HEAT EXCHANGER ANALYSIS

I) Objective

To obtain the overall heat transfer coefficient (U-value) for the hot water heat exchanger under various fluid conditions.

II) Background

Reference text:

Thermal Environmental Engineering, 3rd edition, Chapter 11. Kuehn, T. H., Ramsey, J. W. and Threlkeld, J. L.

Heat exchangers are used extensively in HVAC applications to transfer energy from one fluid to another. A simple example of such a device is a cross flow hot water heat exchanger in an air duct. The device is simply a copper tubing network for hot water flow with aluminum fins attached that increase the heat transfer effectiveness of the device. The heat exchanger is mounted in the flow path and is designed to limit the air side and water side pressure drops.

Heat exchanger analysis is quite complicated and involves flow parameters and geometry quite heavily. Some simpler methods of analysis are the Log-Mean Temperature Difference (LMTD) method and the Number of Transfer Units (NTU) method. These methods will be described in class.

The liquid line contains a water and ethylene glycol mix (Dowtherm SR-1). A table of DowTherm SR-1 fluid properties is located in Appendix F.

III) Data Acquisition Procedure

Write a simple data acquisition program to measure the air and water inlet and outlet temperatures and the water volumetric flow rate. Set the fan speed to 40 Hz and the water pump speed to low. Monitor the system using the computer program until steady state is reached. Determine the airflow rate using the pitot tube. Measure the air and water side pressure drops across the heat exchanger. Repeat this procedure after increasing the fan speed to 60 Hz. Repeat the previous two trials after increasing the water flow rate to the high setting.

IV) Data Reduction Procedure for the NTU method

a) Determine which fluid has the smaller fluid capacity rate, $c_{\min} = (\dot{m}c_p)_{\min}$

Note: $(\dot{m}c_p)_{\min} \Delta t_{\max} = (\dot{m}c_p)_{\max} \Delta t_{\min}$

b) Compute the fluid capacity ratio, c_r

$$c_r = \frac{c_{\min}}{c_{\max}}$$

c) If the $c_{\min}$ fluid is the air (unmixed) use:

$$\varepsilon = \frac{\left(t_{c,o} - t_{c,i}\right)}{\left(t_{h,i} - t_{c,i}\right)}$$

and

$$\varepsilon = \frac{1}{c_r}\left\{1 - \exp\left(-c_r\left[1 - \exp\left(-NTU\right)\right]\right)\right\}$$

If the $c_{\min}$ fluid is the water (mixed) use:

$$\varepsilon = \frac{\left(t_{h,i} - t_{h,o}\right)}{\left(t_{h,i} - t_{c,i}\right)}$$

and

$$\varepsilon = 1 - \exp\left[-\frac{1}{c_r}\left(1 - \exp\left[-NTU\left(c_r\right)\right]\right)\right]$$

d) Solve for NTU from the appropriate equations from part c.

e) Determine the heat exchanger total external surface area, A_o

f) If the $c_{\min}$ fluid is the air:

$$U_o = NTUc_{air} / A_o$$

If the $c_{\min}$ fluid is the liquid:

$$U_o = NTUc_{liquid} / A_o$$

V) Report Requirements

A) Calculate the amount of heat transferred to the air and the amount of heat transferred from the water for each case. How do they compare? Comment on the efficiency of the heat exchanger.

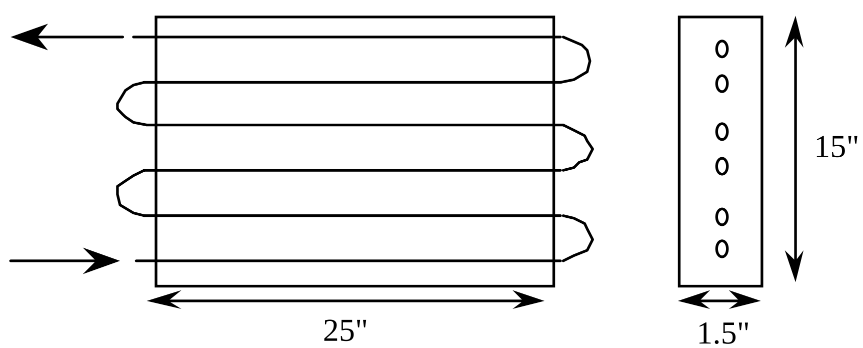
B) Calculate the U-value for the heat exchanger under the four tested conditions using the NTU method. The heat exchanger is a cross flow type with the air unmixed and the water mixed. The procedure for this calculation is outlined above. Comment on the relative magnitudes of the U-values calculated.

C) Compare the pressure drops on the air side and water side of the heat exchanger under the four tested conditions. What are the trade-offs between frictional losses, overall heat transfer coefficient, and the amount of energy delivered to the air?

D) For the fan speed of 40 Hz and high water pump speed, what is the outlet air temperature ($T_{air,out}$) for an inlet air temperature of $50^{o}F$ ($T_{air,in} = 50^{o}F$) and a water/glycol temperature drop of $10^{o}F$ ($\Delta T_{water} = 10^{o}F$)? Calculate this temperature using an energy balance on the heat exchanger.

E) Now, suppose the outlet air temperature is $5^{o}F$ less than the desired value. Think of four different ways to make the outlet temperature reach the desired value without changing any of the hardware of the system (i.e. ducts, heat exchangers, insulation, etc.)

<u>Heat Exchanger Geometrical Analysis</u>



Number of copper tubes passes:	6
Tube outside diameter:	5/8"
Fin length:	1.5"
Fin pitch:	6 / inch
Duct dimensions:	15" x 25"
Fin thickness:	0.04”

<u>Heat Exchanger Data Acquisition Channel Assignments</u>

Refer to Appendix H for sensor channels.

<u>Reference Junction Voltage</u>

V_{ref} should be added to all thermocouple voltage readings.

<u>Thermocouple calibration</u>

$T\ (°C) = Y0 + Y1*v + Y2*v^2 + Y3*v^3 + Y4*v^4$,

where: v is in μV.

$Y0 = 0$ °C

$Y1 = 0.02603$ °C/μV

$Y2 = -9.164$ e -7 °C/μV^2

$Y3 = 1.0$ e-10 °C/μV^3

$Y4 = -7.7$ e-15 °C/μV^4

<u>Volumetric Air Flow Rate</u>

Use the same pitot tube procedure as in previous experiments.

<u>Air and Water Side Pressure Drop</u>

Use the manometer that was used for measuring static pressure across the fan in the Air Handling Characterization lab to determine the air side pressure drop.

Use the Omega pressure gauge on the wall to determine the water side pressure drop.

<u>Humidity Ratio</u>

Use the electric psychrometer and the psychrometric chart to determine the humidity ratio of the air.

<u>Water Volumetric Flow Rate</u>

Measure the frequency from the Sponsler turbine flow meter (SP1/2-21DG-AN, S/N M2082), located on channel 19. The flow meter calibration is:

$\text{Flow Rate (GPM)} = -0.2034 + 0.0087*f - 1.0e\text{-}6*f^2$

where: f is the frequency in Hertz.

Name: ____________________

Date: ____________________

ME 4131 THERMAL ENVIRONMENTAL ENGINEERING LABORATORY
Heat Exchanger Data Acquisition Sheet

Barometric Pressure __________________ in. Hg

		40 Hz/Low	40 Hz/High	60 Hz/Low	60 Hz/High
Air Side ↑	Air Inlet Temperature (°F)				
	Air Outlet Temperature (°F)				
	Air Static Pressure Drop Across HX (in. H_2O)				
	Air Temperature at Pitot Tube Location (°F)				
	Centerline Velocity Pressure (in. H_2O)				
	Relative Humidity at Pitot Tube Location (%)				
Water Side ↓	Dowtherm SR-1 Inlet Temperature (°F)				
	Dowtherm SR-1 Outlet Temperature (°F)				
	Dowtherm SR-1 Inlet Pressure (psig)				
	Dowtherm SR-1 Outlet Pressure (psig)				
	Dowtherm SR-1 Rotameter Flow Rate (GPM)				
	Dowtherm SR-1 Turbine Meter Flow Rate (GPM)				