Evaporative Cooling in Solar Absorption Chiller

Junkun Ma, Min Jae Suh
October 4, 2018

Sam Houston State University

Sam Houston State University

COMSOL CONFERENCE
2018 BOSTON

Absorption Chiller

- *Involve condensation and evaporation of the refrigerant within the system similar to that of mechanical chiller*

- *Use a thermo-chemical process instead of mechanical energy*

www.trane.com

Advantages and Disadvantages

Advantages:

- *Operate on waste heat such as low grade stream*

- *Quiet operation due to much less moving parts*

- *Much less electrical power consumption*

Disadvantages:

- *Lower efficiency than mechanical chillers*

- *Financial consideration (cost of heat vs electricity)*
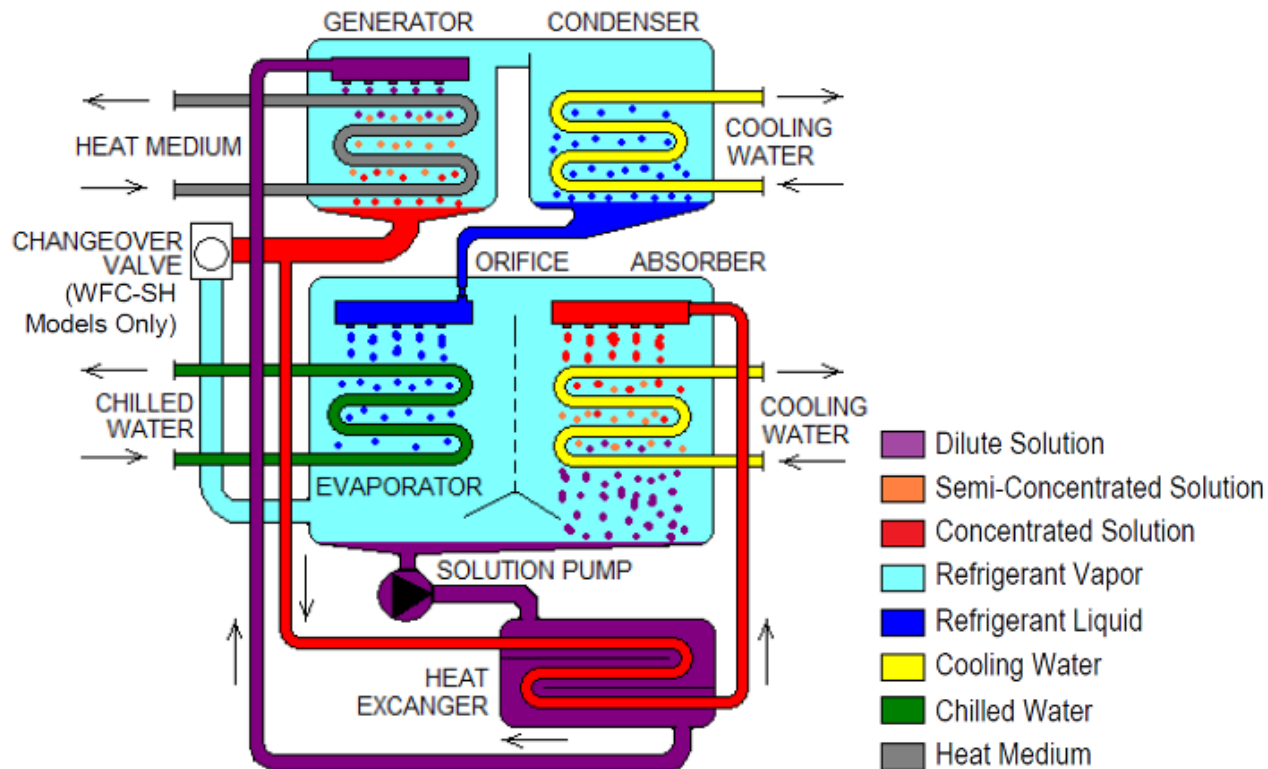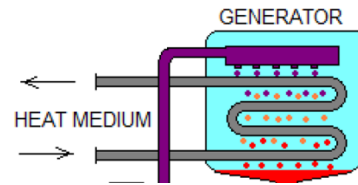
- *Qualified maintenance staff*

Solar Absorption Chiller

- *Relative low and wide range of heating medium temperature*

- *Lithium Bromide salt and water solution as the working fluid*

Absorption Chiller

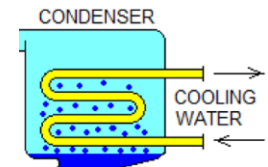## Schematic of a single stage absorption chiller[1]
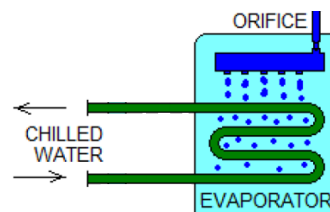
How does it work?

working fluid returned from the absorber vaporizes in generator to high pressure water vapour
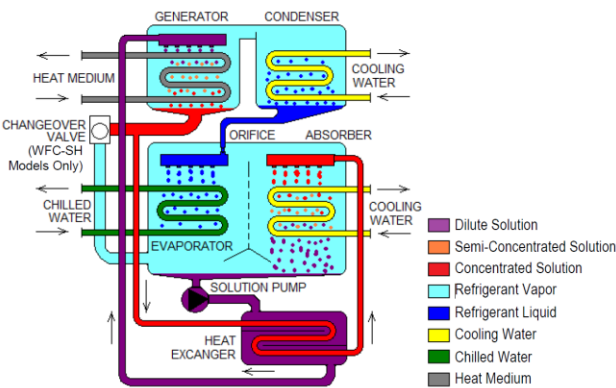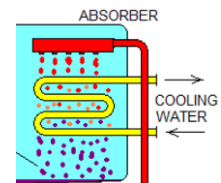
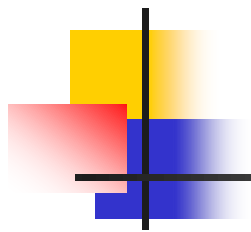The water vapour is condensed into liquid form in the condenser

The liquid form water is injected into and vaporizes in the evaporator and thus cool the chilled water

The lower pressure water vapour is cooled and then mixed with the concentrated working fluid from the generator for next cycle

Dilute Solution
Semi-Concentrated Solution
Concentrated Solution
Refrigerant Vapor
Refrigerant Liquid
Cooling Water
Chilled Water
Heat Medium

COMSOL Model

Turbulence Model

High speed turbulent flow: κ - ε turbulent flow model

$$\mu_T = \rho C_\mu \frac{k^2}{\varepsilon}$$

$$\rho \frac{\partial k}{\partial t} + \rho u \cdot \nabla k = \nabla \cdot \left(\left(\mu + \frac{\mu_T}{\sigma_k} \right) \nabla k \right) + P_k - \rho \varepsilon$$

$$P_k = \mu_T \left(\nabla u : (\nabla u + (\nabla u)^T) - \frac{2}{3} (\nabla \cdot u)^2 \right) - \frac{2}{3} \rho k \nabla \cdot u$$

$$\rho \frac{\partial \varepsilon}{\partial t} + \rho u \cdot \nabla \varepsilon = \nabla \cdot \left(\left(\mu + \frac{\mu_T}{\sigma_\varepsilon} \right) \nabla \varepsilon \right) + C_{\varepsilon 1} \frac{\varepsilon}{k} P_k - C_{\varepsilon 2} \rho \frac{\varepsilon^2}{k}$$

CONSTANT	VALUE
C_μ	0.09
$C_{\varepsilon 1}$	1.44
$C_{\varepsilon 2}$	1.92
σ_k	1.0
σ_ε	1.3

Solve for the turbulence kinetic energy k; and the rate of dissipation of turbulence kinetic energy ε

Heat Transfer

- *Convection due to the turbulent flow*
- *Conduction within the evaporator coil and a thin layer of water on top of it*
- *Evaporative heat flux*

$$-\boldsymbol{n} \cdot (-k\nabla T) = H_{vap}\boldsymbol{n} \cdot (-D\nabla c + \boldsymbol{u}c)$$

where:

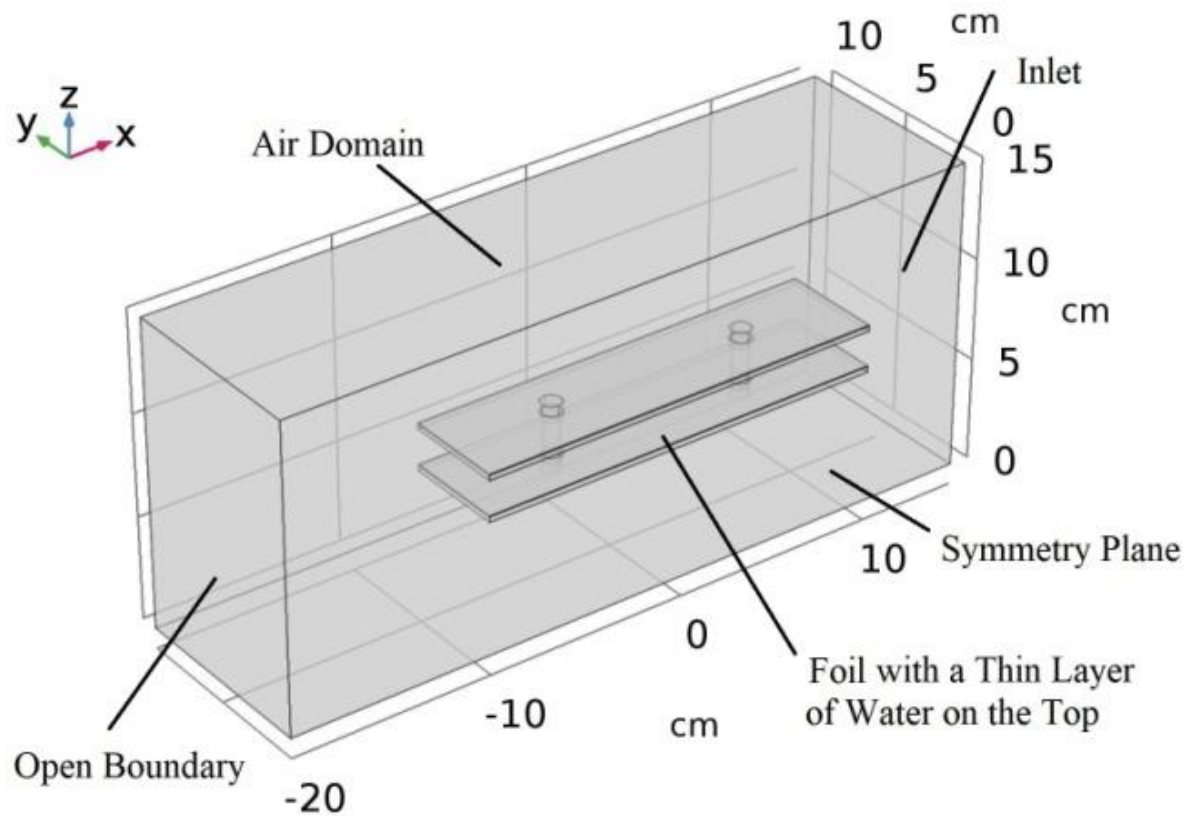*Saturation concentration:*
$$c_{sat} = \frac{P_{sat}(T)}{RT}$$

Saturation pressure:
$$P_{sat} = 610.7 Pa \cdot 10^{7.5\frac{T-273.15K}{T-35.85K}}$$
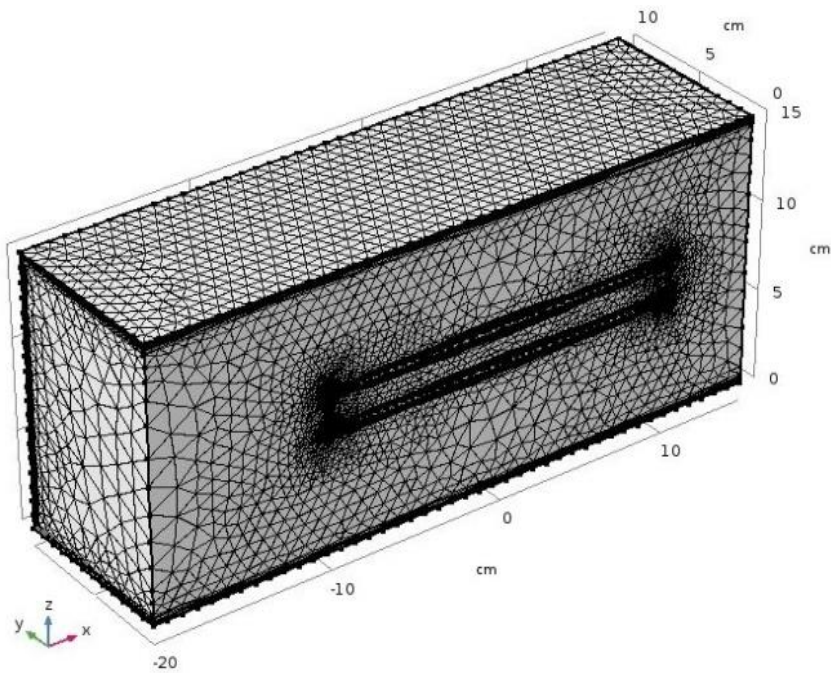
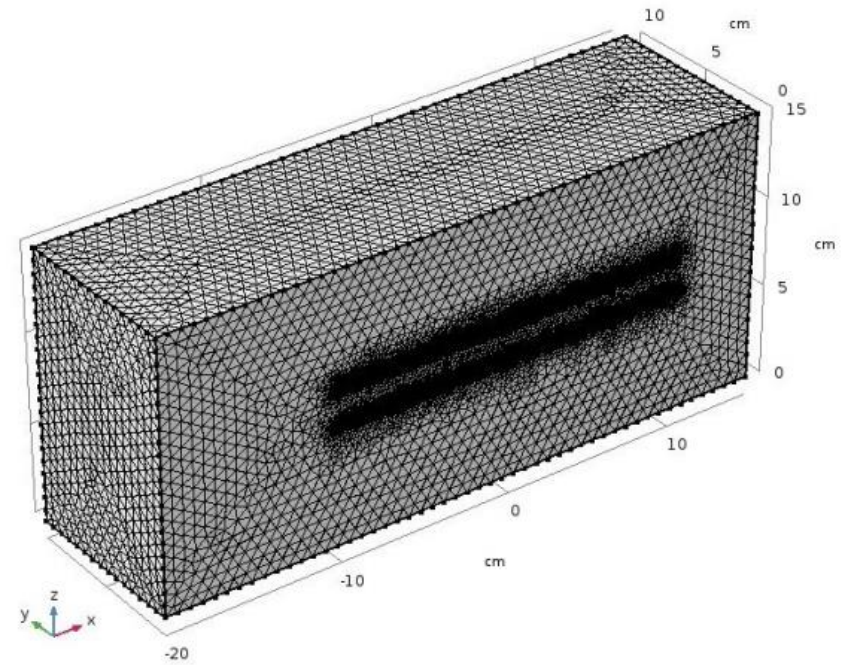*Amount of Evaporated water:*
$$M_{evap} = k(c_{sat} - c_V)M_V$$

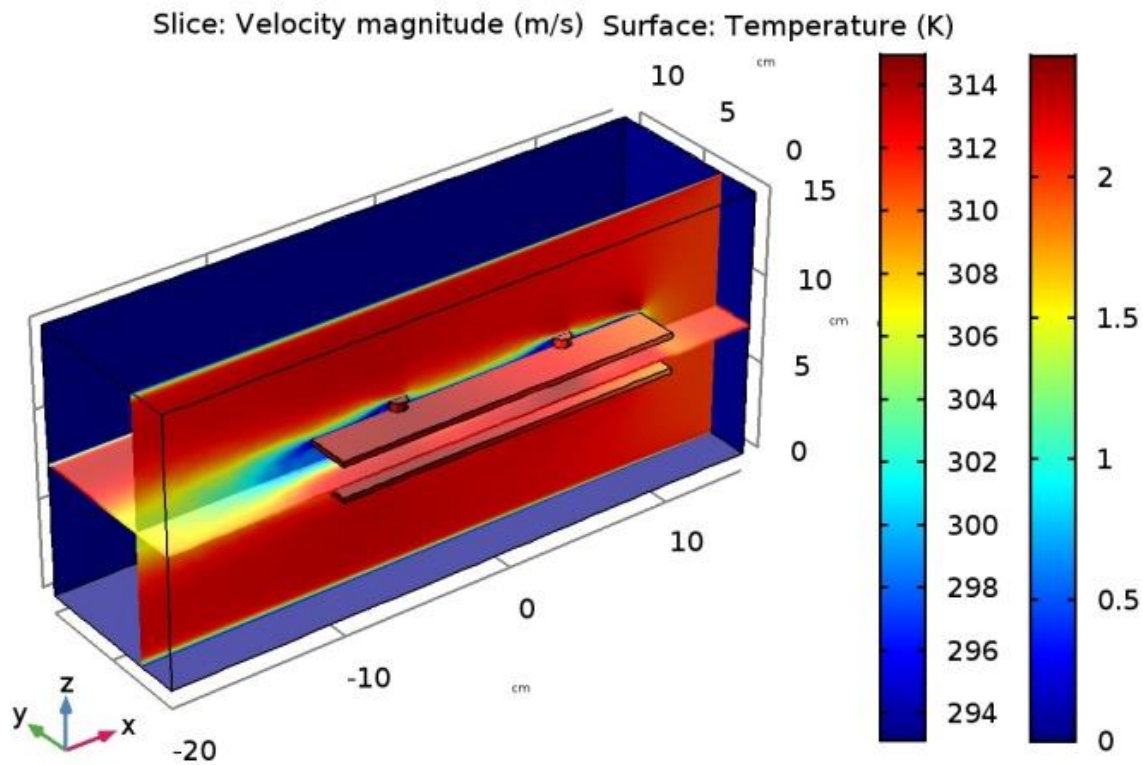# COMSOL Model

Meshes for Calculation

Turbulent Flow
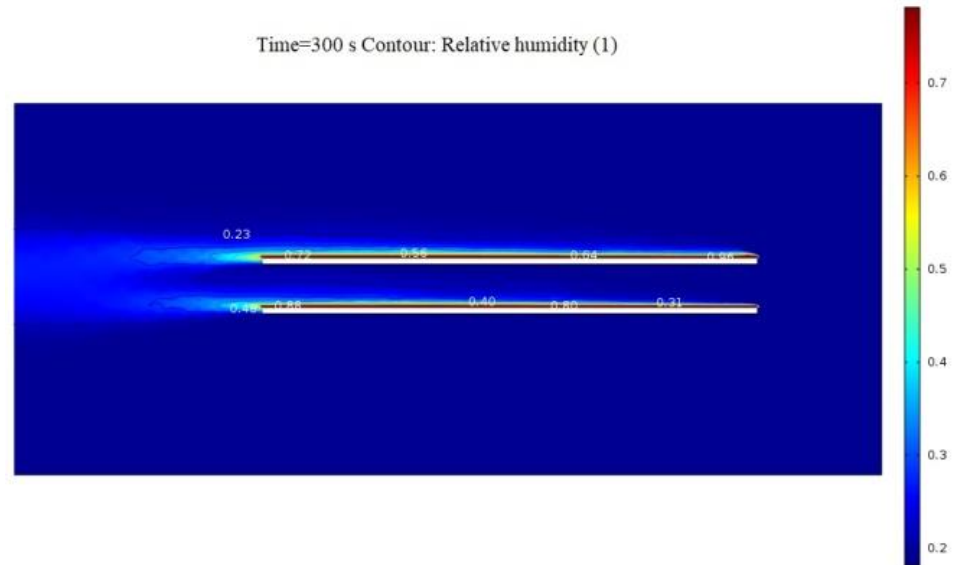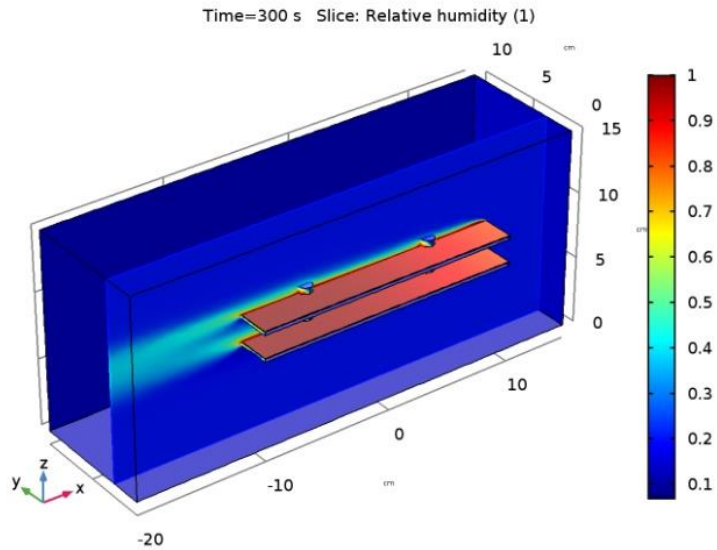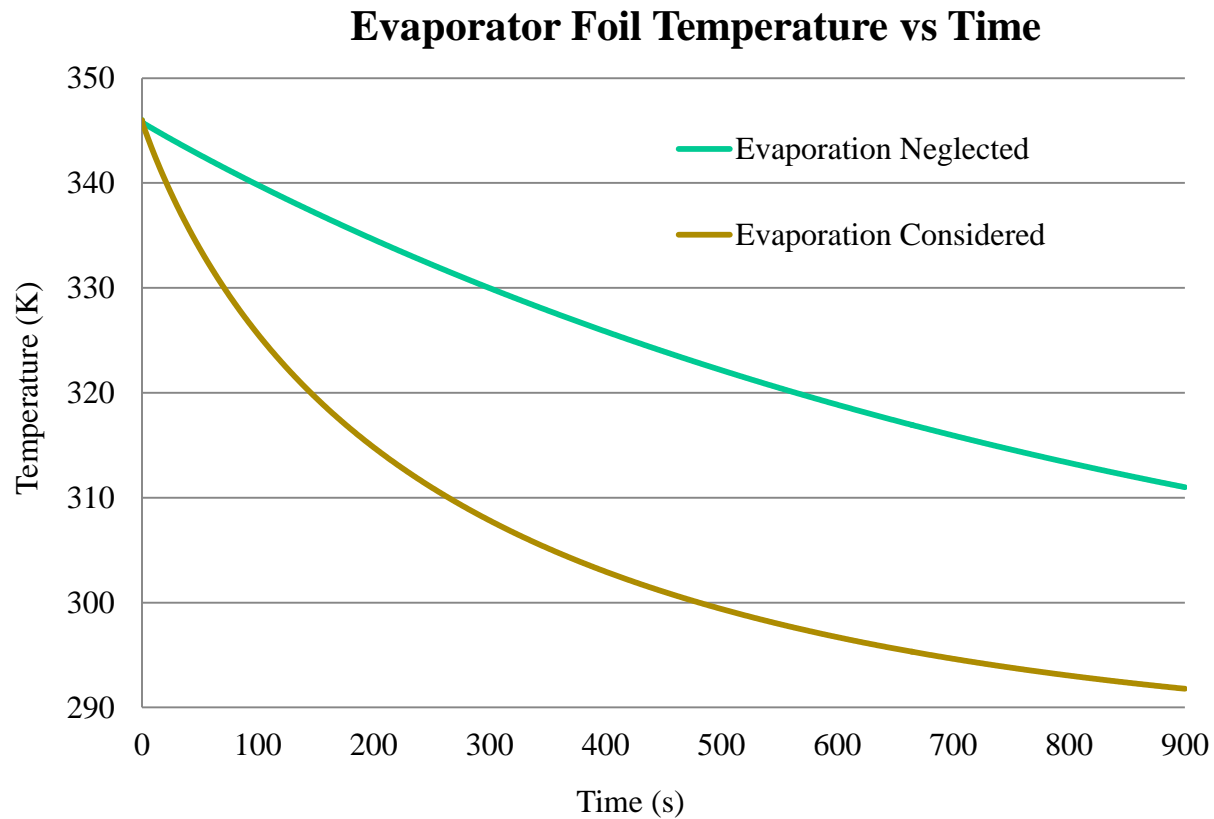
Heat transfer & transport of water vapor
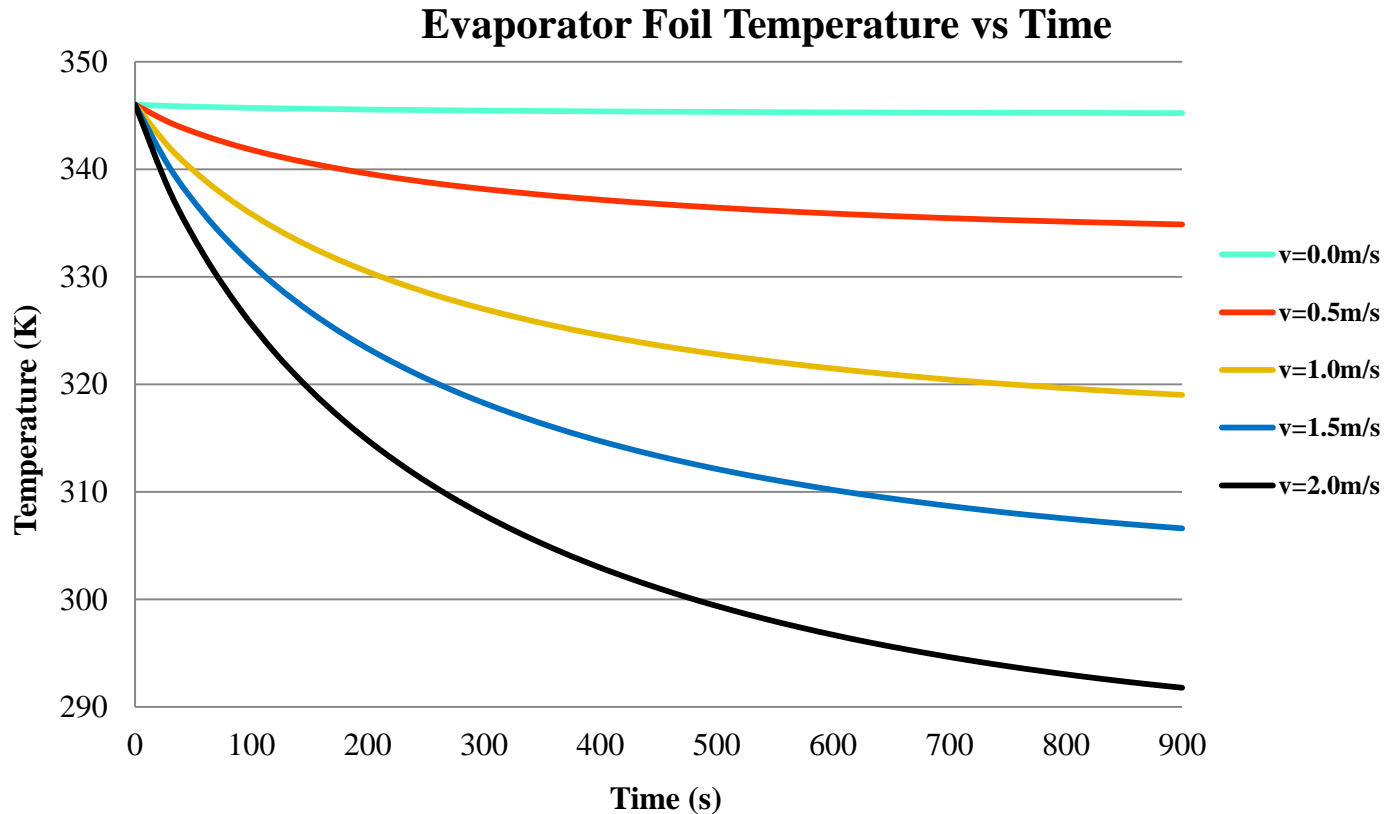
Velocity Field & Foil Temperature

Slice: Velocity magnitude (m/s)   Surface: Temperature (K)

Relative Humidity

Time=300 s   Slice: Relative humidity (1)

Time=300 s Contour: Relative humidity (1)

Cooling due to Evaporation

Effect of Inlet Air Flow Velocity

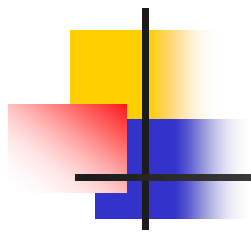

Evaporator Foil Temperature vs Time

Conclusions

- *Heat transfer due to evaporation and transfer contribute significantly to cooling of solar evaporative chiller*

- *Higher flow rate results in higher evaporation rate, which causes more heat being released to the domain and thus cooling the evaporator coil more.*

- *Initial humidity in the domain has insignificant effects on evaporative cooling*

Future Work

The vapor flow in the actual system is based on pressure difference between the evaporator and the absorber.

Our future plan is to simulate the flow by modeling the combined evaporation and condensation.

Questions?