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CoDECS

Combined desiccant dehumidification and dew point evaporative cooling
A potential greener and cheaper alternative to compressor-based air conditioners

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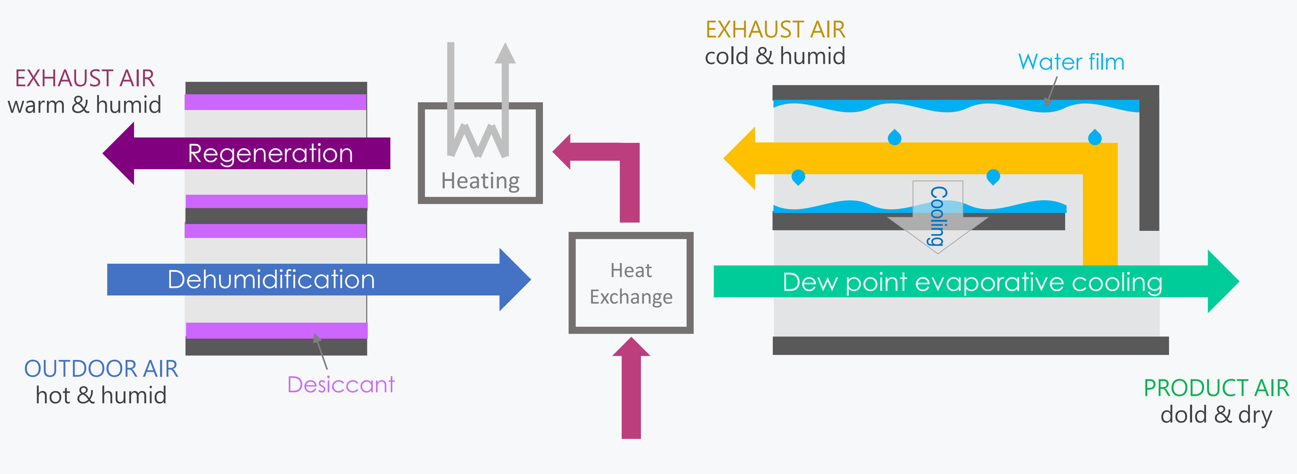
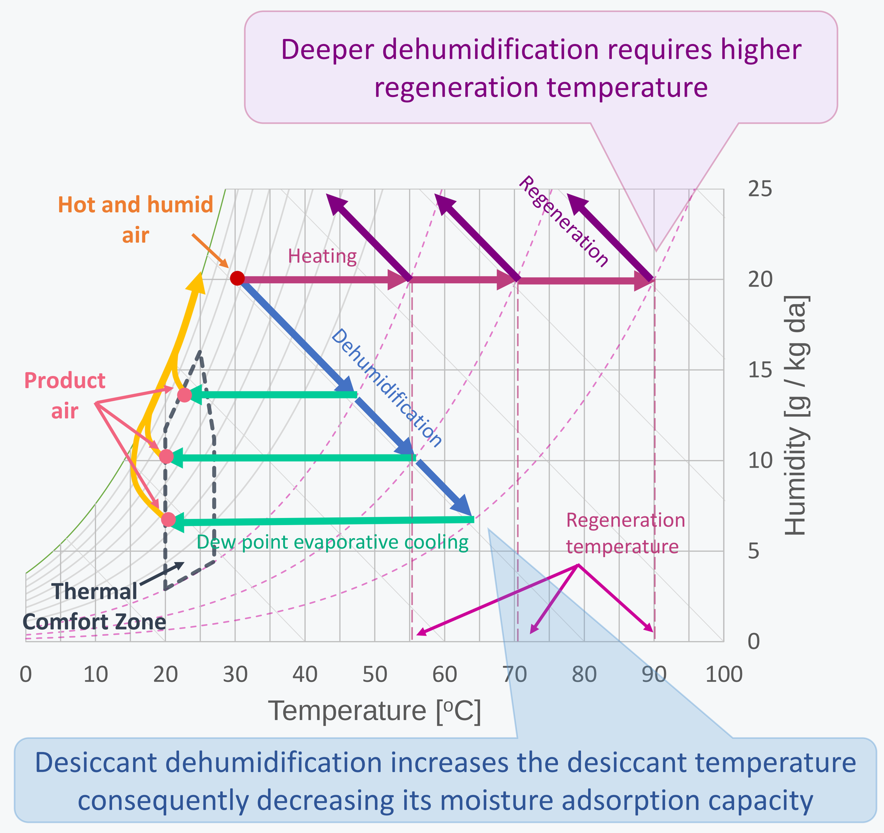
Background

- Air conditioners consume large amounts of electricity
- Heat-driven desiccant dehumidifier can reduce latent heat load while dew point evaporative cooling can reduce sensible heat load



Independent desiccant dehumidification and dew point evaporative cooling.

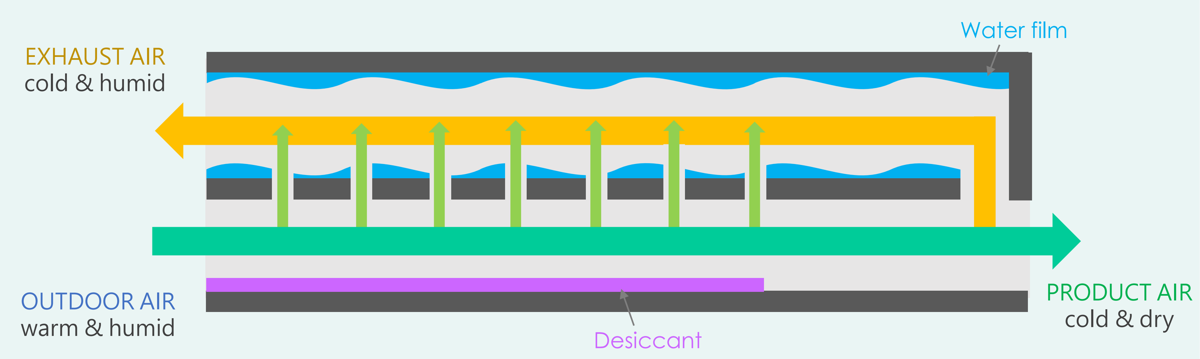


Psychrometric plot of independent desiccant dehumidification and dew point evaporative cooling.

Proposed system

Combination of desiccant dehumidification in dew point evaporative cooler (DPEC)

- Evaporative cooling will limit temperature increase in the desiccant
- Lower desiccant temperature will increase moisture adsorption capacity



Combined desiccant dehumidification and dew point evaporative cooling system (CoDECS).

Objective

- The primary objective of this study is to investigate the feasibility of CoDECS in conditioning hot and humid air to human thermal comfort levels via numerical simulations

Methodology

- Numerical simulations were performed following the governing equations for heat and mass transfer in the proposed system

Wet air (wa) mass & energy balance

$$\frac{\partial \rho_{v,wa}}{\partial t} = D\frac{\partial^2 \rho_{v,wa}}{\partial x^2} + u_{wa}\frac{\partial \rho_{v,wa}}{\partial x} + \frac{h_{mwa}}{d_{h,wa}}(\rho_{vsat,wa} - \rho_{v,wa})$$

$$\rho_{v,wa}c_{pwa}\frac{\partial T_{wa}}{\partial t} = k_{wa}\frac{\partial^2 T_{wa}}{\partial x^2} - \frac{h_{wa}}{z/2}(T_{wa} - T_{wf}) + \rho_{wa}c_{pwa}u_{wa}\frac{\partial T_{wa}}{\partial x} + u_{wa}\frac{\partial \rho_{v,wa}}{\partial x}H_v + \frac{\bar{h}_{wa}}{z/2}(\rho_{vsat,wa} - \rho_{v,wa})H_v$$

Combined water film & plate (wf) energy balance

$$\rho_{wf}c_{wf}\frac{\partial T_{wf}}{\partial t} = k_{wf}\frac{\partial^2 T_{wf}}{\partial x^2} + \frac{h_{da}}{d_{wf}}(T_{da} - T_{wf}) + \frac{h_{wa}}{d_{wf}}(T_{wa} - T_{wf}) - \frac{\bar{h}_{wa}}{d_{wf}}(\rho_{vsat,wa} - \rho_{v,wa})H_v$$

Dry air (da) mass & energy balance

$$\frac{\partial \rho_{v,da}}{\partial t} = -u_{da}\frac{\partial \rho_{v,da}}{\partial x} + \frac{4\bar{h}_{da}}{d_{h,da}}(\rho_{v,sb} - \rho_{v,da})$$

$$\rho_{da}c_{pda}\frac{\partial T_{da}}{\partial t} = k_{da}\frac{\partial^2 T_{da}}{\partial x^2} + \frac{4h_{da}}{d_{h,da}}(T_{sb} - T_{da}) - \frac{h_{da}}{d_{da}}(T_{da} - T_{wf}) - \rho_{da}c_{pda}u_{da}\frac{\partial T_{da}}{\partial x}$$

Desiccant sorbent (sb) mass & energy balance

$$\frac{\partial \rho_{v,sb}}{\partial t} = \frac{\bar{h}_{da}\rho_d}{d_d}(\rho_{v,da} - \rho_{v,sb}) - \rho_{sb}\frac{\partial W}{\partial t}$$

$$\rho_{sb}c_{psb}\frac{\partial T_s}{\partial t} = \frac{h_{da}}{d_{sb}}(T_{da} - T_{sb}) + \rho_{sb}q_{ads}\frac{\partial W}{\partial t}$$

- The instantaneous and equilibrium water uptake of RD Silica gel desiccant is expressed by the Linear Driving Force model and the DA model as follows

$$\frac{W - W_0}{W_{eq} - W_0} = 1 - exp\left\{-F_o\left(\frac{D_s}{R_p^2}t\right)^{0.678}\right\} \qquad W_{eq} = W_{max}exp\left\{-\left(\frac{RT_d}{E}ln\frac{P_s}{P_v}\right)^n\right\}$$

- The following fixed CoDECS design parameters were used

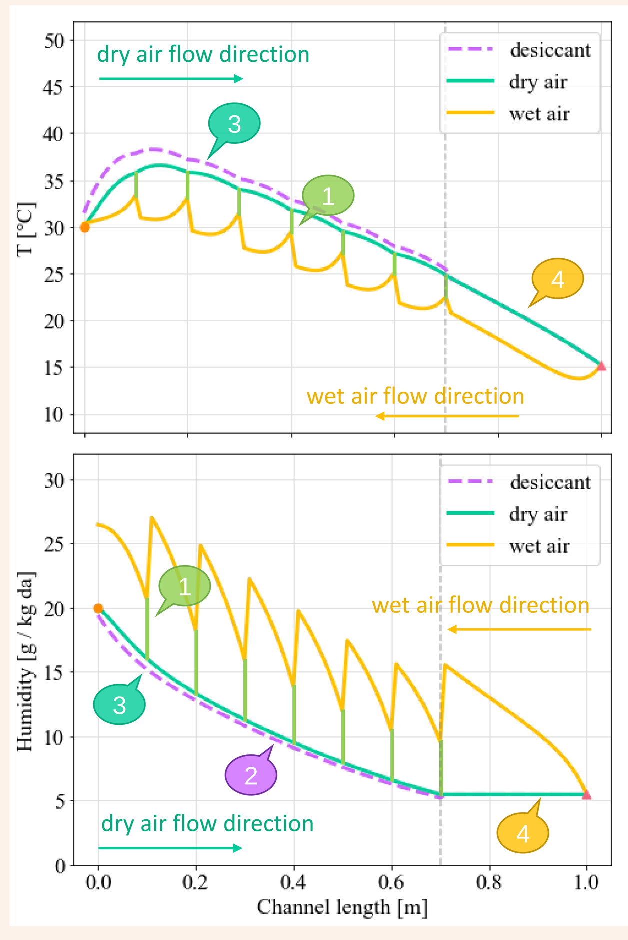
Design parameter	Value	Design parameter	Value
Channel height, m	0.003	Desiccant-filled length, m	0.7
Channel width, m	0.004	Desiccant thickness, m	0.0002
Combined water film & plate thickness, m	0.00025	Adsorption heat (q_{ads}), J/kg	-12400W+3500, W≤ 0.05 -14000W+2900, W>0.05

- The following nominal and experimental variables were used during the simulation

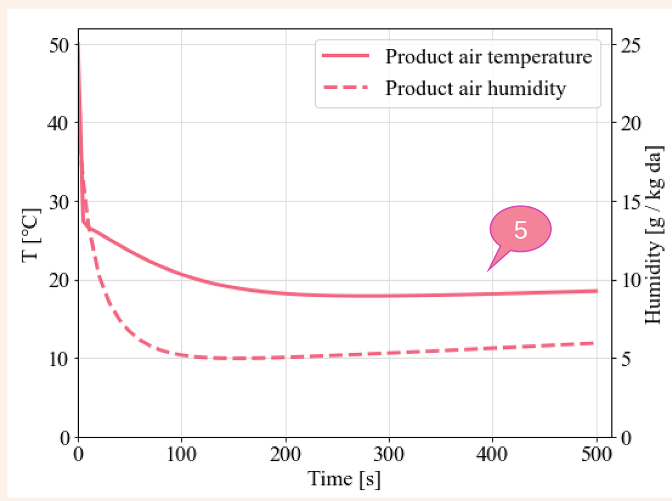
Parameter	Nominal Value	Simulated Range
Regeneration temperature, °C	50	40 – 70
CoDECS channel length, m	1.0	0.5 – 2.0
Air velocity, m/s	1.0	0.5 – 2.0
Product air extraction ratio	0.3	0.1 – 0.9

Results & Conclusion

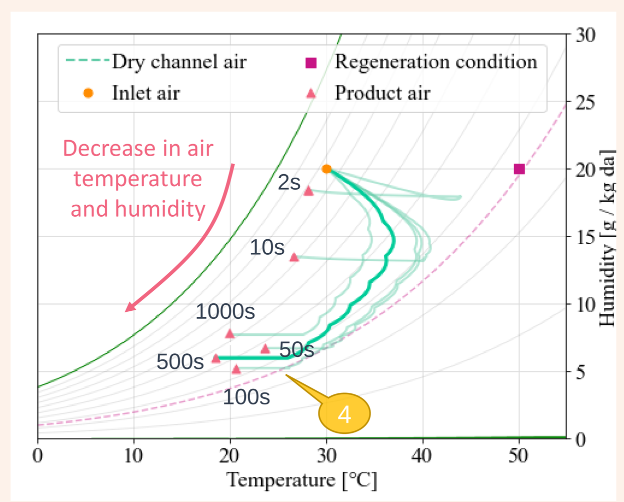
1. Diversion of dehumidified air from dry to wet channel induces evaporative cooling thereby facilitating the decrease in dry channel temperature
2. Humidity decreases along CoDECS length due to integration of desiccant
3. Decrease in desiccant temperature promotes continuous dehumidification
4. Due to reduced humidity, dew point evaporative cooling facilitates further decrease in temperature
5. CoDECS can produce dry and cold air for a long time period.



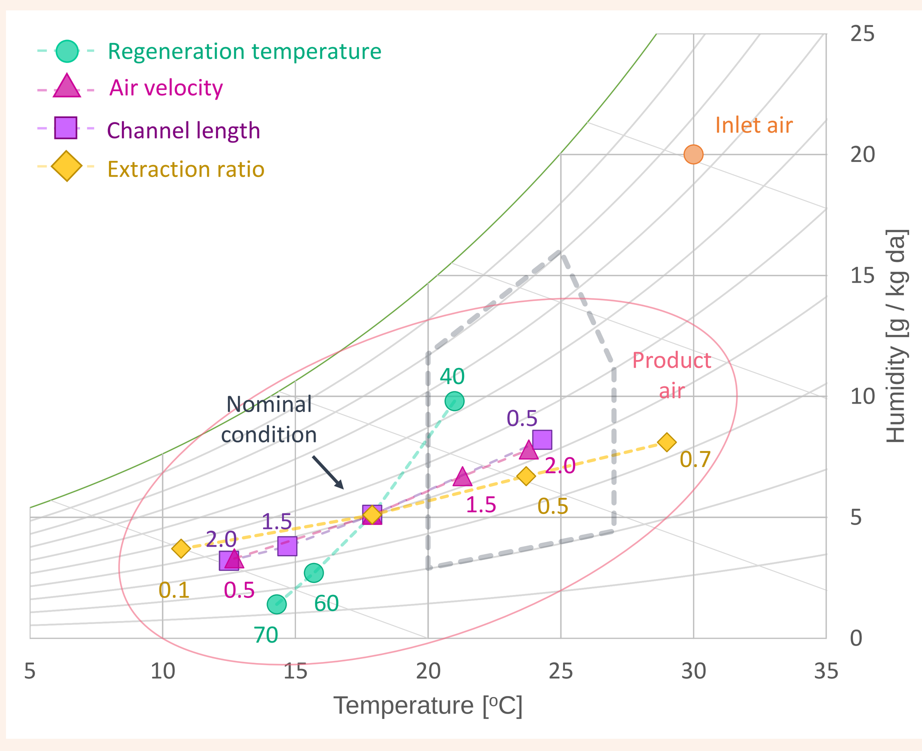
Temperature and humidity distribution along the dry and wet channels of CoDECS at nominal operating condition and t = 500s.



Temporal product air temperature and humidity profile.



Psychrometric plot of dry air in CoDECS at nominal operating condition and at different time periods.



Effect of varying regeneration temperature, channel length, air velocity, and product air extraction ratio to product air minimum temperature & humidity in CoDECS.

Various strategies may be employed in CoDECS to produce air with reduced temperature and humidity such as:

- increase in regeneration temperature;
- increase in system length;
- decrease in air velocity; or
- reduction of extraction ratio.

Major References:

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