Performance of indicators for IEC water chillers

Ce Zhao, Xiaoyun Xie

Tsinghua University, Beijing, China

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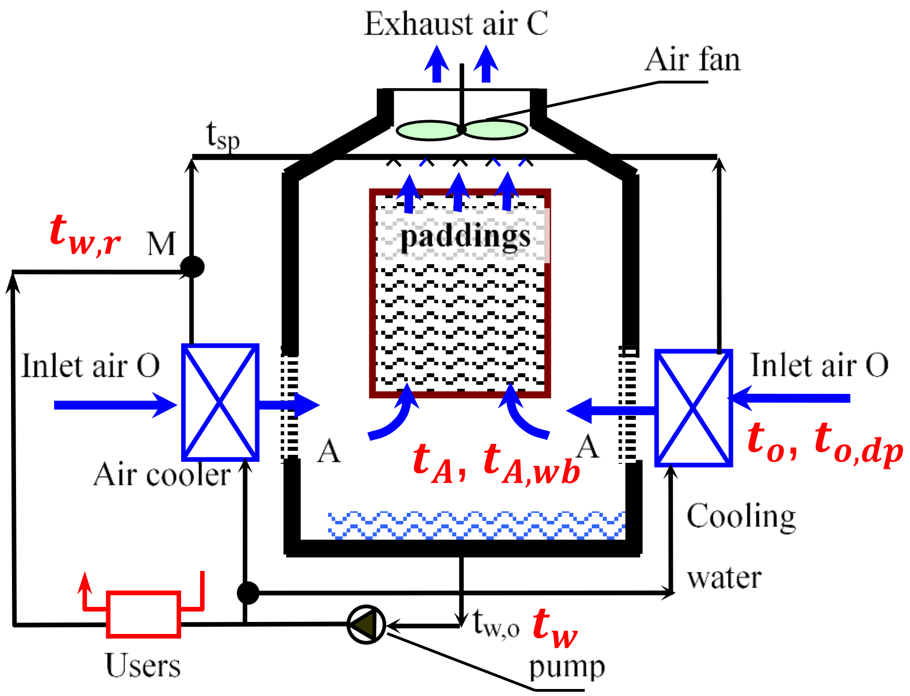
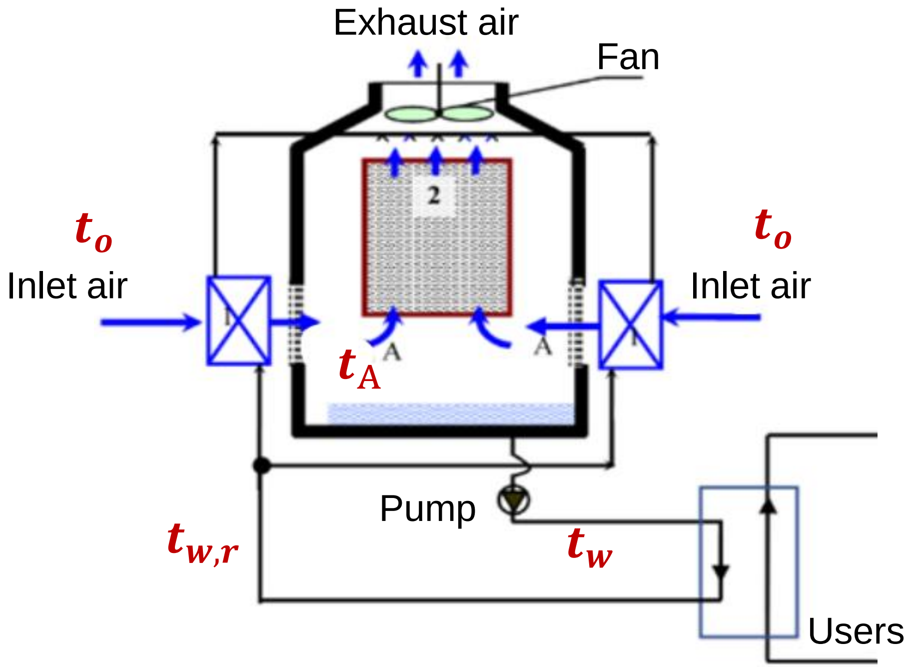
IEC water chiller processes

parallel-connected IEC water chillers



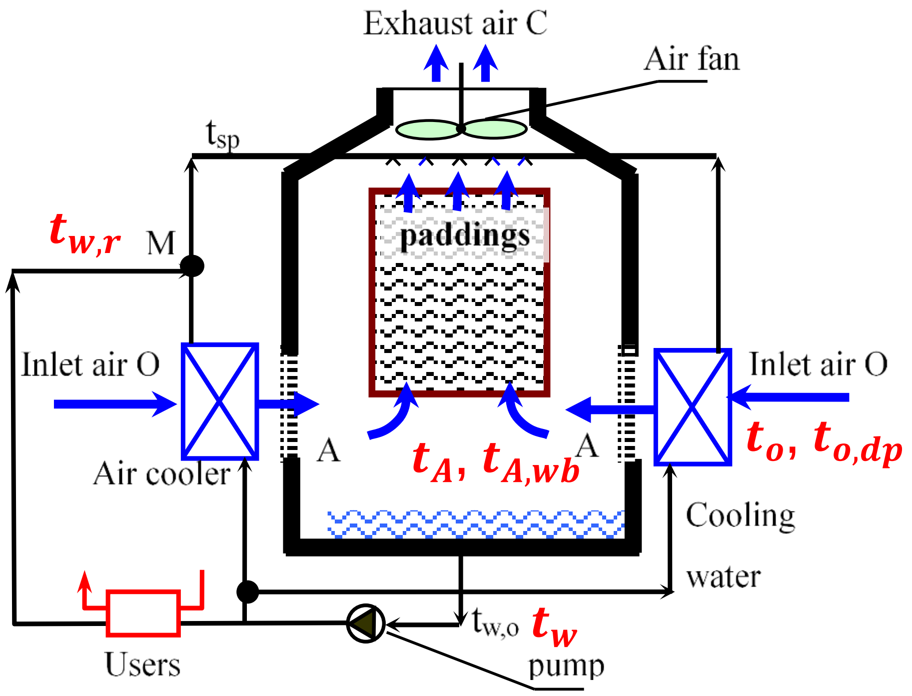
series-connected IEC water chillers



- Suitable indicators are expected with features affected by its own NTU and the flowrate ratio rather than climate conditions.

Define suitable indicators for IEC water chiller processes

- The indicators should better be stable or vary slightly with climate conditions.
- Two ways to indicate the IEC water chillers in this report:



- Only define one efficiency - Dew point temperature efficiency, to express the cooling performance.

$$\eta_{dew} = \frac{t_{w,r} - t_w}{t_{w,r} - t_{O,dp}}$$

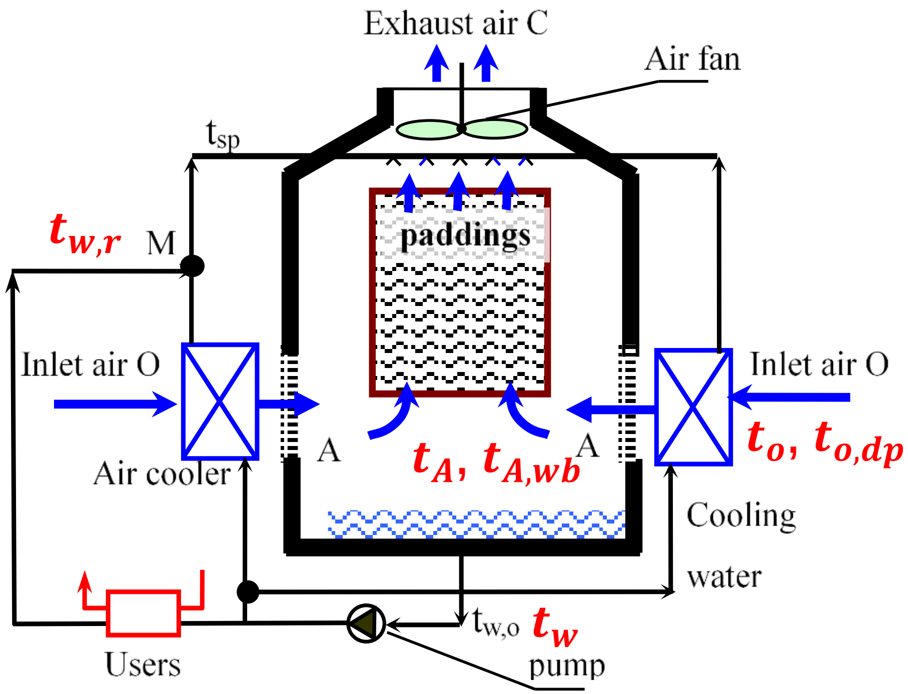
- Define two efficiencies - the evaporative cooling efficiency η_{ev} and the sensible cooling efficiency η_c

$$\eta_c = \frac{t_o - t_A}{t_o - t_{o,dp}}$$

$$\eta_{ev} = \frac{t_{w,r} - t_w}{t_{w,r} - t_{A,wb}}$$

Using η_{dew} as the indicator for IEC water chiller processes

- If only define one efficiency-Dew point temperature efficiency



$$\eta_{dew} = \frac{t_{w,r} - t_w}{t_{w,r} - t_{o,dp}}$$

Thus, t_w could be described as the follow equation:

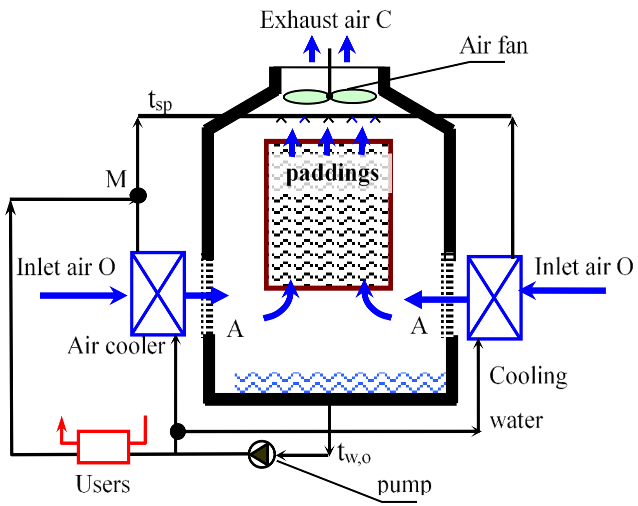
$$t_w = t_{w,r} - \eta_{dew} * \{t_{w,r} - t_{o,dp}\}$$

t_o: inlet air temperature;
$t_{o,dp}$: inlet air dewpoint temperature;
$t_{w,r}$: inlet water temperature;
t_w : outlet water temperature.

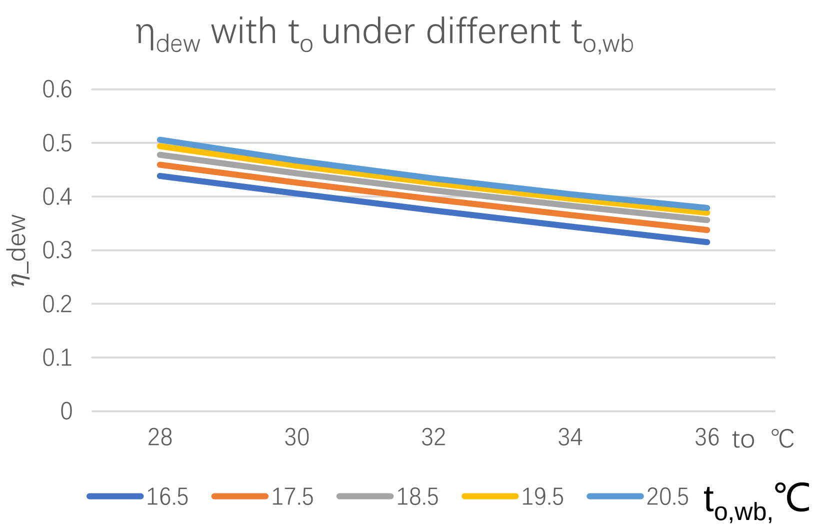
Using η_{dew} as the indicator for IEC water chiller processes

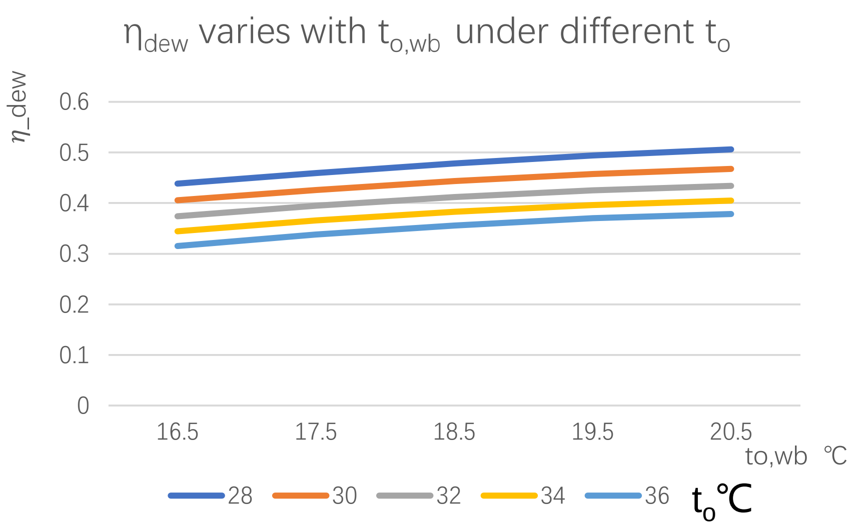
- For **parallel-connected** IEC water chillers

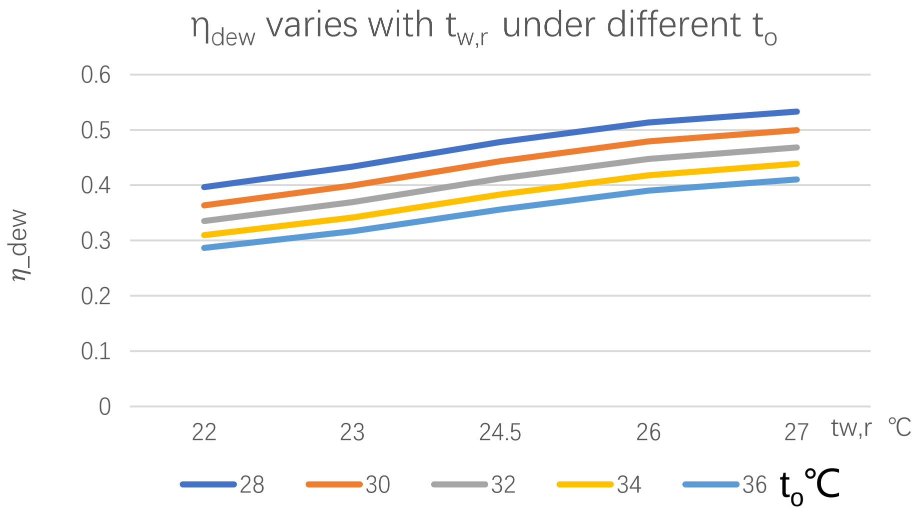
$$\eta_{dew} = \frac{t_{w,r} - t_w}{t_{w,r} - t_{O,dp}}$$



parameter	design value
inlet air dry-bulb temperature t_O ℃	34^{+2}_{-6} ℃
inlet air wet-bulb temperature $t_{O,wb}$	18.5^{+2}_{-2}℃
returned water temperature $t_{w,r}$	$24.5^{+2.5}_{-2.5}$℃
Flow rate $G_a/G_{w,r}$	m=2.25
capacity of heat exchanger	Ntu_{ex}=2
capacity of padding	$Ntu_{padding}$=1.5





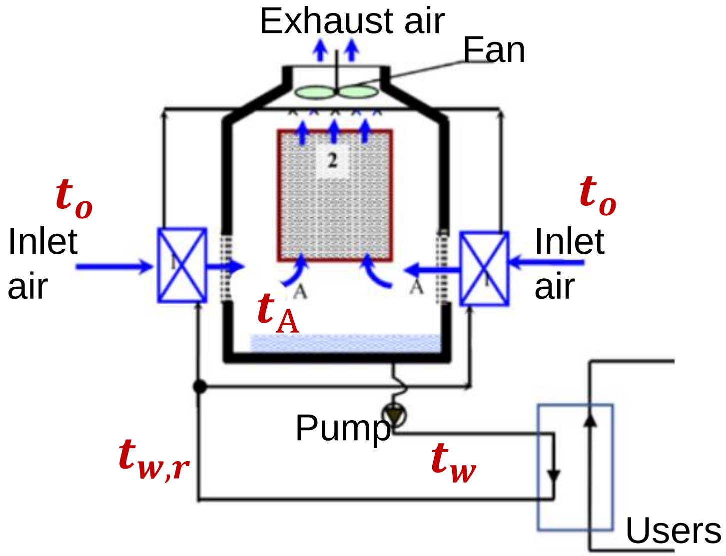


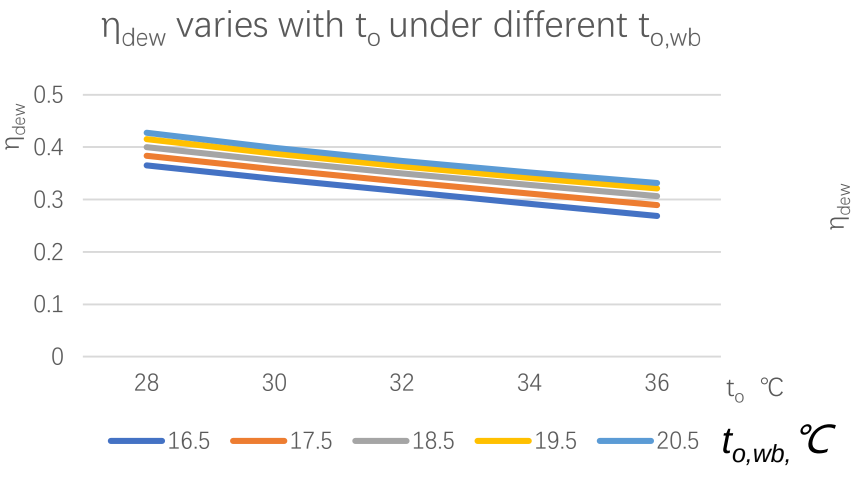
η_{dew} decreases when t_O increases
η_{dew} increases when $t_{O,wb}$ increases
η_{dew} increases when $t_{w,r}$ increases

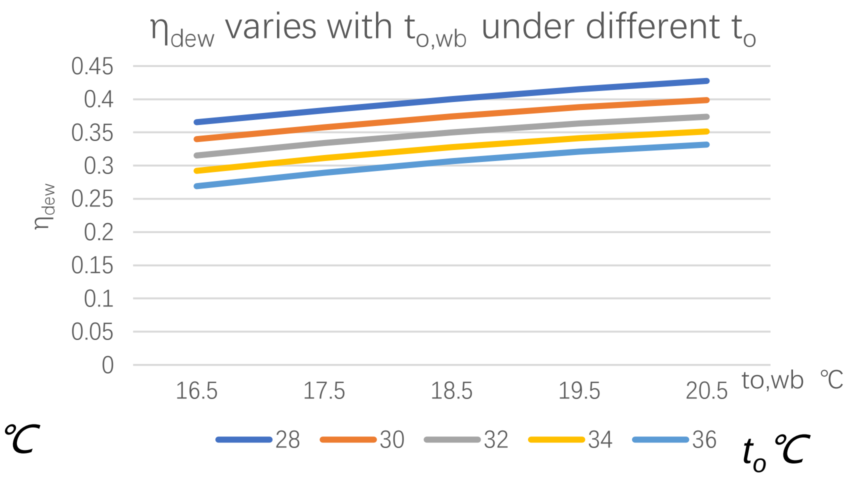
Using η_{dew} as the indicator for IEC water chiller processes

- For **series-connected** IEC water chillers

$$\eta_{dew} = \frac{t_{w,r} - t_w}{t_{w,r} - t_{O,dp}}$$







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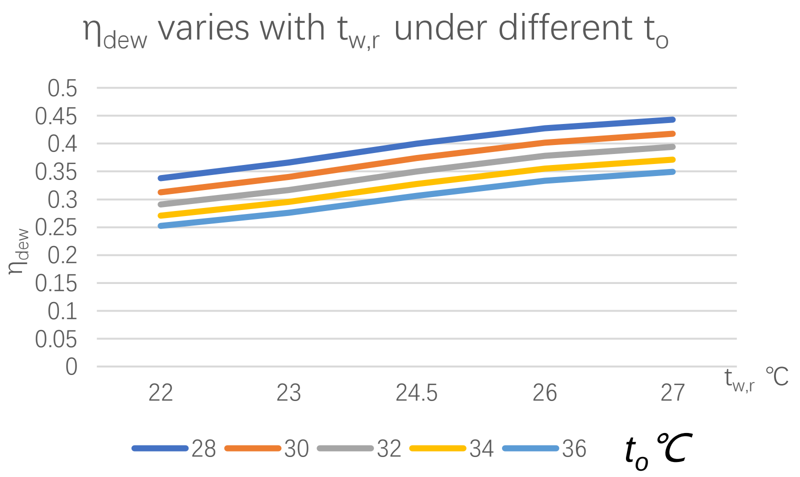

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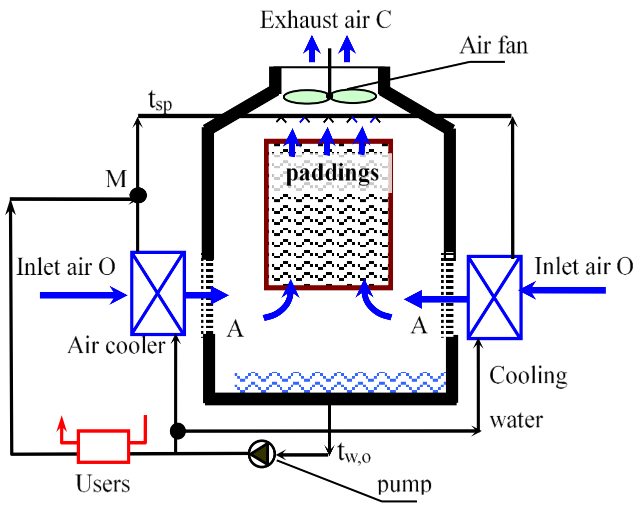
Using η_{dew} as the indicator for IEC water chiller processes

- For **parallel-connected** IEC water chillers



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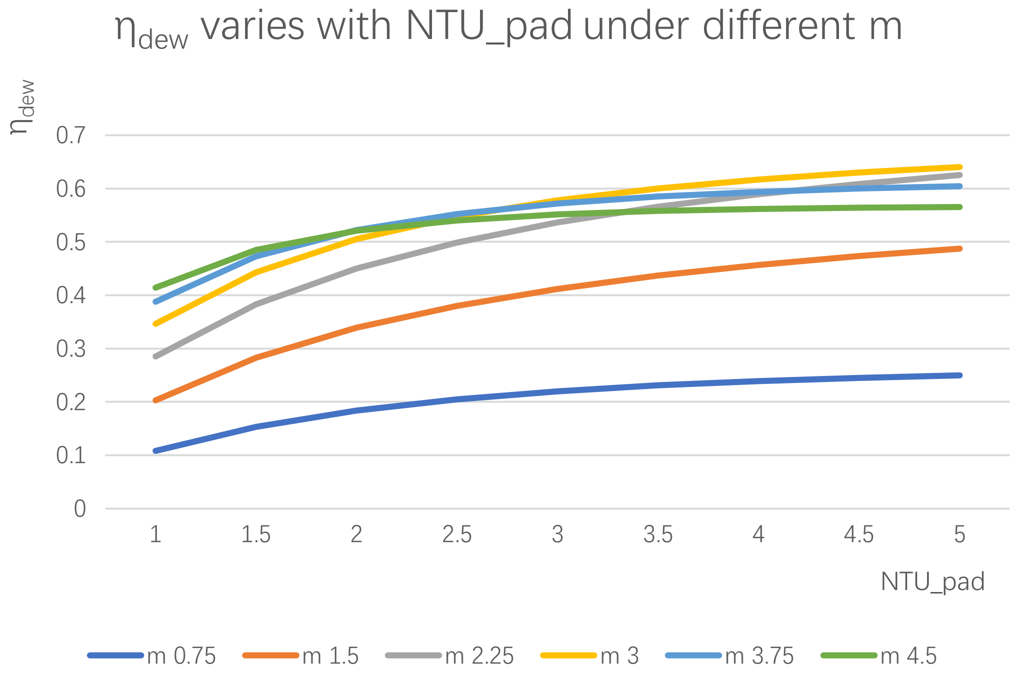
inlet air wet-bulb temperature $t_{O,wb}$	18.5℃
returned water temperature $t_{w,r}$	24.5℃
Flow rate $G_a/G_{w,r}$	$m = 2.25^{+1.5}_{-1.5}$
capacity of heat exchanger	$NTU_{ex}=2$
capacity of padding	$\mathrm{NTU}_{pad} = 3^{+2}_{-2}$

$$m = \frac{G_a}{G_{w,r}}$$

$$\mathrm{NTU\_pad} = \frac{K_s A}{G_a c_{pa}}$$



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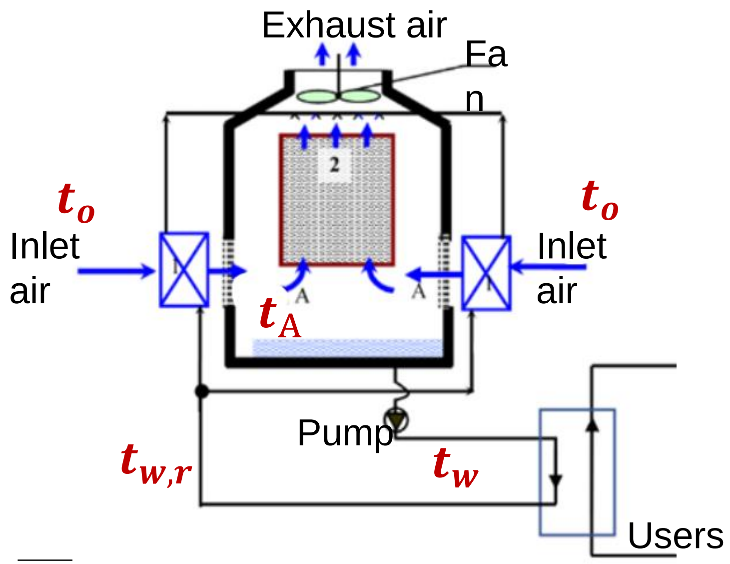

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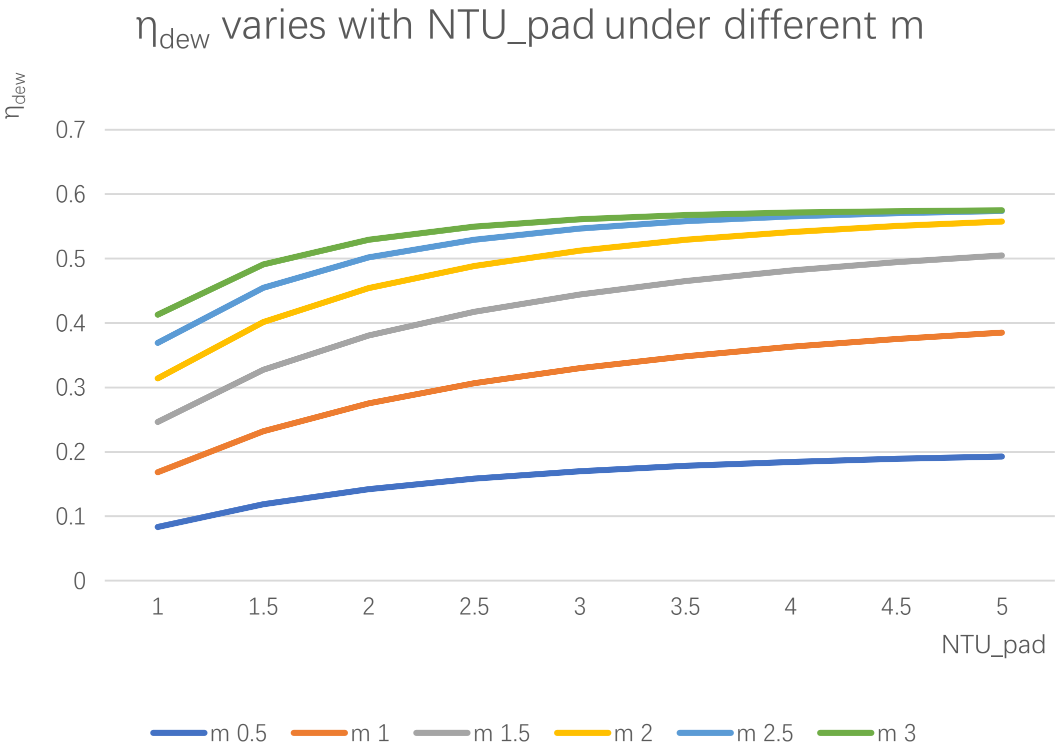
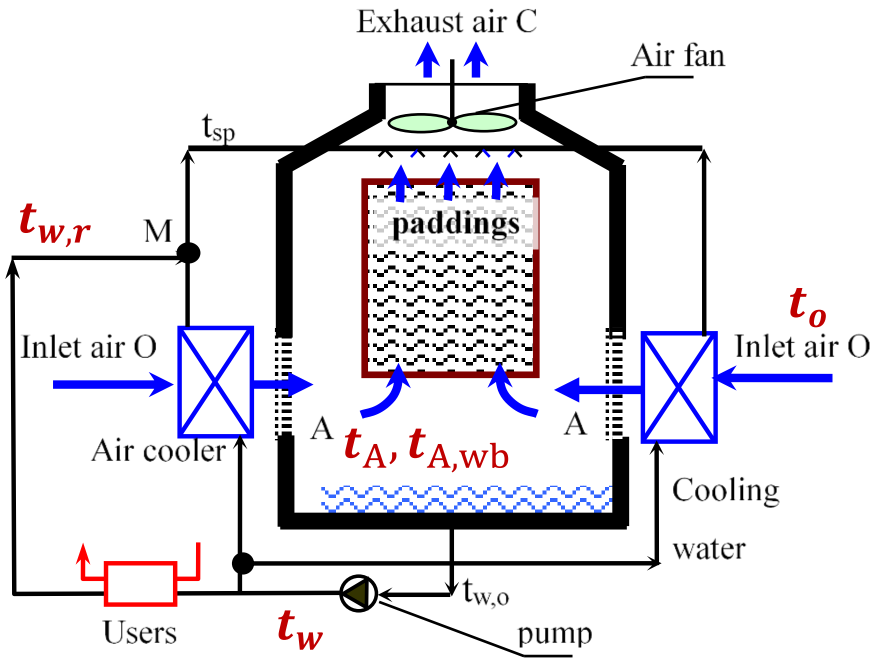


Using $\eta_c \& \eta_{ev}$ as the indicators for IEC water chiller processes

- Indicators for cooling performance
  - Two efficiencies identified, for air cooler and padding tower， which could be used to express the outlet water temperature
  - the evaporative cooling efficiency η_{ev} and the sensible cooling efficiency η_c



Sensible cooling efficiency:
$$\eta_c = \frac{t_o - t_A}{t_o - t_{o,dp}}$$

Evaporative cooling efficiency:
$$\eta_{ev} = \frac{t_{w,r} - t_w}{t_{w,r} - t_{A,wb}}$$

t_o: inlet air temperature;
$t_{o,dp}$: inlet air dewpoint temperature;
t_A: air past air−cooler temperature;
$t_{A,wb}$: air past air−cooler wet bulb temperature;
$t_{w,r}$: inlet water temperature;
t_w : outlet water temperature.

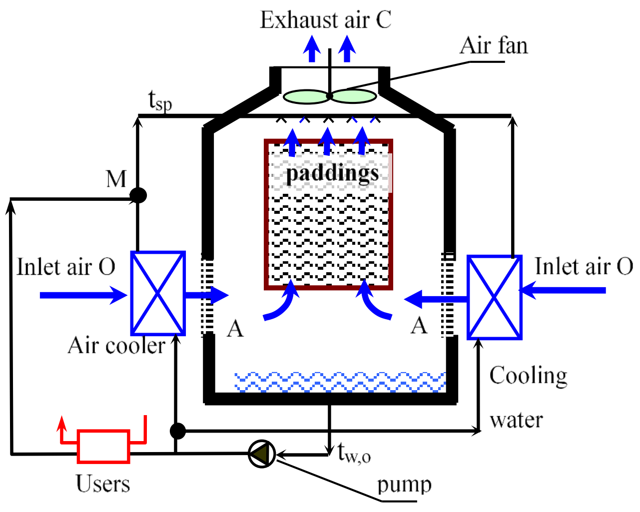
Thus, t_w could be described as the follow equation:

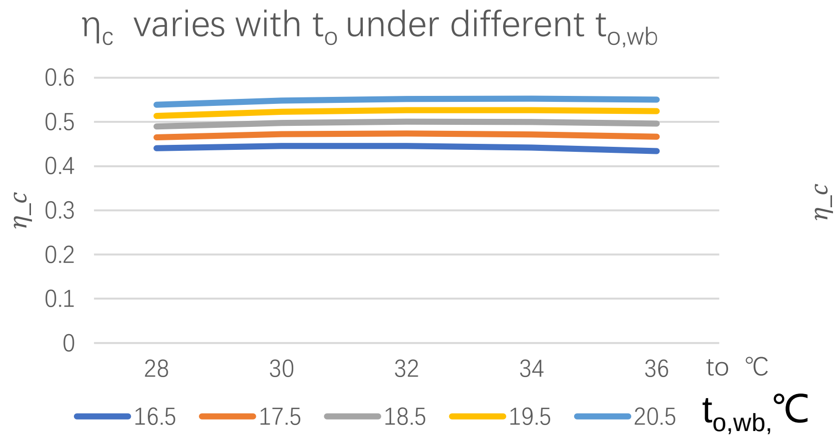
$$t_w = t_{w,r} - \eta_{ev} * \{t_{w,r} - [t_{o,wb} - \eta_c * (t_{o,wb} - t_{o,dp})]\}$$

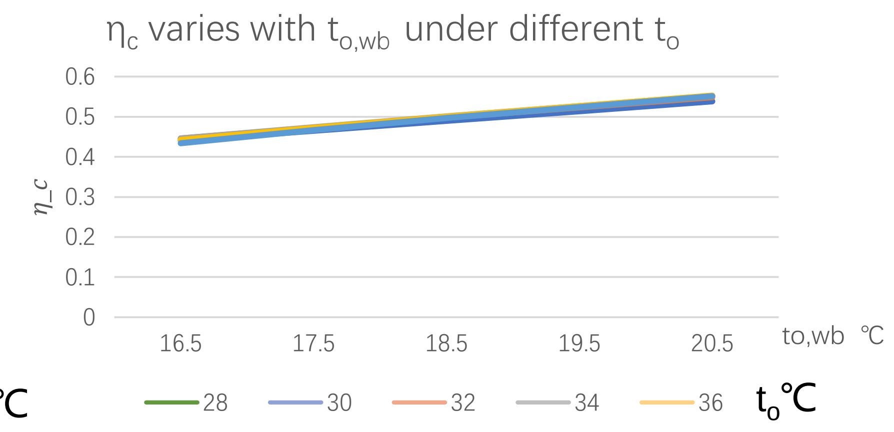
Using η_c&η_{ev} as the indicators for IEC water chiller processes

- For **parallel-connected** IEC water chillers

$$\eta_c = \frac{t_o - t_A}{t_o - t_{o,dp}}$$







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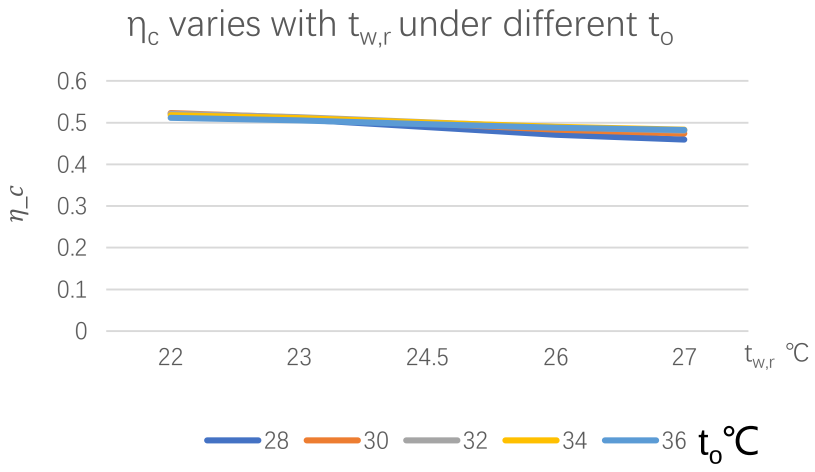
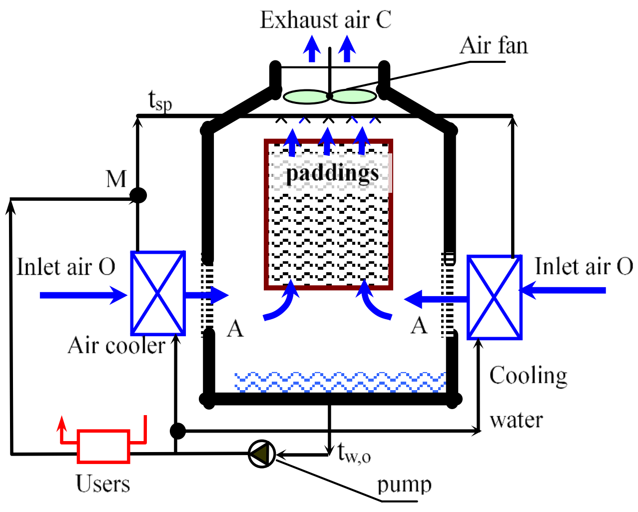


Using η_c&η_{ev} as the indicators for IEC water chiller processes

- For **parallel-connected** IEC water chillers

$$\eta_{ev} = \frac{t_{w,r} - t_w}{t_{w,r} - t_{A,wb}}$$



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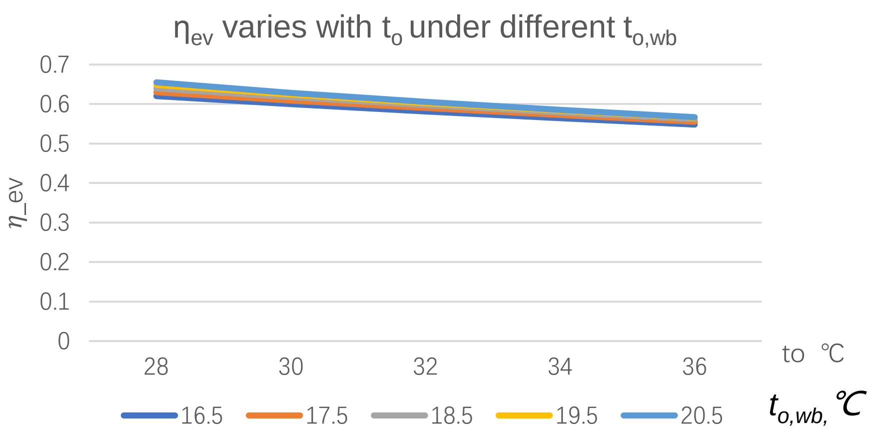

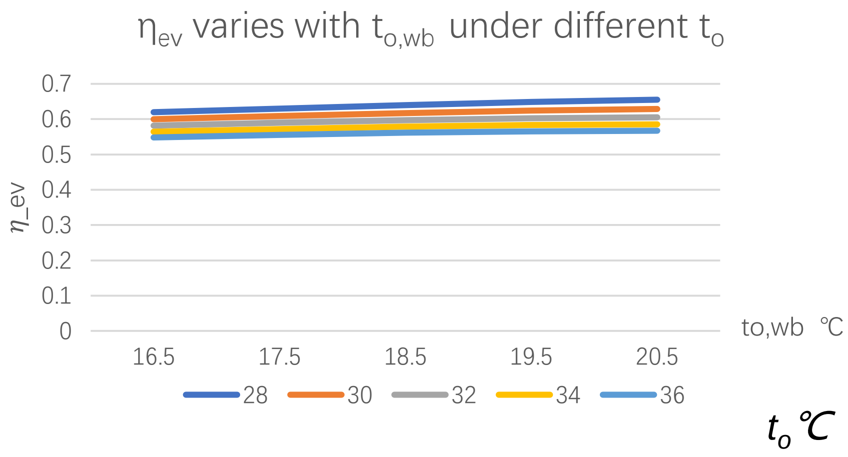

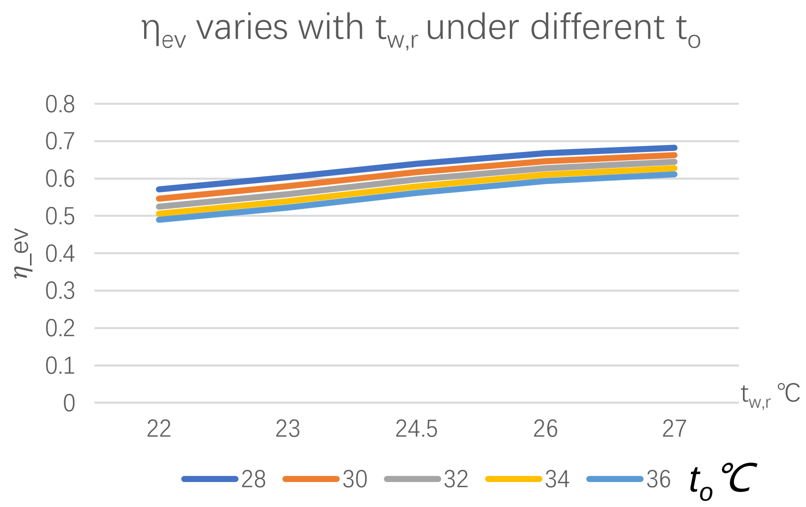

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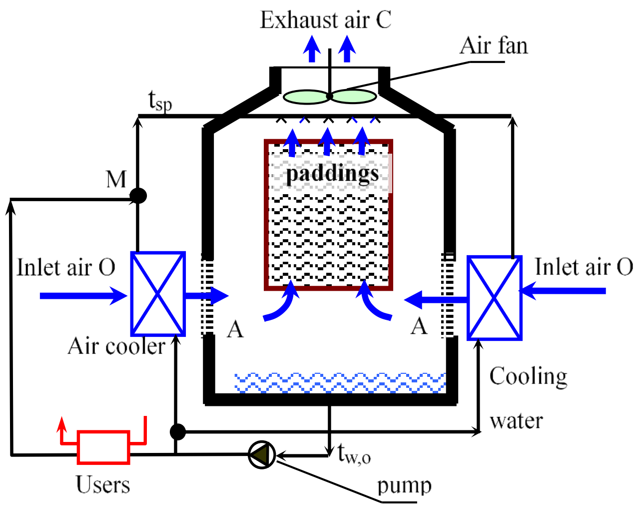

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capacity of heat exchanger	$\mathrm{NTU}_{ex} = 2^{+1}_{-1.5}$
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$$m = \frac{G_a}{G_{w,r}}$$

$$\mathrm{NTU\_ex} = \frac{KA}{G_a c_{pa}}$$

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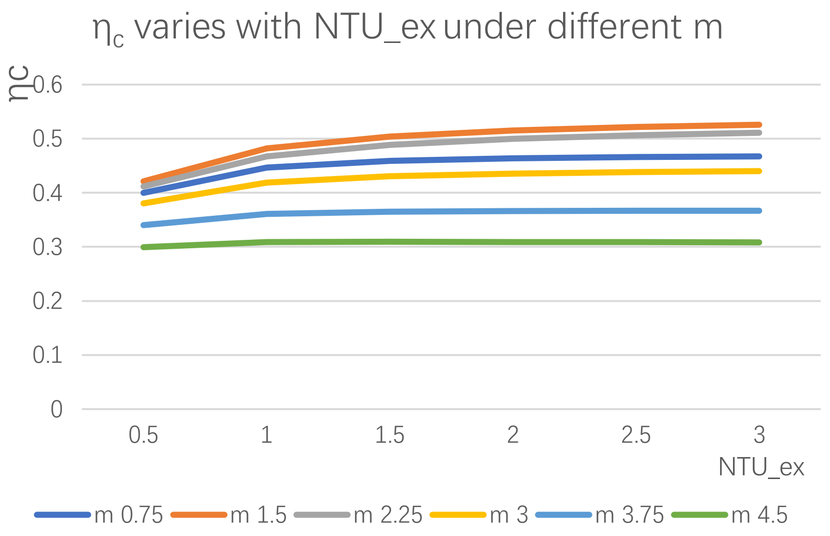
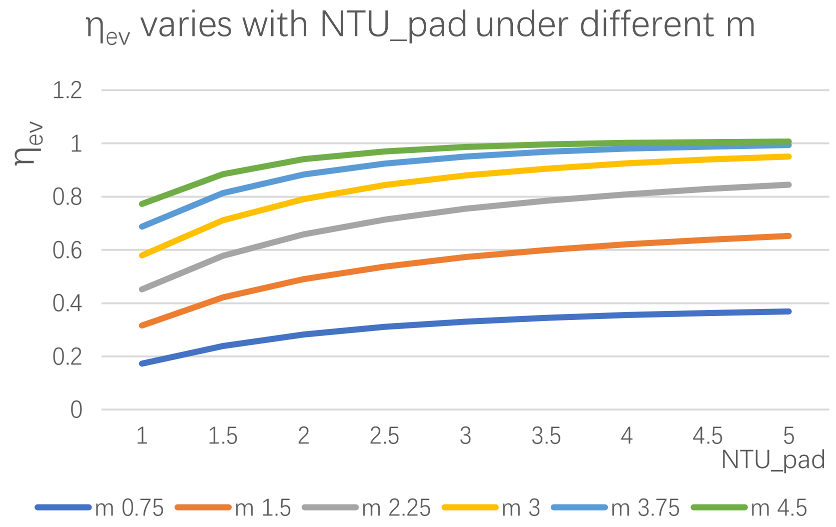
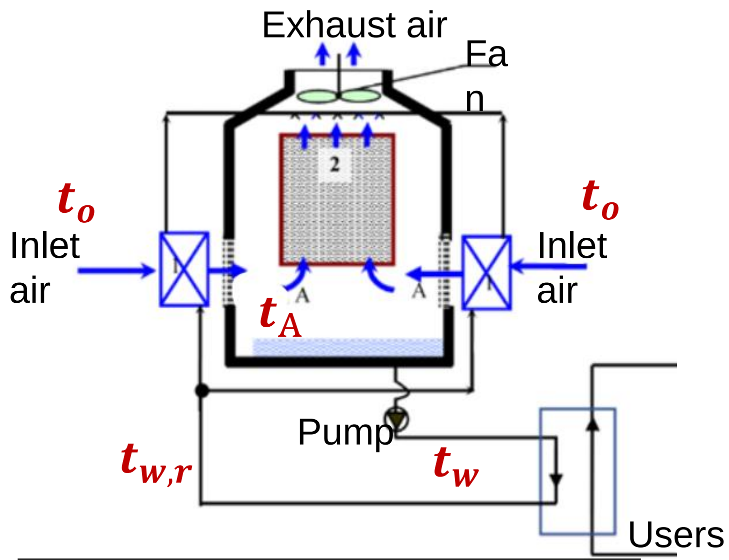




Using $\eta_c \& \eta_{ev}$ as the indicators for IEC water chiller processes

- For **series-connected** IEC water chillers

$$\eta_c = \frac{t_o - t_A}{t_o - t_{o,dp}}$$



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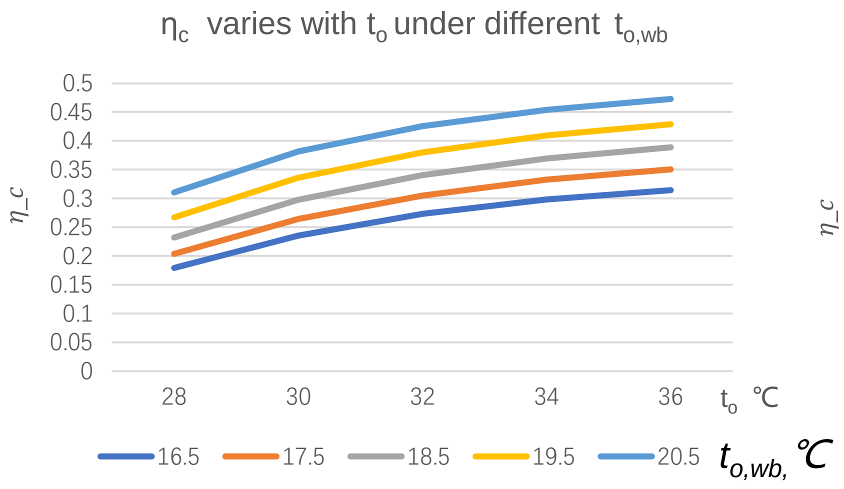
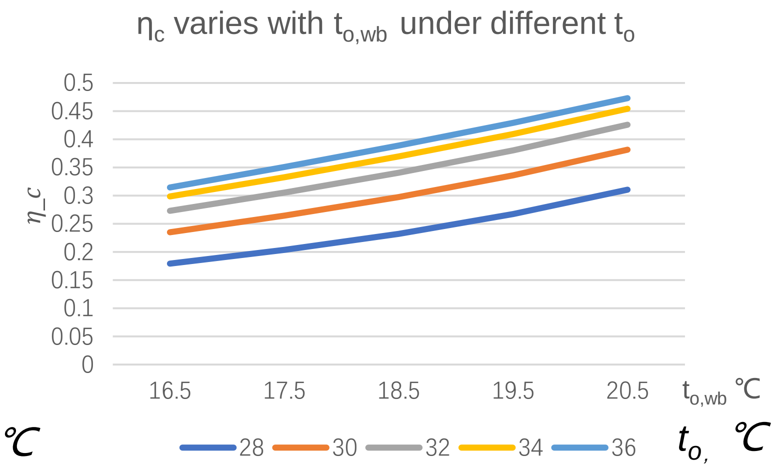
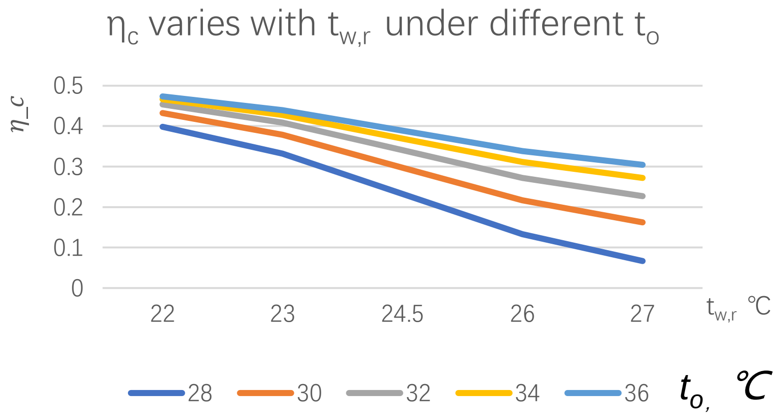




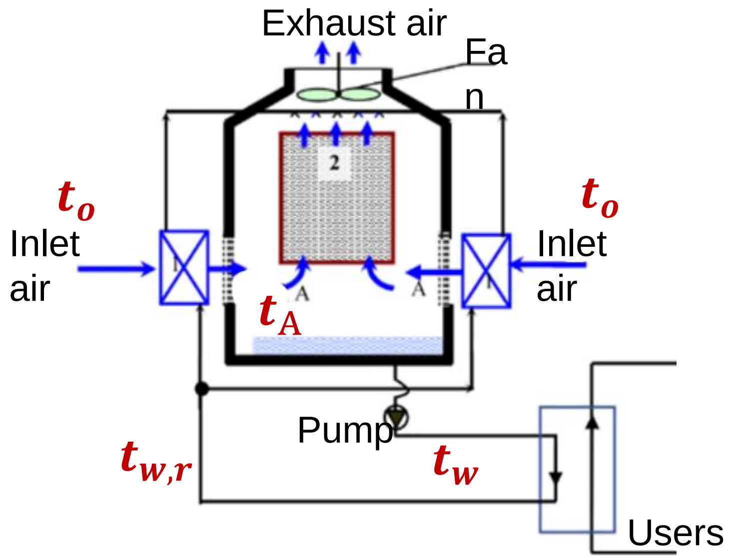


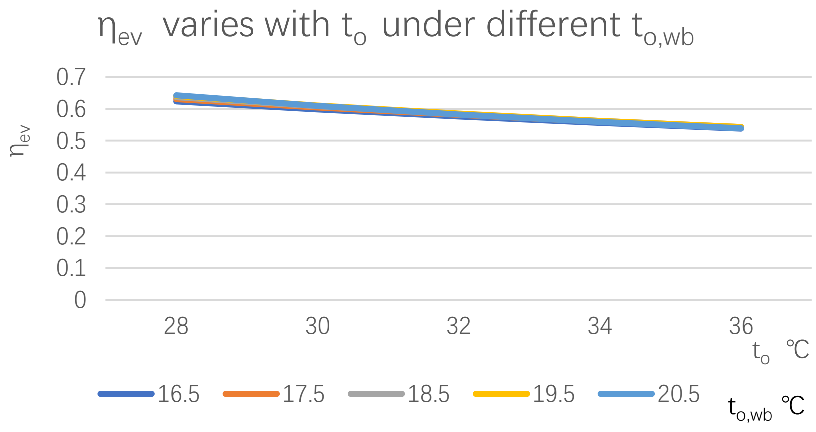
η_c increases when t_O increases
η_c increases when $t_{O,wb}$ increases
η_c decreases when $t_{w,r}$ increases

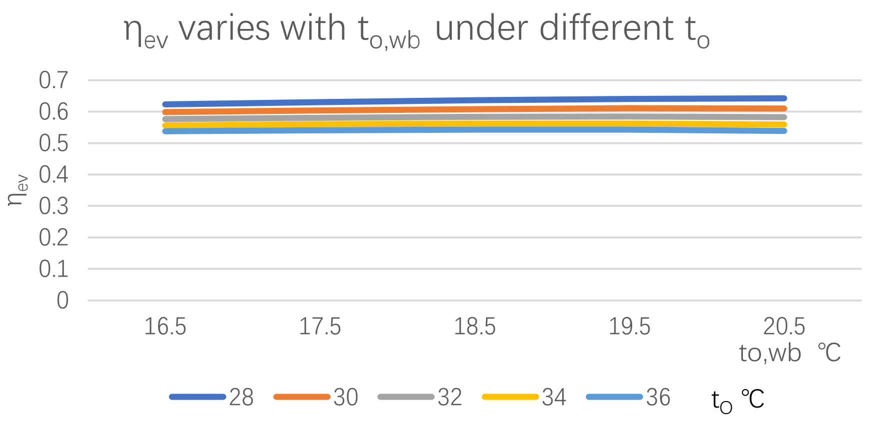
Using $\eta_c \& \eta_{ev}$ as the indicators for IEC water chiller processes

- For **series-connected** IEC water chillers

$$\eta_{ev} = \frac{t_{w,r} - t_w}{t_{w,r} - t_{A,wb}}$$







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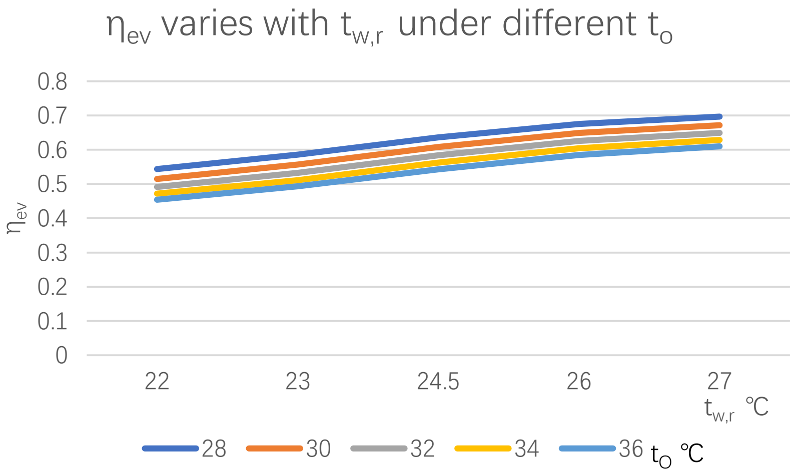

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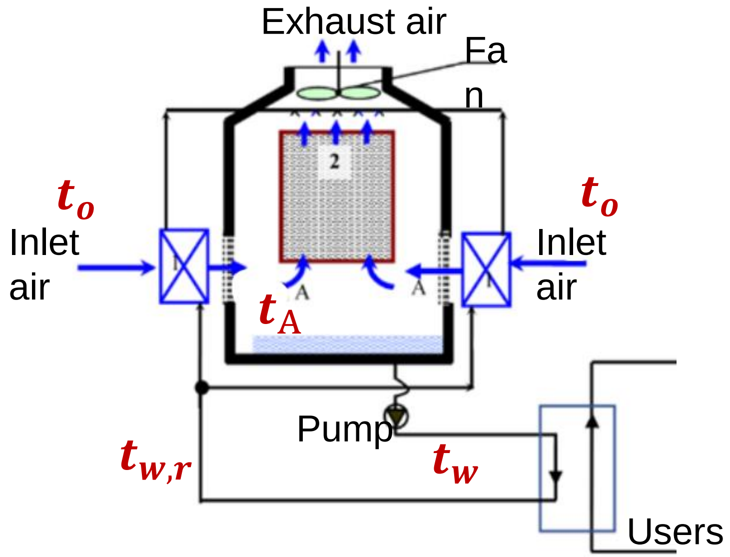

$$m = \frac{G_a}{G_{w,r}}$$

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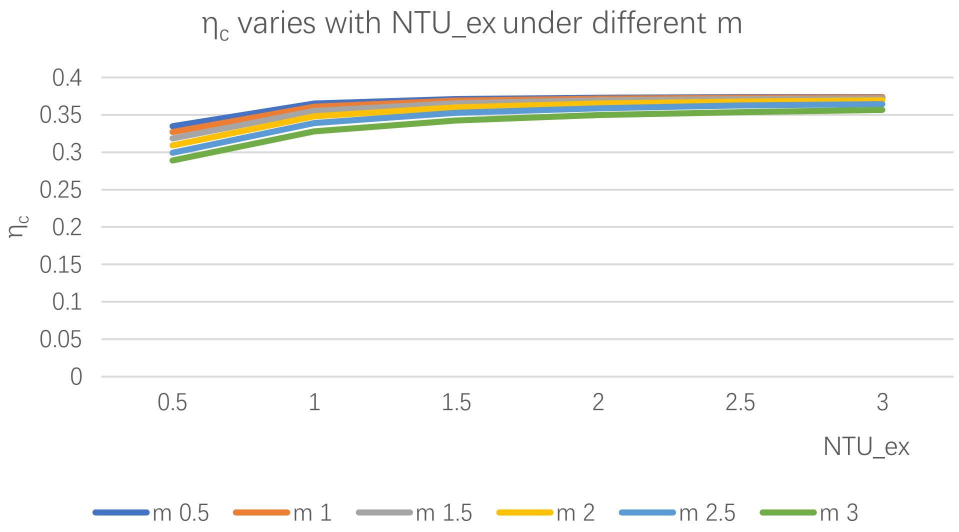
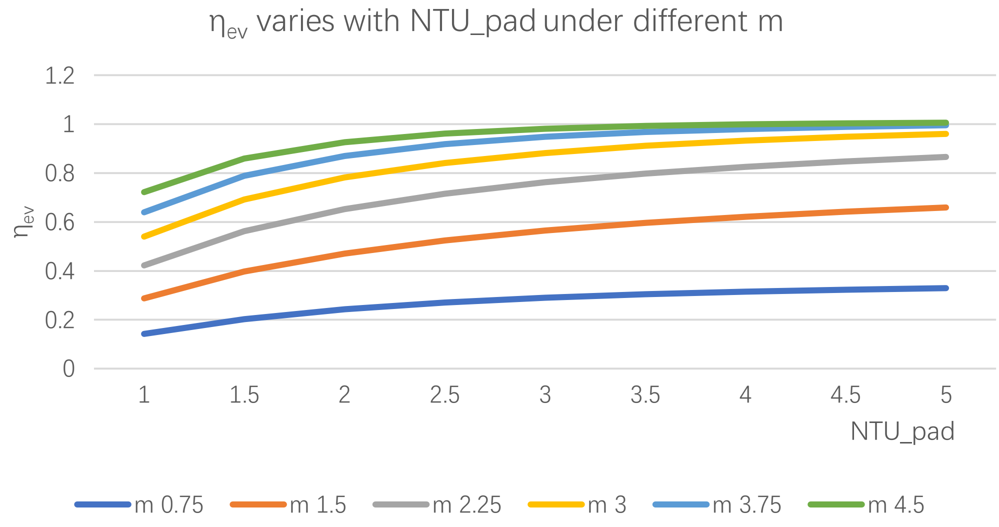
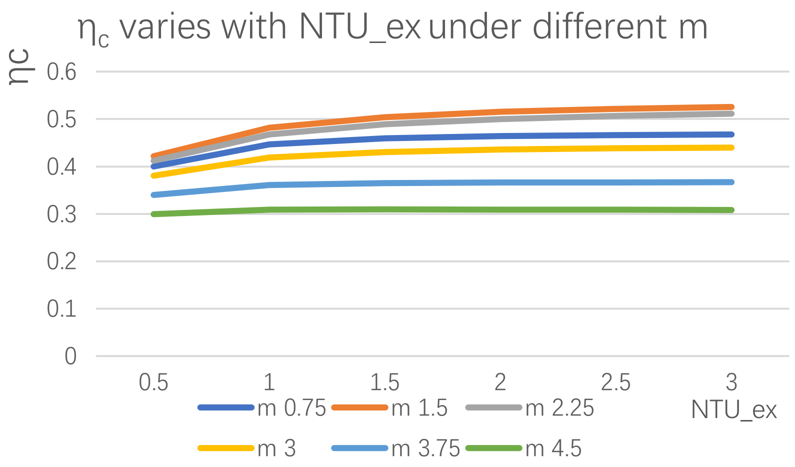
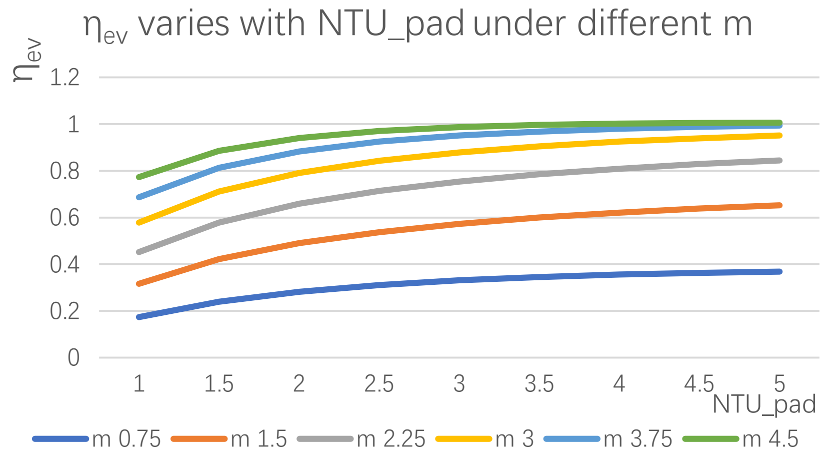




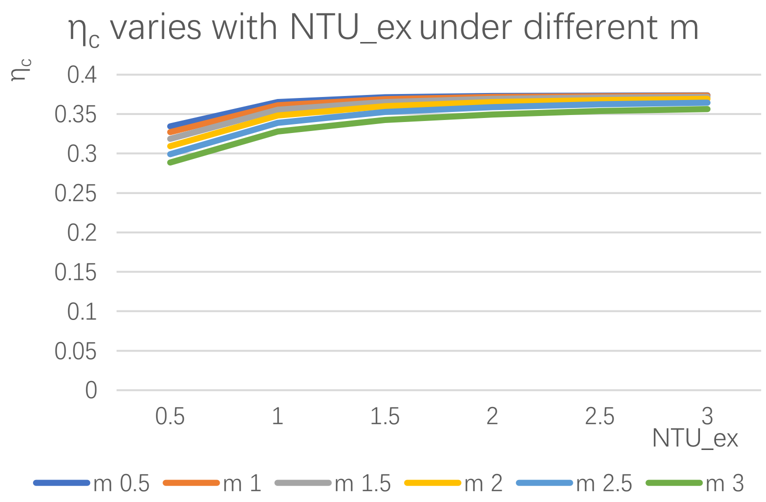
Summary

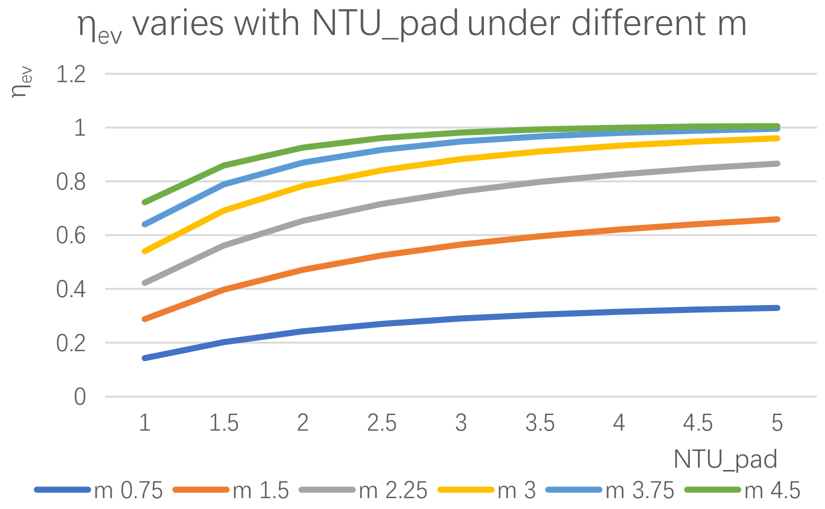
- For **parallel-connected** IEC water chillers, the evaporative cooling efficiency $\boldsymbol{\eta_{ev}}$ and the sensible cooling efficiency $\boldsymbol{\eta_c}$ are more suitable with a stable performance under various climate conditions.





- For **series-connected** IEC water chillers, all three indicators are not completely stable with t_o,$t_{o,wb}$,$t_{w,r,}$. NTU-m-η curves are used as a reference. Maybe linear fitting?





Thank you very much for your attention!