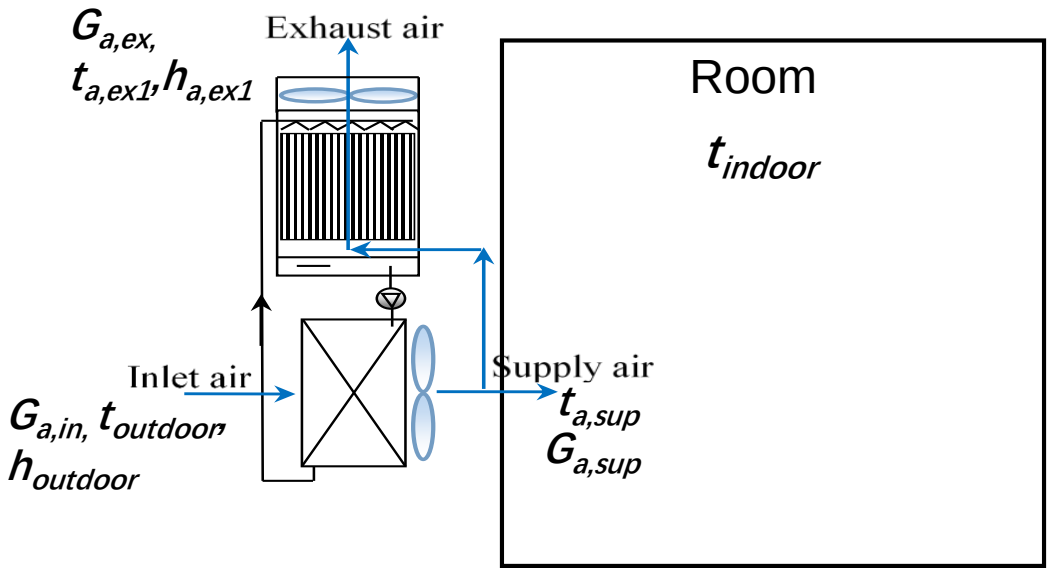


IEC chiller II

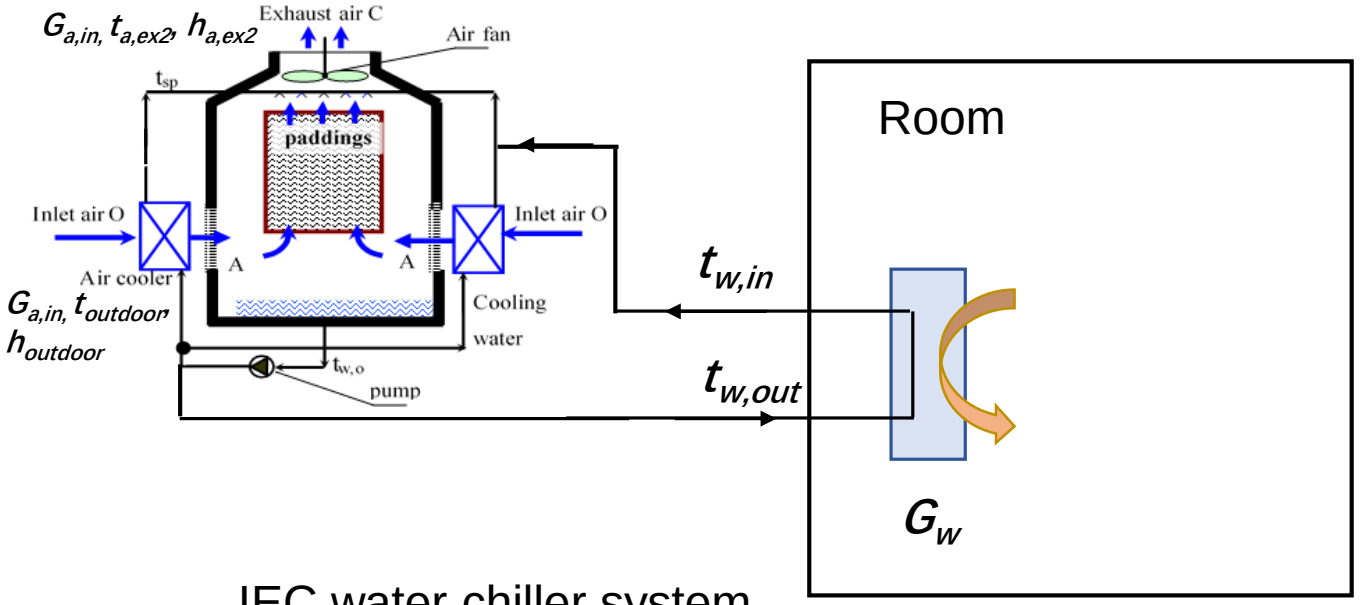


Different IEC water chillers	Supply water temperature limit	Ability to remove indoor heat	Cooling medium
IEC chiller I	Lim $t_{w,o}=t_{dp,o}$	The same (lower water flow rate, higher temperature difference)	water
IEC chiller II	Lim $t_{w,o} < t_{dp,o}$	The same (Higher water flow rate, lower temperature difference)	water

Comparison between IEC air cooler system and IEC water chiller system



IEC air cooler system

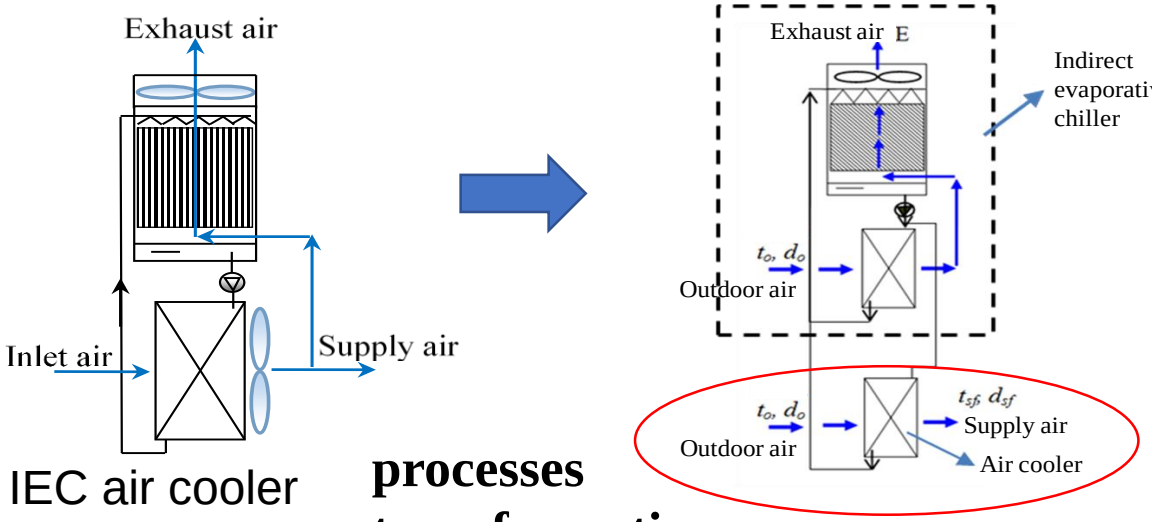


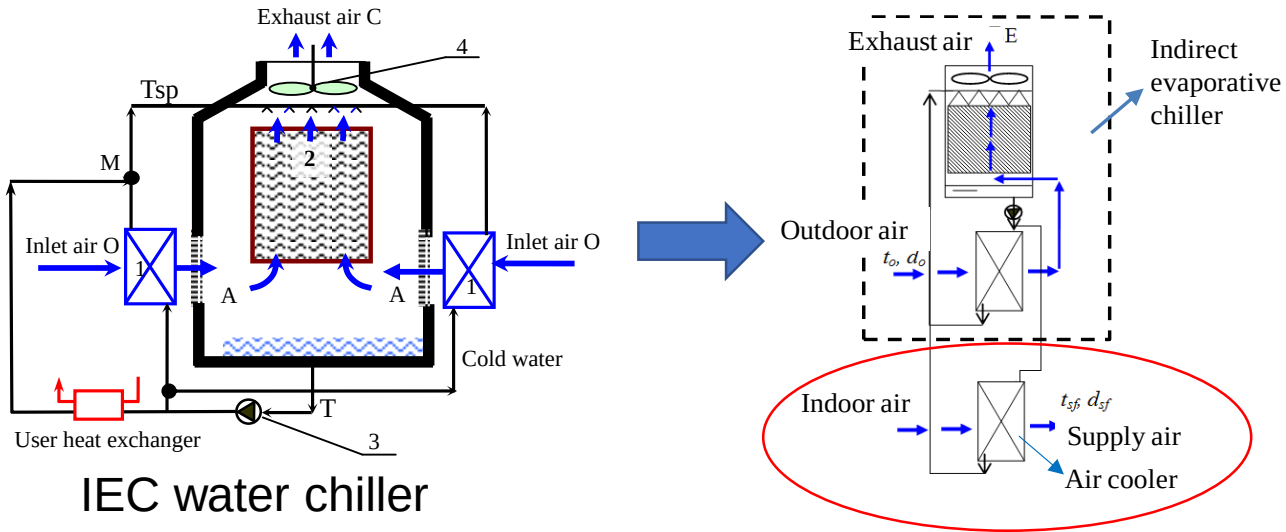
IEC water chiller system

- Comparison:
  - Remove the same indoor sensible heat, the demanded heat transfer area and the electricity consumption
  - Through theoretical analysis and real cases

Theoretical analysis

- Process transformation





Through process transformation

- IEC air cooler system, is an IEC water chiller combined an outdoor air-water heat exchanger
- IEC water chiller system, is an IEC water chiller combined a indoor air-water heat exchanger.

To remove the same quantity of indoor heat:

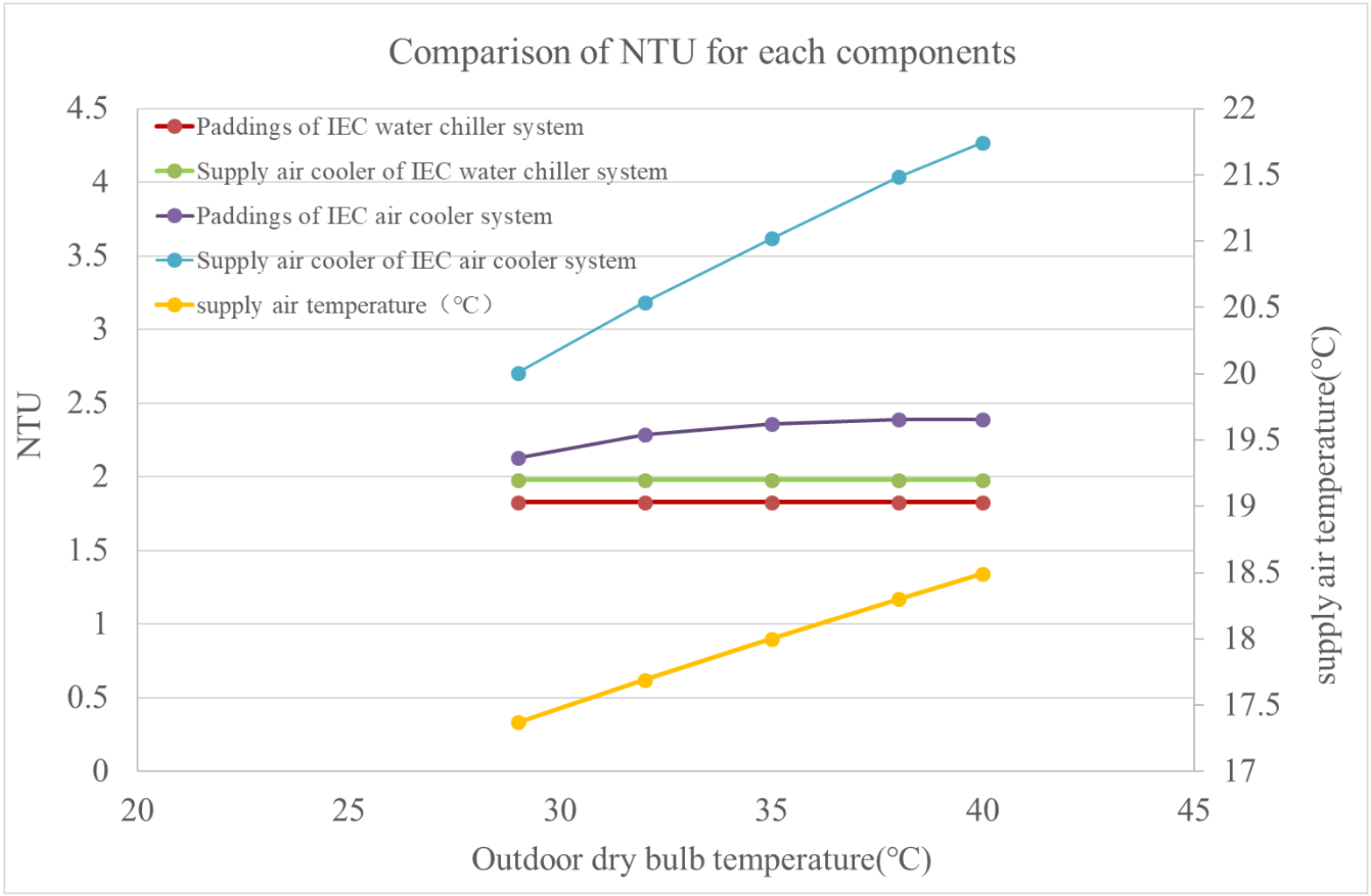
- The process produced cooling energy IEC air cooler is larger than IEC water chiller, when outdoor air is hotter than indoor air, the difference is the outdoor air heat load of IEC air cooler.

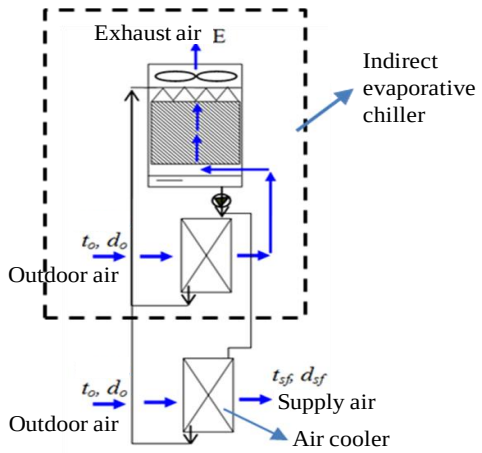
$$\Delta Q = G_{a,sup}\, c_{pa}(t_{outdoor} - t_{indoor})$$

- Thus, larger heat transfer area and larger cost when using IEC air cooler to remove indoor sensible heat.

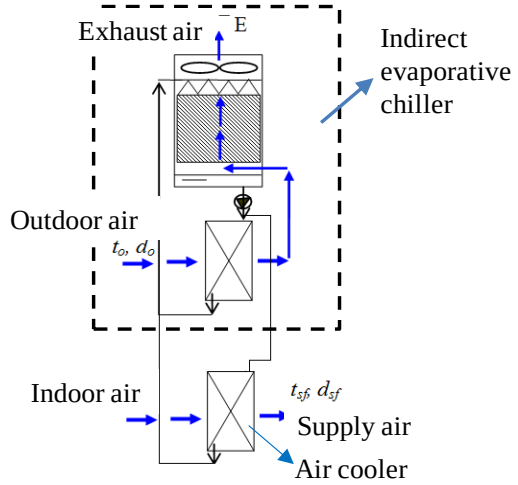
Theoretical analysis

- To remove the same quantity of indoor sensible heat, comparison of NTU for each components, for IEC air cooler system and IEC water chiller system.





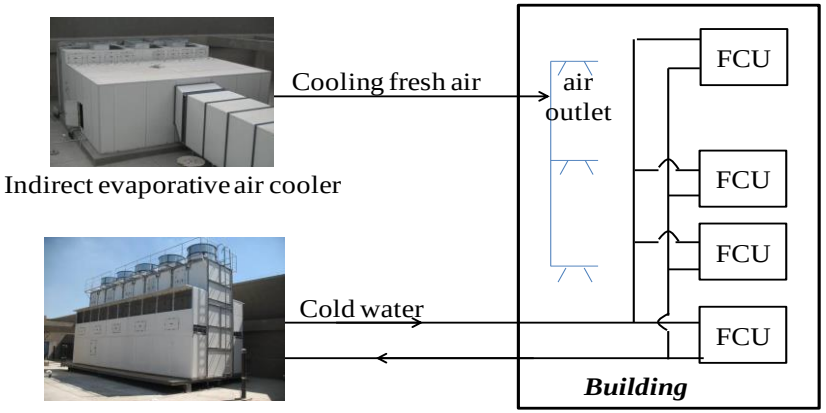
IEC air cooler system

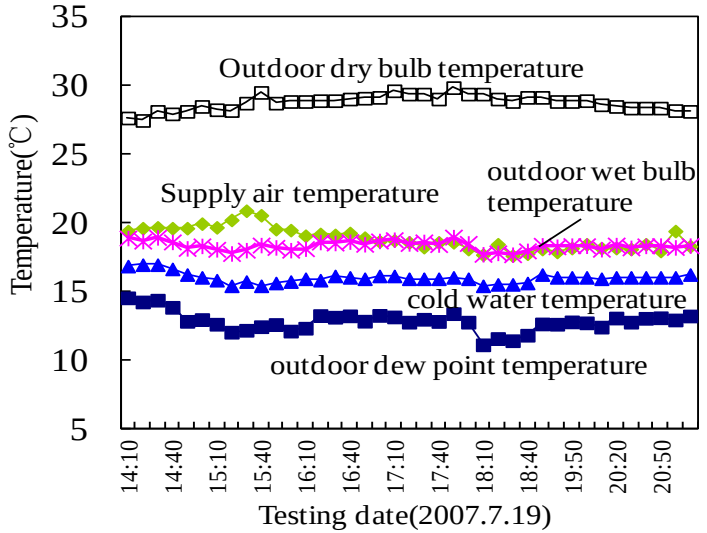


IEC water chiller system

Comparison through real cases

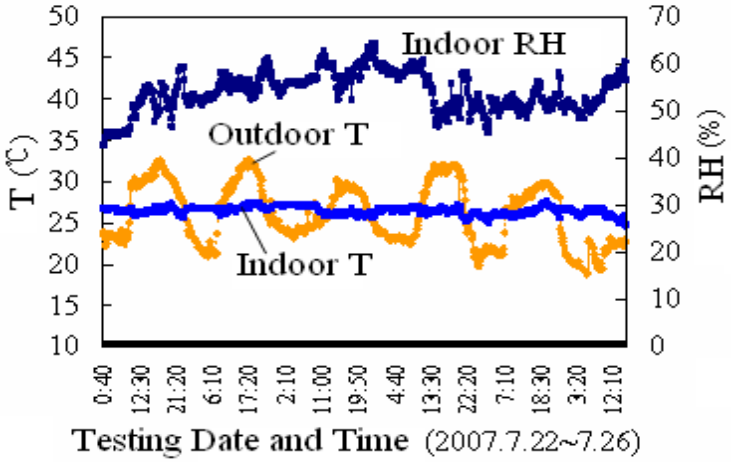
- **Case I*:*** Xinjiang Traditional Medicine Hospital (13000m^2)
- *With fan coil units as terminals to remove sensible heat, indirect* evaporative chiller to produce cold water, and indirect evaporative fresh air handling unit to produce cooling air with humidity ratio as dry as outdoor conditions.





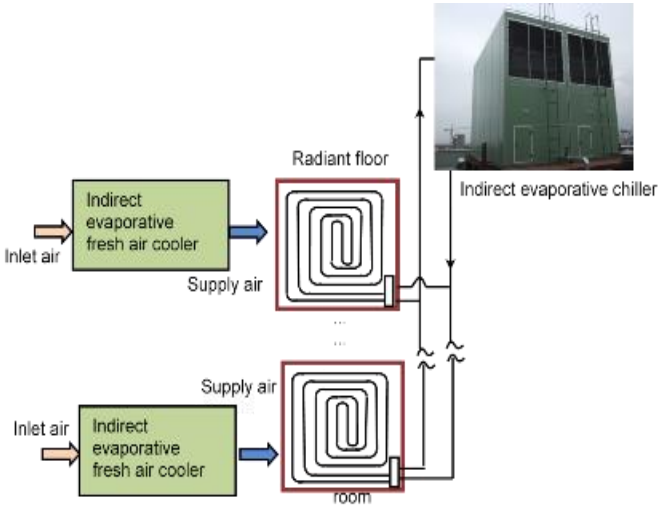
Sensible heat removed by cold water (kW)	Electricity consumption of Fan of IEC chiller （kW)	Electricity consumption of water pump (kW)	Electricity consumption of Fan-coils(kW)	Water system COP to remove indoor sensible heat
219	13.8	14.9	19.2	4.6

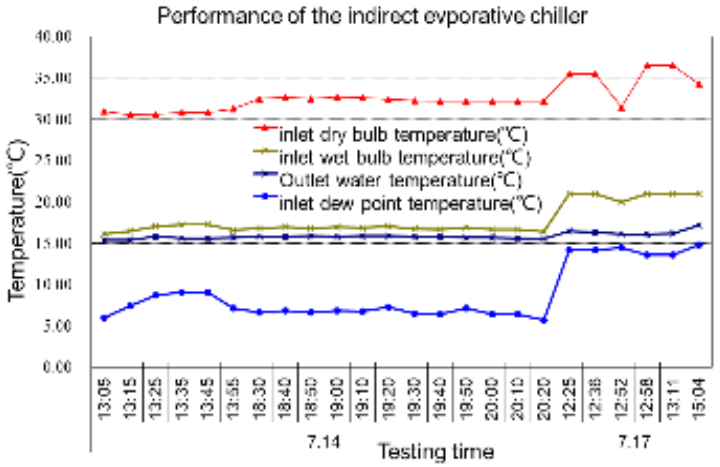
Fresh air supply (m3/h)	Sensible heat removed by cooling air (kW)	Electricity consumption of IEC air cooler(kW)	Electricity consumption of supply air fan (kW)	Air system COP to remove indoor sensible heat
88000	169	13.5	28.3	4.05



Comparison through real cases

- **Case II*:*** Urumqi Air Force hospital (17231.4m^2)
- With radiant floor as terminals to remove sensible heat, using indirect evaporative chiller to produce cold water and indirect evaporative fresh air handling unit to produce cooling air with humidity ratio as dry as outdoor conditions.



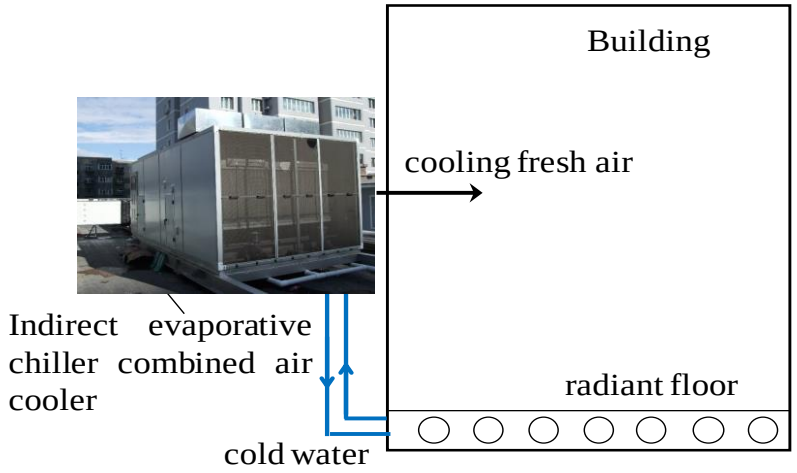


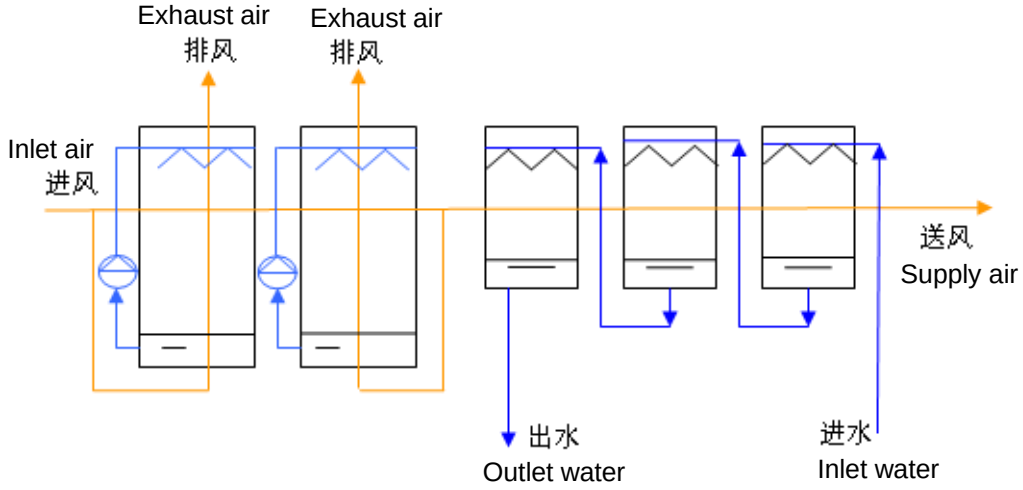
Sensible heat removed by cold water (kW)	Electricity consumption of Fan of IEC chiller （kW)	Electricity consumption of water pump (kW)	Electricity consumption of user terminals (kW)	Water system COP to remove indoor sensible heat
186	18.7	13.4	0	5.8

Fresh air supply (m3/h)	Sensible heat removed by cooling air (kW)	Electricity consumption of IEC air cooler(kW)	Electricity consumption of supply air fan (kW)	Air system COP to remove indoor sensible heat
174290	421	54.3	91.5	2.9

Comparison through real cases

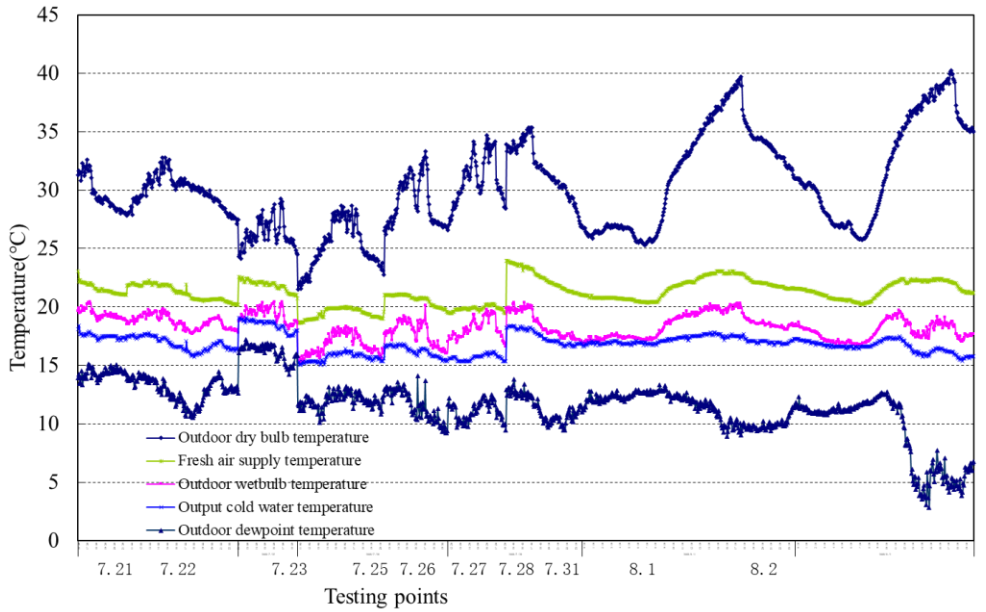
- **Case III*: An office building in Xinjiang province*** (1000m^2)
- With radiant floor as terminals to remove sensible heat, using indirect evaporative chiller combined air cooler to remove indoor sensible heat and to supply demanded fresh air.





Sensible heat removed by cold water (kW)	Electricity consumption of Fan of IEC chiller (kW)	Electricity consumption of water pump (kW)	Electricity consumption of radiant floor (kW)	Water system COP to remove indoor sensible heat
29.3	1.4	2.16	0	8.23

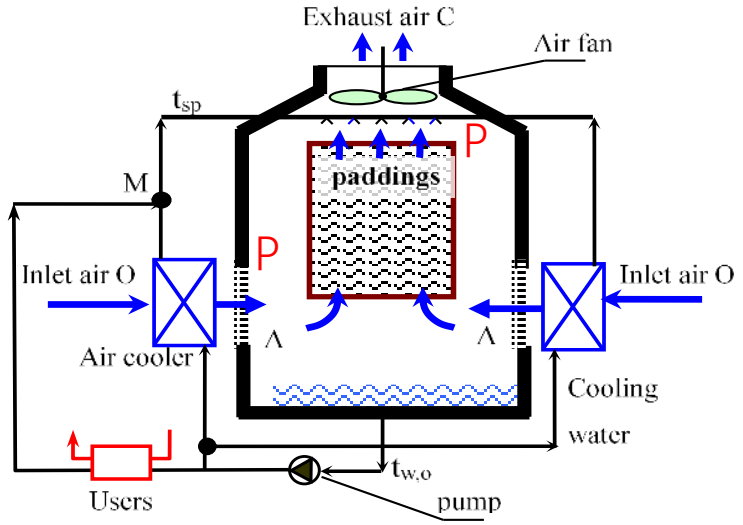
Fresh air supply (m3/h)	Sensible heat removed by cooling air (kW)	Electricity consumption of IEC air cooler(kW)	Electricity consumption of supply air fan (kW)	Air system COP to remove indoor sensible heat
8400	10.8	2.0	1.76	2.9



Performance of components of IEC water chillers

- Pressure drop of air coolers and padding towers-tested data by ourselves

Heights of tested paddings (m)	Electricity consumption of fan(kW)	Total air flow rate (m3/h)	Pressure drop of air cooler (Pa)	Total pressure drop(Pa)	Air velocity of air cooler (m/s)	Air velocity of paddings (m/s)
3	7.46	28840		193	2.0	2.0
2.5	7.42	28880	87	183	2.0	2.0
2	7.27	29724	89	174	2.1	2.1
1.5	7.3	30256	91	165	2.1	2.1
1	7.26	30980	93	156	2.2	2.2
0.5	7.3	31160	96	149	2.2	2.2
0	7.29	32660	101	140	2.3	2.3



Testing instrument: Micro differential pressure gauge

For IEC water chiller with 3 meters high paddings, for the tested air velocity:

Total pressure drop of paddings (Pa)	53
Pressure drop of air coolers with 8 rows (Pa)	101
Other local resistance, like air turning, et al.(Pa)	39

Pressure drop of air coolers

air velocity (m/s)	Pressure drop (Pa/row)
2.3	12.6
2.78	19

Pressure drop of paddings with 3 meters high

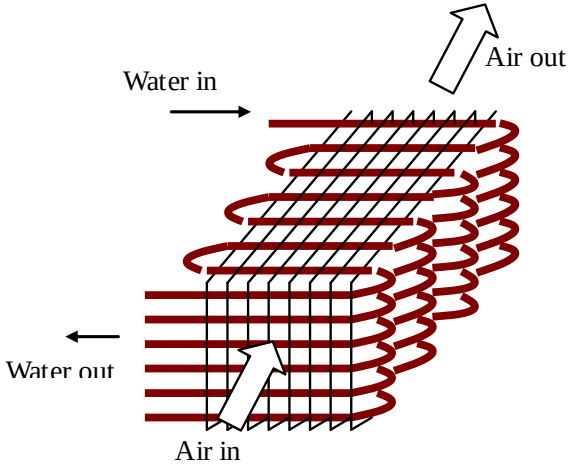
air velocity (m/s)	Pressure drop (Pa/m)
2.16	18.8
2.78	31

Information from manufactures

- For pressure drop of air coolers, which is higher than our tested value

4 rows：ΔP=30.714*V^1.593*E^0.001
6 rows：ΔP=31.332*V^1.663*E^0.005
8 rows：ΔP=45.217*V^1.66*E^0.033

V is air face velocity，m/s
E is moisture absorption coefficient;



Information from manufactures

- For different type of paddings

Height of paddings (m)	Air velocity (m/s)	Spraying density of water (t/h/m2)	Air mass velocity g (kg/m2/s)	Water volumetric velocity q (m3/h/m2)	Mass transfer coefficient of padding I Ka (kg/m3/h)	Mass transfer coefficient of padding II Ka(kg/m3/h)	Padding I a	Padding I m	Pressure drop of padding I (Pa)	Padding I a	Padding II m	Pressure drop of padding II (Pa)
1	2.77	10	3.324	10	23716.43772	23341.83426	1.0944	1.7353	62.90428568	1.2624	1.9914	94.19334
1.25	2.77	10	3.324	10	21235.89251	20248.05915	1.2704	2.0038	95.99540688	1.3919	1.9824	102.908
1.5	2.77	10	3.324	10	18514.19988	18317.43047	1.4604	2.0059	110.588763	1.4757	1.9894	109.8845

Tested mass transfer coefficient of paddings

风量 (m3/h)	水量 (t/h)	气水比 (相同单位)	进风温度	进风湿球	喷淋温度	出水温度	排风温度	排风相对湿度(%)	塔板冷量(kW)(水侧计算)	按出水计算的填料的体积传质系数
6715.8	9.42	0.86	24.05	15.18	27.46	20.45			76.71	7138
6846.3	8.24	1	23.79	14.63	29.565	19.96	26.2	93.7	91.9	7272
6846.3	8.24	1	25.05	13.51	27.32	18.985	24.77	93.2	79.75	6786
6715.8	7.46	1.08	26.41	15.66	26.29	18.695	24.77	96.3	65.8	9136
6715.8	8.7	0.93	24.11	15.19	28.83	20.31	26.32	95.5	86.1	7576
6814.8	5.75	1.42	26.23	15.14	27.56	17.29	23.73	98.9	68.59	9114
6814.8	5.75	1.42	22.45	15.23	26.24	17.08			61.18	9766

Main conclusions and next step

- To remove indoor sensible heat, if outdoor air temperature is higher than indoor air temperature, always it is better to use IEC water chiller system than to use IEC air cooler system, with lower input heat transfer area and system electricity consumption.
- If outdoor air is extremely dry, the best system could be direct evaporative cooling process to produce cooling dry air, which is much simple and cheaper, with less system electricity consumption.
- Next: give the suitable zone of different IEC/DEC processes in the psychrometric chart.

Thank you for your attentation and welcome discussions

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Another IEC water chiller combined air cooler