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A Modeling Study to Determine the Effectiveness of an Energy Recovery Ventilator (ERV)

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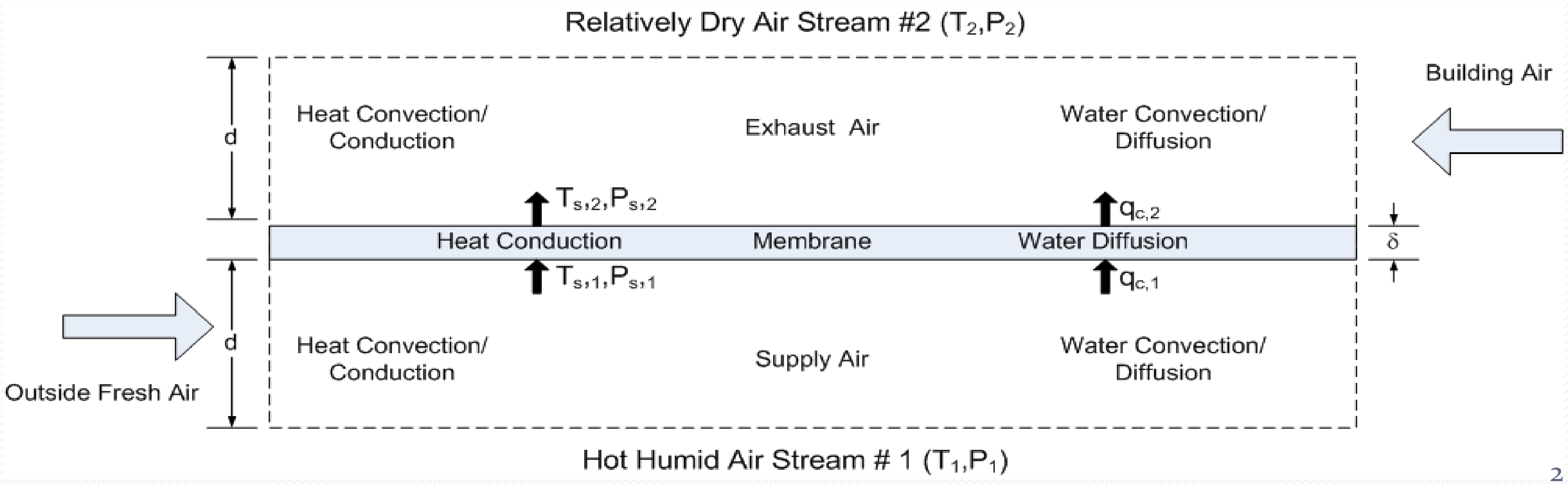
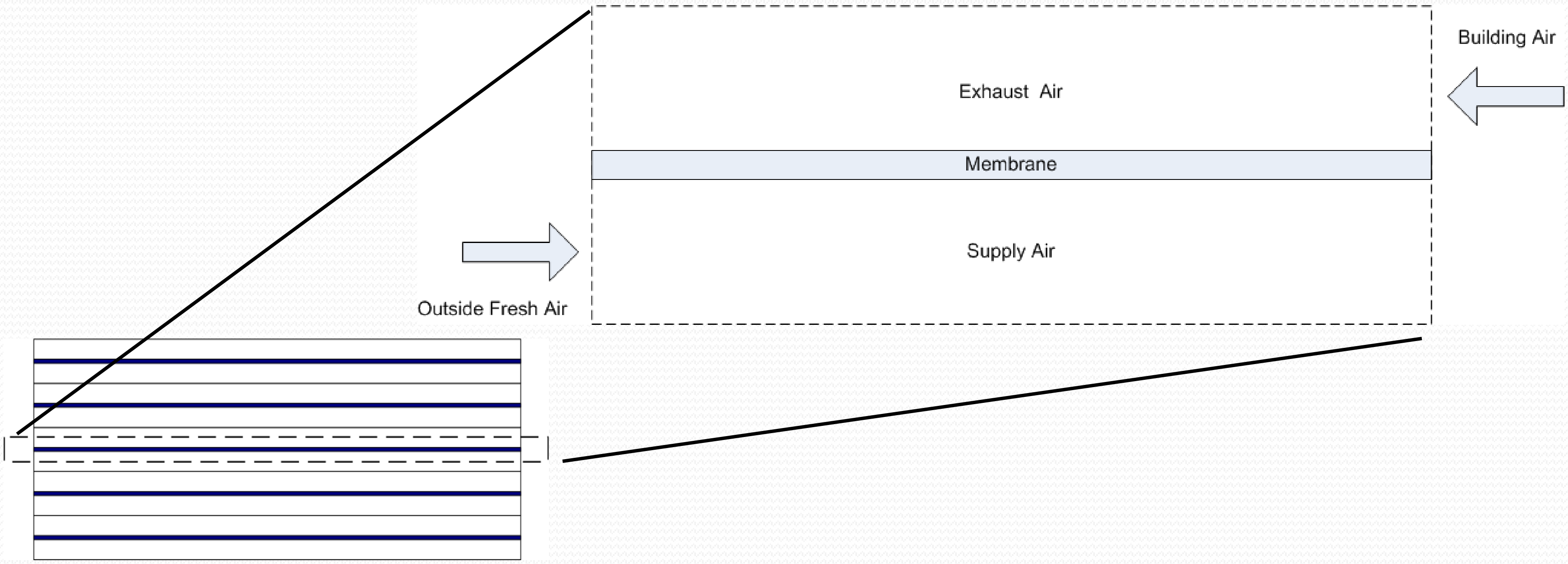
Background

- Energy Recovery Ventilator
  - A heat exchanger used in HVAC applications that allows heat and mass transfer between two airstreams separated by a membrane
  - Utilizes conditioned air to:
    - Heat or cool outside air
    - Humidify or dehumidify outside air



Objective

- To numerically evaluate the effectiveness of an energy recovery ventilator during the summer and winter seasons with both countercurrent and concurrent flow



Governing Equations - Multiphysics

- Fluid Equation
  - Momentum transport

$$\rho \frac{\partial u}{\partial t} - \nabla \left[\eta \left(\nabla u + (\nabla u)^T \right) \right] + \rho (u \cdot \nabla) u + \nabla p = F$$

  - Continuity

$$\nabla \cdot u = 0$$

- Mass Transfer

$$\delta_{ts} \frac{\partial c}{\partial t} + \nabla \cdot \left(-D \nabla c + cu \right) = R$$

- Heat Transfer

$$\delta_{ts} \rho c_p \frac{\partial T}{\partial t} + \nabla \cdot \left(-k \nabla T \right) = Q - \rho c_p u \cdot \nabla T$$

Sensible and Latent Effectiveness

$$\varepsilon_S = \frac{\rho_s c_{ps} u_s d_s \left(T_{si} - T_{so}\right) + \rho_e c_{pe} u_e d_e \left(T_{eo} - T_{ei}\right)}{2\left(\rho c_p u d\right)_{\min} \left(T_{si} - T_{ei}\right)}$$

$$\varepsilon_L = \frac{\rho_s u_s d_s \left(c_{si} - c_{so}\right) + \rho_e u_e d_e \left(c_{eo} - c_{ei}\right)}{2\left(\rho u d\right)_{\min} \left(c_{si} - c_{ei}\right)}$$

Finite Element Model Inputs

- Outside Air Properties (Summer and Winter Seasons)

	Summer	Winter
Outside Dry Bulb Temperature (C)	35.000	1.700
Outside Dry Bulb Temperature (K)	308.150	274.850
Outside Wet Bulb Temperature (C)	26.000	0.600
Outside Web Bulb Temperature (K)	299.150	273.750
Relative Humidity (%)	49.340	82.020
Pressure (mbar)	56.280	6.910
Density (kg/m^3)	1.145	1.284
Dynamic Viscosity (kg/m*s)	1.895E-05	1.738E-05
Thermal Conductivity (W/m*K)	0.026	0.024
Diffusivity (m^2/s)	2.680E-05	2.120E-05
Concentration Air (mol/m^3)	39.550	44.342
Concentration Water (mol/m^3)	1.085	0.248

- Building Air Properties (Summer and Winter Seasons)

	Summer	Winter
Building Dry Bulb Temperature (C)	24.000	21.000
Building Dry Bulb Temperature (K)	297.150	294.150
Building Wet Bulb Temperature (C)	17.000	14.000
Building Wet Bulb Temperature (K)	290.150	287.150
Relative Humidity (%)	49.590	45.866
Pressure (mbar)	29.850	24.877
Density (kg/m^3)	1.188	1.200
Dynamic Viscosity (kg/m*s)	1.844E-05	1.830E-05
Thermal Conductivity (W/m*K)	0.025	0.025
Diffusivity (m^2/s)	2.484E-05	2.436E-05
Concentration Air (mol/m^3)	41.014	41.432
Concentration Water (mol/m^3)	0.600	0.467

Finite Element Model (2D)

- ERV Basic Dimensions

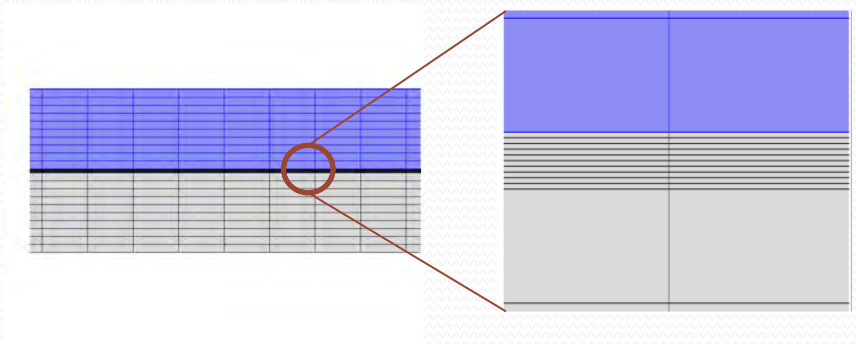
Length (mm)	250
Half Channel Height (mm)	2
Membrane Thickness (mm)	0.1

- Membrane Properties

	Summer	Winter
Density (kg/m^3)	1.160	1.240
Thermal Conductivity (W/m*K)	0.130	0.130
Diffusivity (m^2/s) of H2O	8.000E-06	8.000E-06

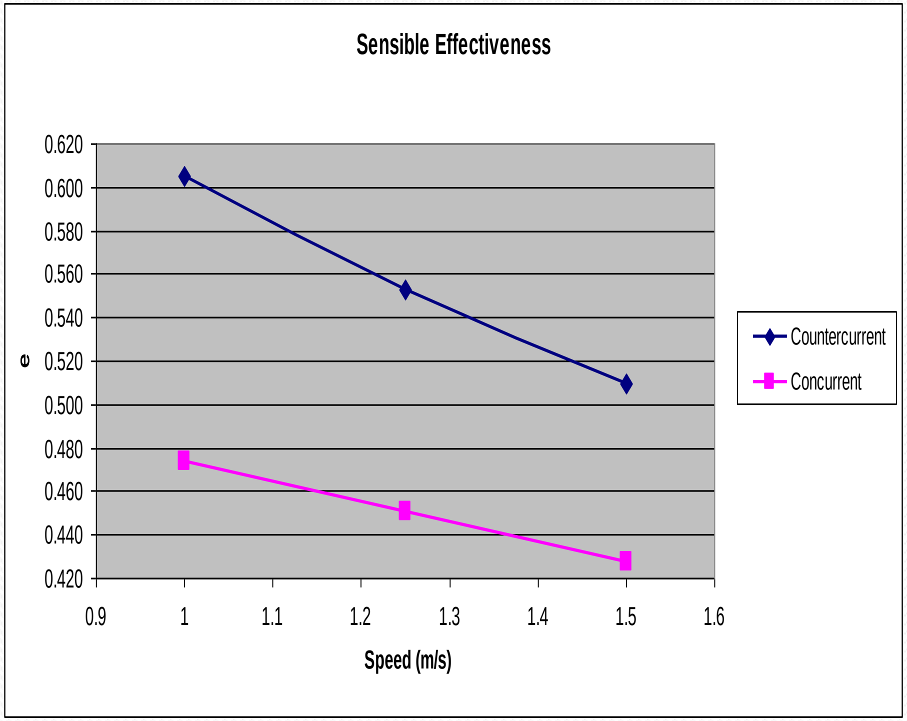
- Mesh

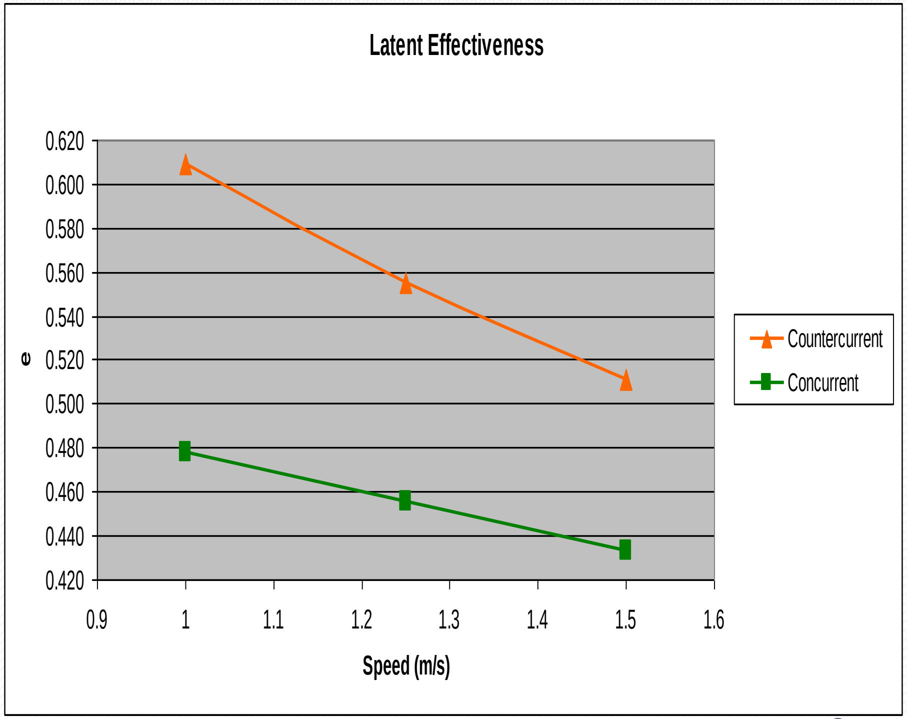
d	10
δ	10
L	200



Results - ERV Effectiveness

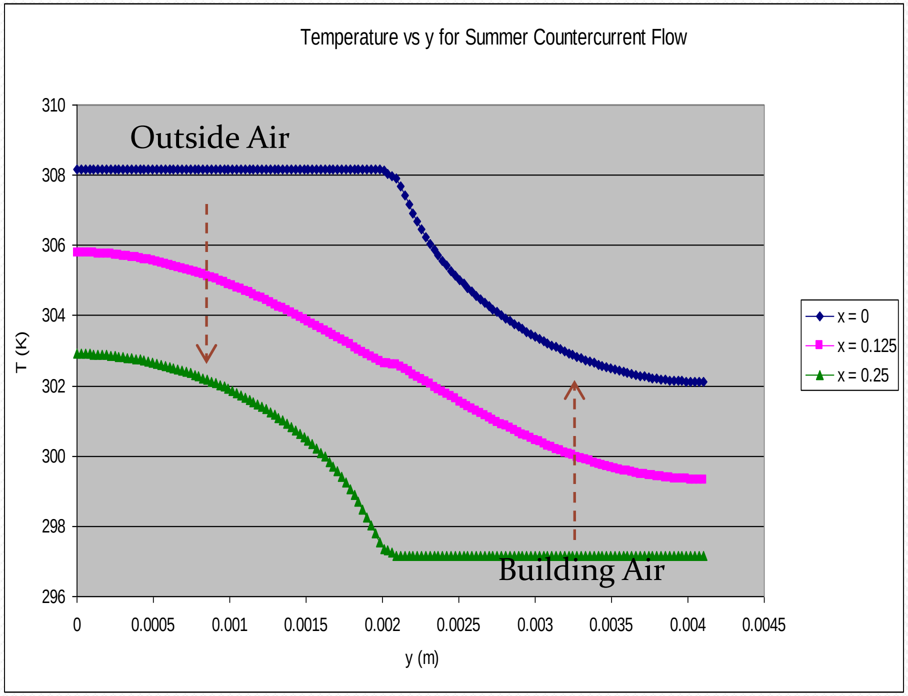
- Sensible and Latent Effectiveness with Equal Velocities in both Channels (Summer Conditions)

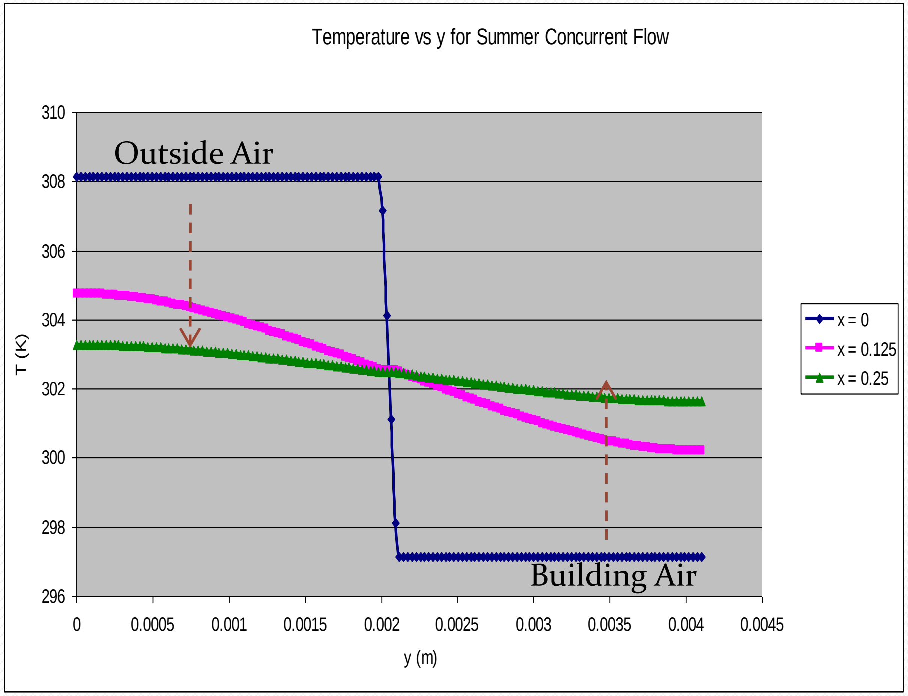




Results – ERV Temperature Profiles

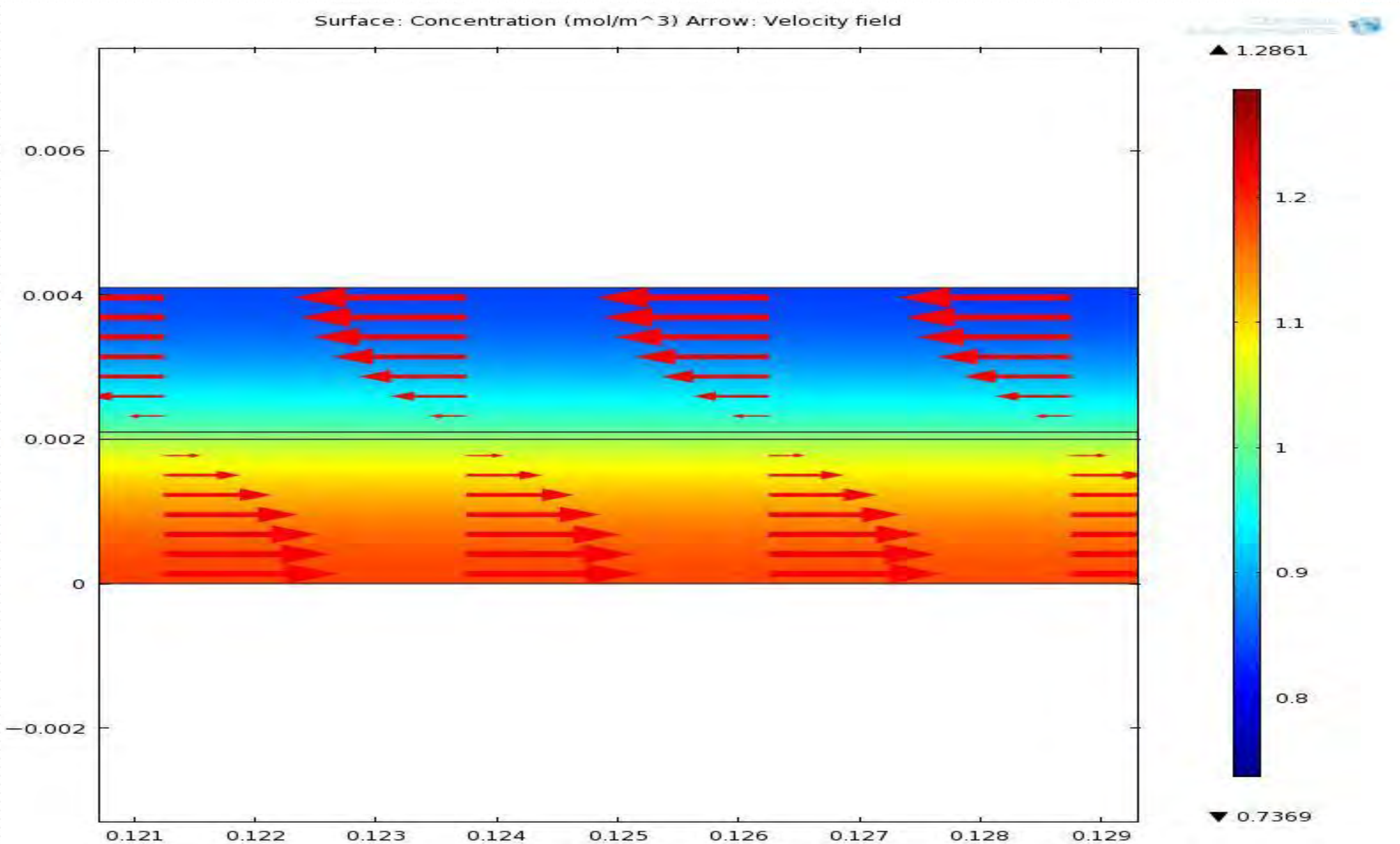
- Across the channel at several axial locations (Summer Conditions)





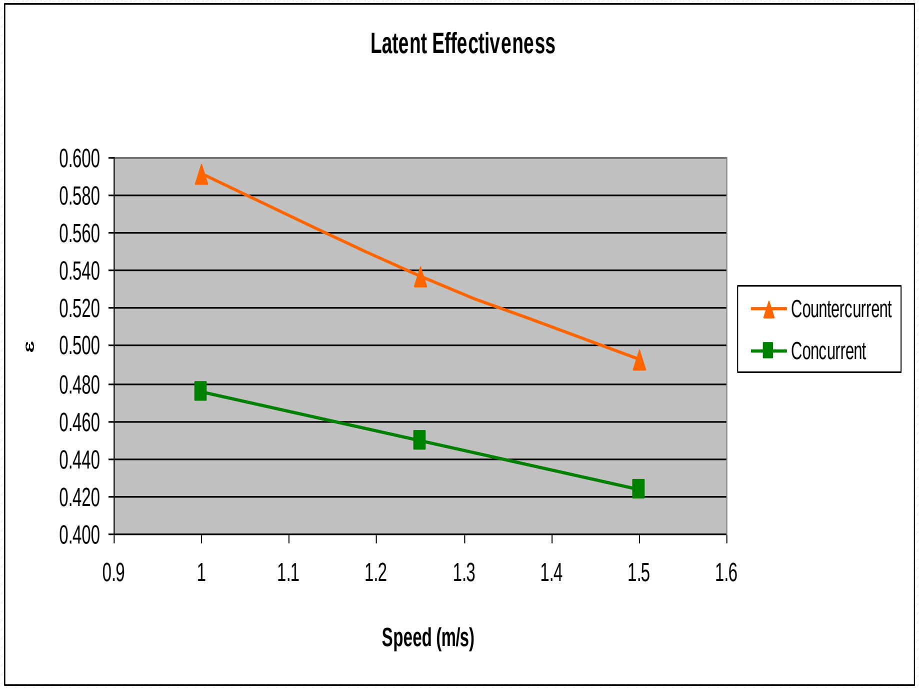
Results – Velocity & Concentration Fields

- Midsection of the channel (Summer Conditions)



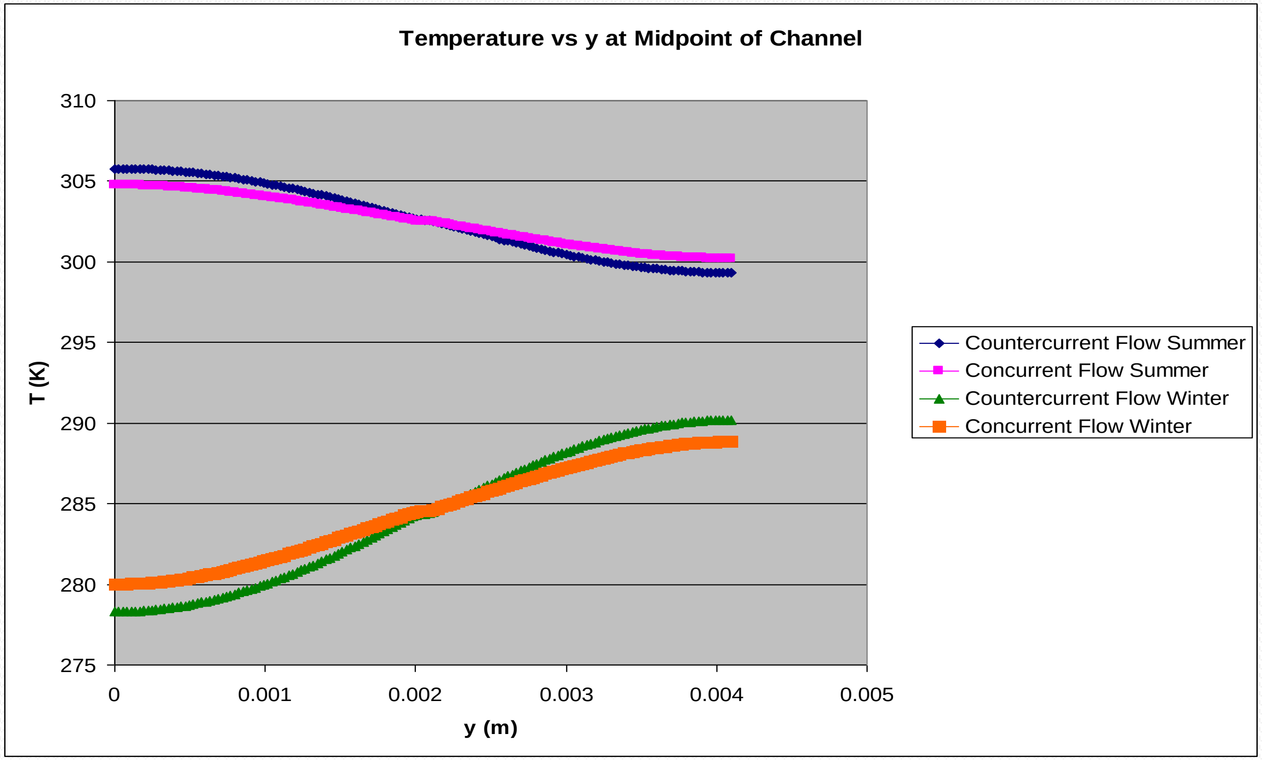
Results – ERV Effectiveness

- Sensible and Latent Effectiveness with Equal Velocities in both Channels (Winter Conditions)



Results – Temperature Profiles

- Across the channel at the axial midpoint (x = 0.125 m) and at a speed of 1.25 m/s (Winter Conditions)



Conclusions

- Countercurrent flow ERV is more effective than concurrent flow
- The performance of a countercurrent flow ERV has the potential to improve as the size increases.
- The effectiveness of the ERV increases as the flow through the channel decreases, and an optimum size/velocity can be determined
- 3D modeling of the crossflow ERV must be explored