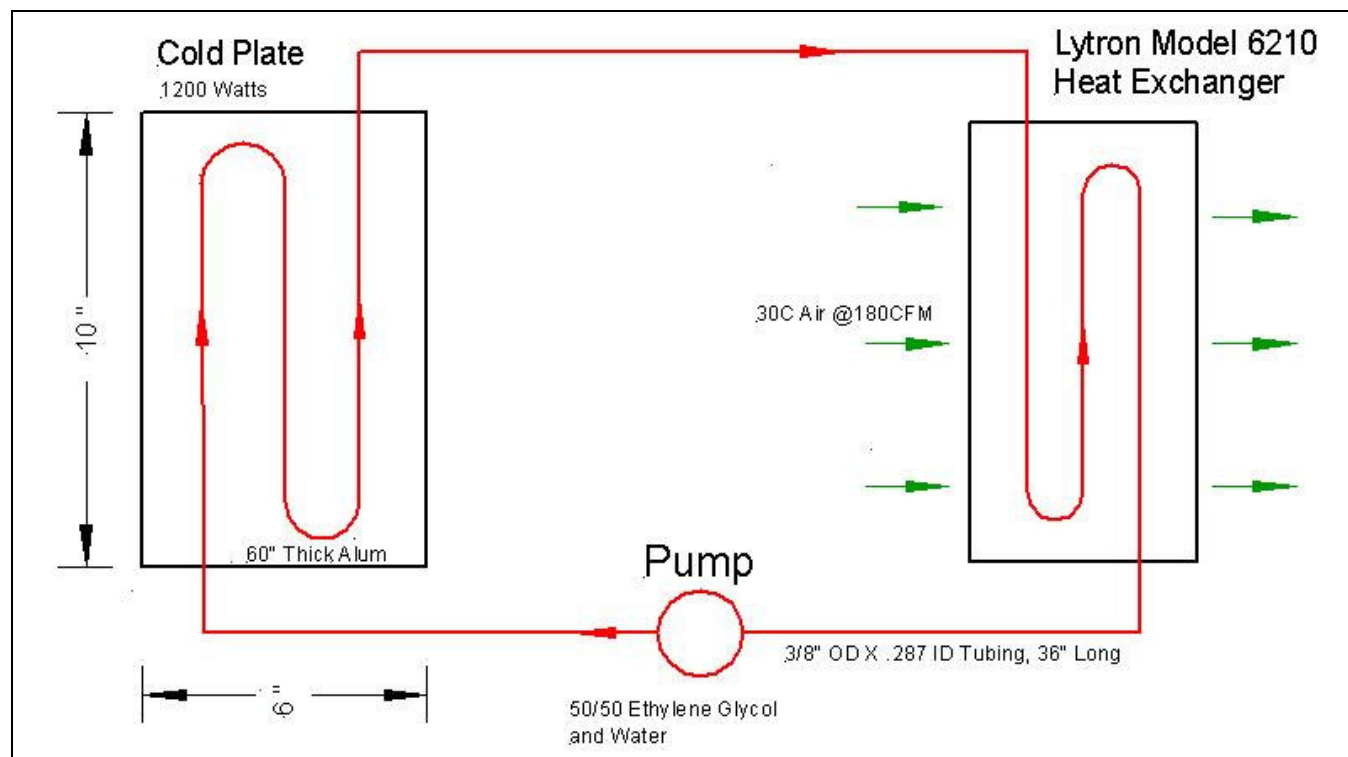


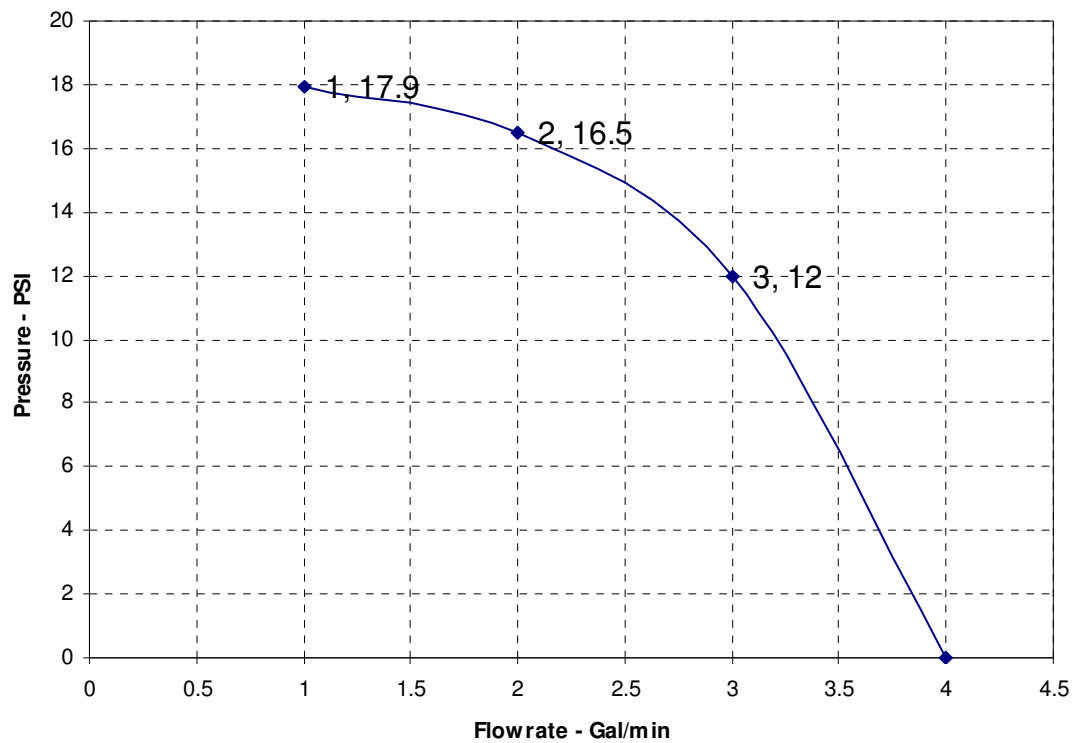
## Use Coldplate to model a cold plate and heat exchanger circuit

The cold plate and heat exchanger to be modeled are shown below. It is assumed the heat exchanger is a Lytron model 6210 and the cold plate parameters are shown in Figure 1. Figure 2 is the assumed pump curve used to circulate 50% ethylene glycol and water through both the cold plate and heat exchanger.

Figure 1: Cold plate and heat exchanger setup



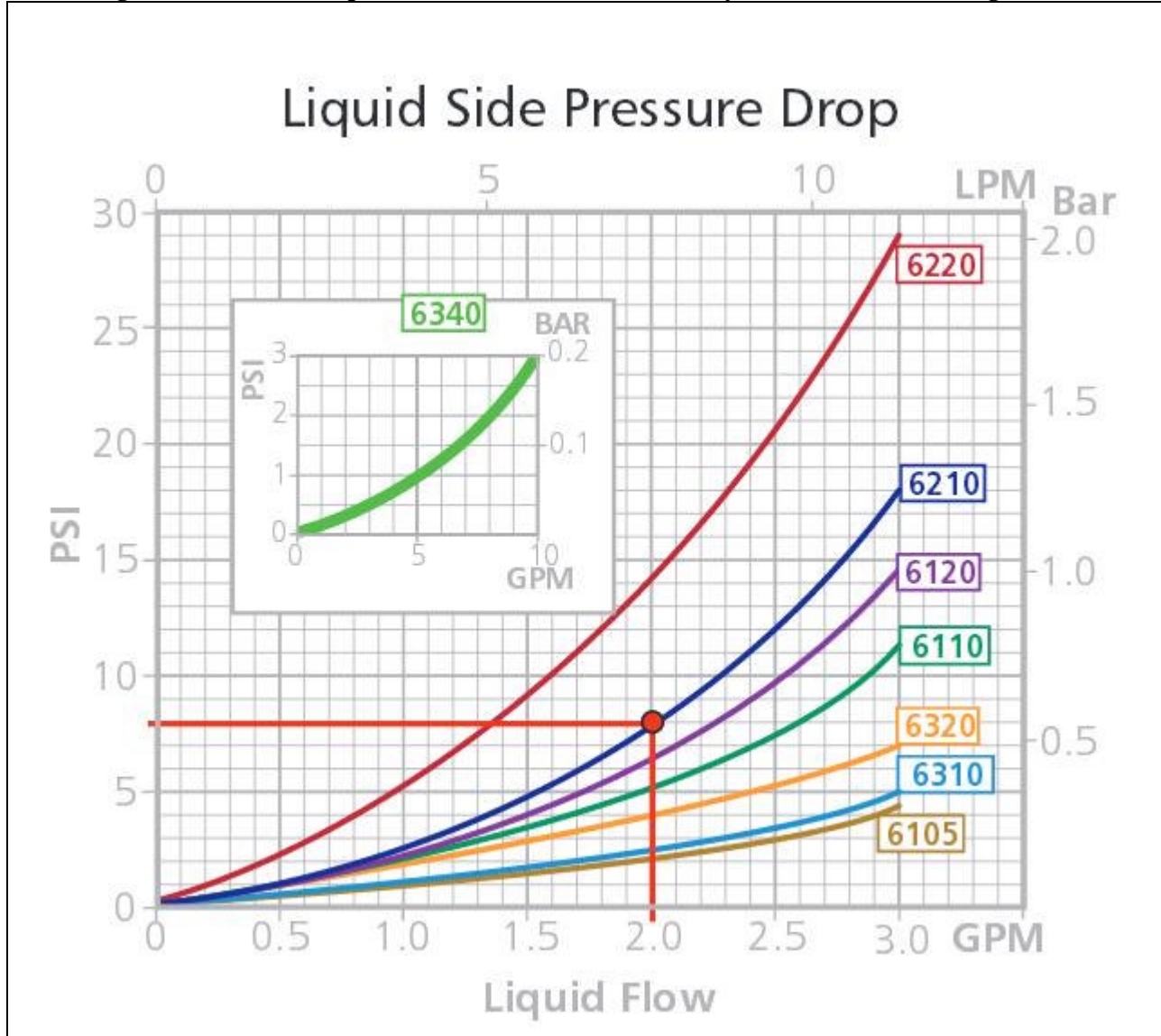
**Figure 2: Pump curve used to circulate the ethylene glycol/water fluid through both the cold plate and heat exchanger**



## Determine the pressure loss coefficient of the heat exchanger

The effective pressure loss coefficient K for the liquid side of the heat exchanger is calculated as follows assuming an ID of .287 inches and 20 degree C. This loss coefficient K along with the pump curve, the 36 inch length of tubing and the internal pressure drop in the cold plate are used to determine the ethylene glycol/water flow rate.

**Figure 3: Pressure drop versus flow rate curve for the Lytron 6210 heat exchanger**



Assume the pressure drop,  $\Delta P$ , through the exchanger is given by:

$$\Delta P = \frac{K\rho V^2}{2g} = \frac{K\rho\Psi^2}{2gA^2}$$

Where:

$\rho = 66.4 \text{ lb/ft}^3$ , the density of ethylene glycol and water at 20C.

V is the velocity.

G is the gravity constant.

A is the cross sectional area of tube.

D is the ID of the tube.

$\Psi$  is the volume flow rate in  $\text{ft}^3/\text{min}$ .

Q is the volume flow rate in  $\text{gal}/\text{min}$ .

Solving for K:

$$K = \frac{2gA^2\Delta P}{\rho\Psi^2} = \frac{2(32.17 \text{ ft/sec}^2)(\pi D^2/4)^2(\text{in}^4)(\Delta P(\text{lb/in}^2))(1 \text{ ft}^2/144 \text{ in}^2)}{(66.4 \text{ lb/ft}^3)(\Psi \text{ ft}^3/\text{min})^2(1 \text{ min}/60 \text{ sec})^2}$$

$$K = 14.93 D^4 \Delta P / \Psi^2$$

Convert flow rates:

$$Q(\text{gal/min}) = \Psi(\text{ft}^3/\text{min})(7.48 \text{ gal/ft}^3)$$

$$\Psi = Q/7.48$$

Substitute into K:

$$K = 835.21 D^4 \Delta P / Q^2$$

For D = .287 in. and from the Lytron pressure drop curve at Q = 2gal/min,  $\Delta P = 8 \text{ lb/in}^2$ :

$$K = 11.33$$

And for D = .287 inches, at Q = 3gal/min,  $\Delta P = 18 \text{ lb/in}^2$ :

$$K = 11.33$$

Since the value of K is the same for both data points, then the assumed equation for calculating K appears to be correct.

**Determine the flow rate of the fluid through the cold plate/heat exchanger**

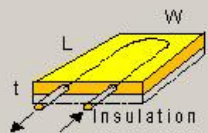
Figures 4 through 7 lists the inputs to Coldplate necessary to determine the fluid flow rate. Note that the Inlet Fluid Temperature is assumed to be 30C; the pressure drop is a weak function of temperature so in this case using 30C will result in a small error. The model can be easily rerun with an updated temperature.

**Figure 4: Geometry Input**



**Tube/Channel Cold Plate**

Geometry | Material | Fluid Properties | Power Dissipation | Pressure Drop | External Heat Transfer | Generate Plots



**Geometry**

 Length (in.)   
Width (in.)   
Base Thickness (in.)  Variable  
Insulation Thickness (in.)  Variable

Choose Type of Cooling Tube/Channel Cross Section ☒ Circular ☐ Rectangular

   
Diameter (in.)  Variable  
Width (in.)   
Height (in.)

**Tube/Channel to Base Plate Resistance**

 Thermal Resistance from Tube to Base (C-in/W)   
 Percent Convection/Tube in Contact with Base

Model Description

Figure 5: Fluid Properties Input

**Tube/Channel Cold Plate**

Geometry | Material | **Fluid Properties** | Power Dissipation | Pressure Drop | External Heat Transfer | Generate Plots

Fluid Temperature, Pressure or Altitude

Inlet Fluid Temperature (C)

*Input one or more matching pressures/altitudes below:*

Inlet Fluid Pressure (lb/in<sup>2</sup>)

Exit Fluid Pressure (lb/in<sup>2</sup>)

Inlet Fluid Altitude (ft)

Exit Fluid Altitude (ft)

Variable

Type of Cooling Fluid

- ☐ AIR
- ☐ COOLANOL20
- ☐ COOLANOL25
- ☐ EG\_H2O\_30/70
- ☐ EG\_H2O\_40/60
- ☒ EG\_H2O\_50/50
- ☐ EG\_H2O\_60/40
- ☐ FC75
- ☐ GALDEN-HT110
- ☐ HFE7100

Fluid Flow Rate

*Input one or more:*

Mass Flow Rate (lb/min)  Variable

Volume Flow Rate (gal/min)  Variable

*Predict Flow Rate That Results In:*

Cold Plate Temperature (C) of

Fluid Exit Temperature (C) of

Pressure Drop (in.-H2O) of

**Min, Max and Number of Values**

Minimum value

Maximum value

Number of values

OK Cancel Help

Model Description OK Cancel

Figure 6: Pressure Drop Parameters

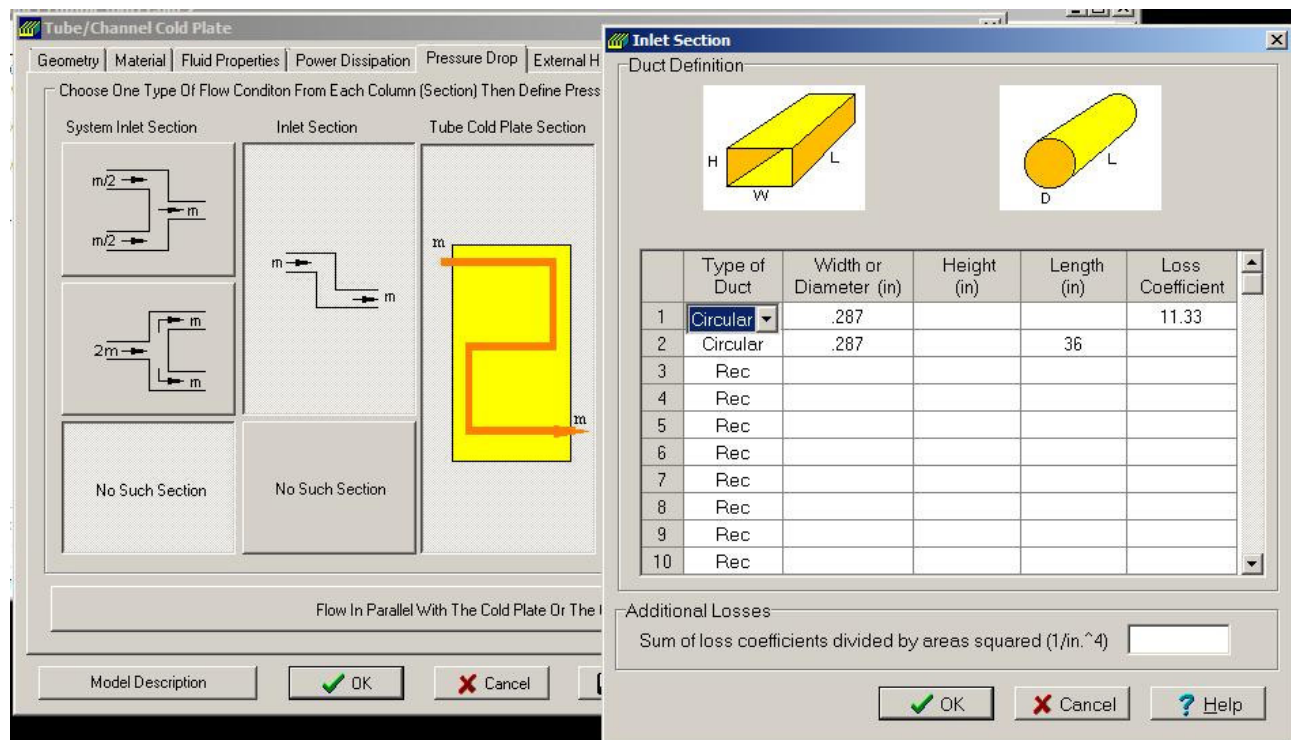
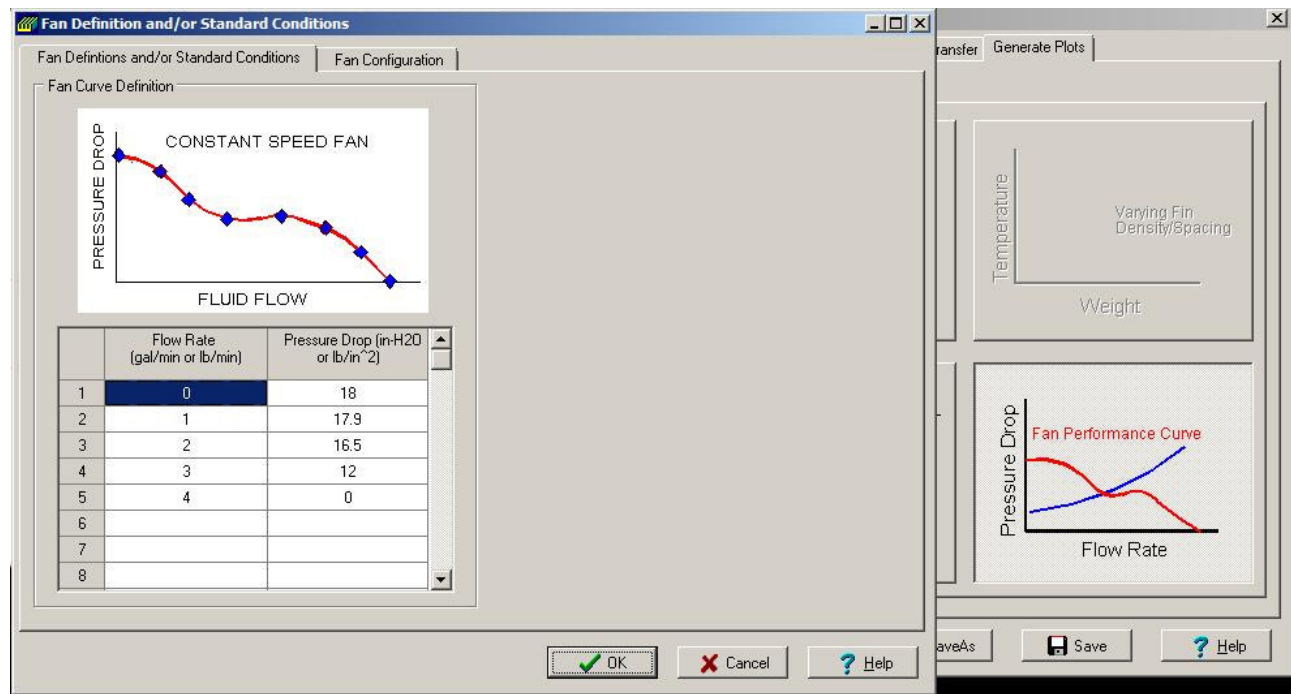


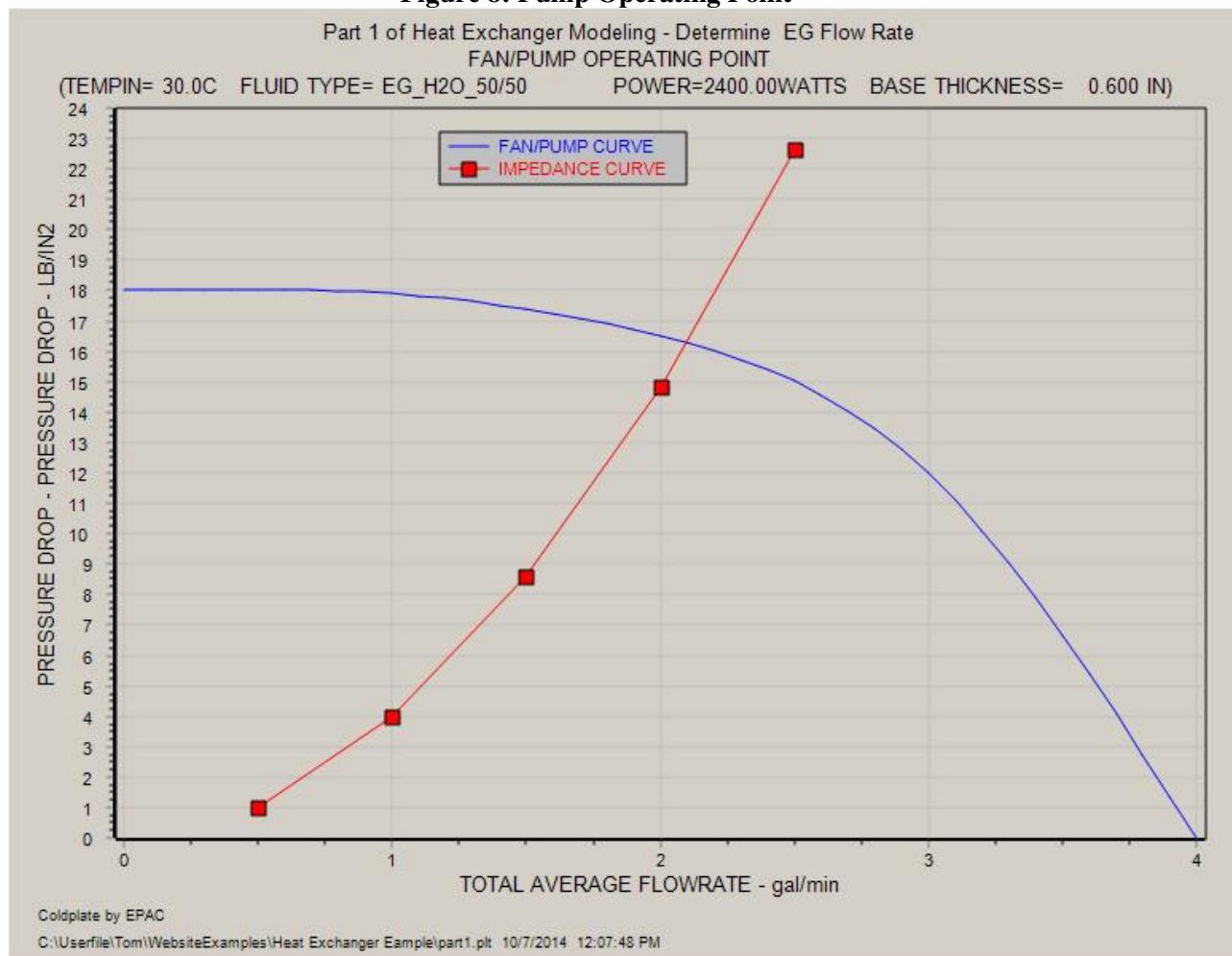
Figure 7: Pump Impedance Curve





The intersection of the pressure drop and pump curves shows the operating point has a flow rate of approximately 2 gal/min. This value will be used for the rest of analysis.

**Figure 8: Pump Operating Point**

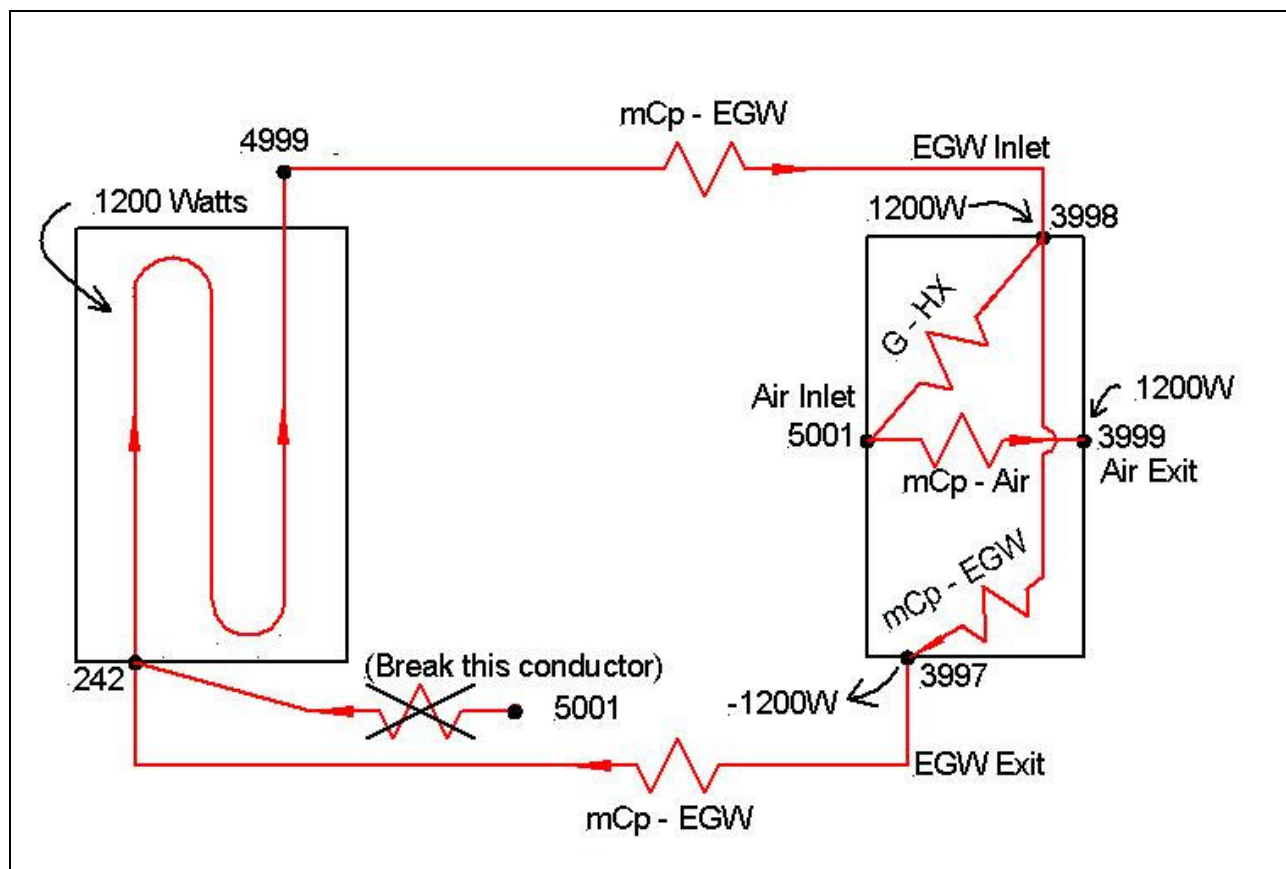




### Thermal/fluid circuit and conductor connection values

The thermal/fluid circuit for connecting the cold plate to the heat exchanger is shown in Figure 9 and the value of the conductors are calculated below.

### Figure 9: Thermal/Fluid Circuit

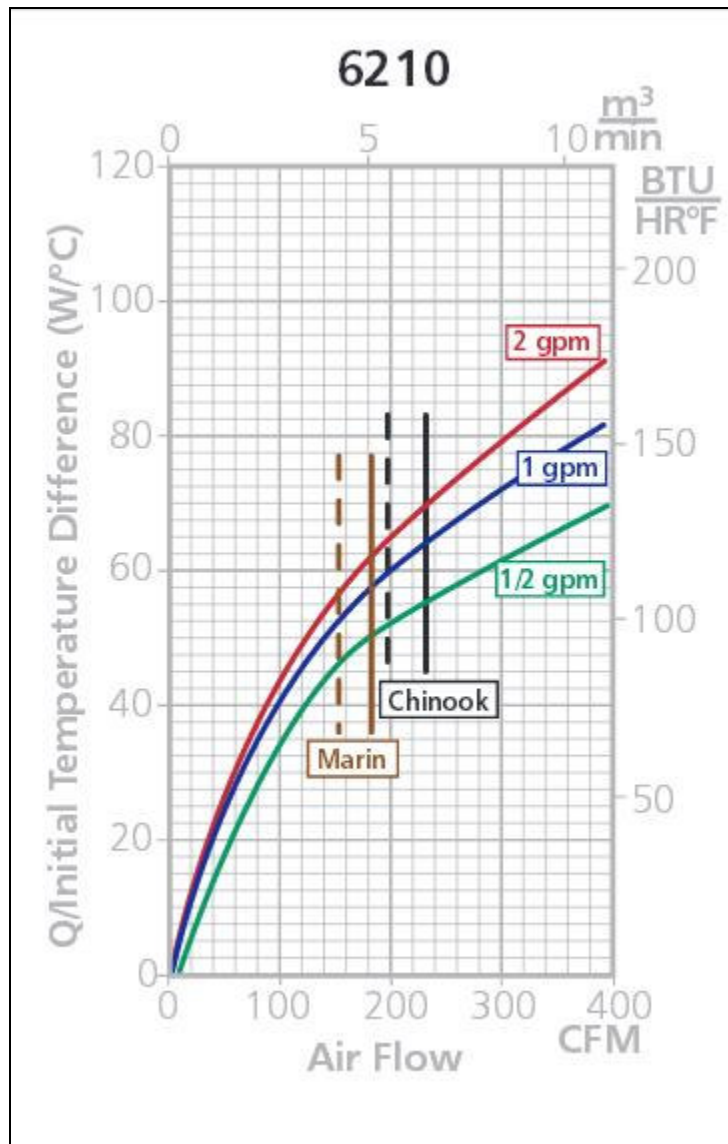


The conductor G – HX is taken from the Lytron curve for the model 6210 heat exchanger, Figure 10 at 2 gal/min and 180 CFM it is:

$$G - HX = 62 \text{ W/C}$$

G – HX can be treated as a conductor from the air inlet temperature (node 5001) to the inlet EGW inlet temperature (node 3998).

Figure 10: Lytron Heat Exchanger Thermal Conductance Curves



The EGW (ethylene glycol and water) fluid flow conductor mCp –EGW is calculated as below:

$$\rho = 65.9 \text{ lb/ft}^3$$

$$C_p = 25.52 \text{ (W-min)/(lb-C)}$$

$$m = \rho \Psi = (65.9 \text{ lb/ft}^3)(2\text{gal/min})(1\text{ft}^3/7.48\text{gal}) = 17.62 \text{ lb/min}$$

$$mC_p - \text{EGW} = (17.62 \text{ lb/min})(25.52 \text{ (W-min)/(lb-C)}) = 449.7 \text{ W/C}$$

The air inlet fluid flow conductor for the heat exchanger is calculated as below:

$$\rho = P/RT$$

$$\rho = [(14.7 \text{ lb/ft}^2)(144\text{in}^2/\text{ft}^2)]/[(53.34\text{ft/R})(30+273)\text{K}(1.8\text{R}/1.0\text{K})]$$

$$\rho = .073 \text{ lb/ft}^3$$

$$C_p = 7.6 \text{ (W-min)/(lb-C)}$$

$$m = \rho \Psi = (.073 \text{ lb/ft}^3)(180\text{ft}^3/\text{min}) = 13.14 \text{ lb/min}$$

$$mC_p - \text{Air} = [13.14 \text{ lb/min}][7.6 \text{ (W-min)/(lb-C)}] = 99.9 \text{ W/C}$$

## **Input the thermal/fluid model into Coldplate**

The thermal/fluid circuit shown in Figure 9 is inputted to Coldplate as shown in Figures 11 through 14. Note that the connection from the inlet air node (5001) to the first fluid node (242) in the cold plate needs to be disconnected as shown. This is done by over-writing the connection and adding a new connection with a value of 0.

For this analysis, assume the cold plate is 12 nodes wide and 20 nodes long. In addition, assume the cold plate has a 4 pass tube configuration. Assume also the power is uniformly distributed.

Figure 11: Define Cold Plate Node Structure and Extra Nodes Used in Figure 9

**Nonisothermal Analysis**

Analysis | Nodes | Power | Conductors | Arrays | Comments

Cold Plate Nodes

Number of nodes along width:

Number of nodes along length:

Connect Coolant Tube/Channel to Base

Example: 5 Nodes along Length, 4 Nodes along Width

Flow Direction →

Length					Width
4	8	12	16	20	
3	7	11	15	19	
2	6	10	14	18	
1	5	9	13	17	

Node Layout Scheme

List of Extra Nodes

	Node Number	Initial Temperature (C)	Thermal Mass (W-sec./C)	Comment Number
1	3998	30	0	
2	3999	30	0	
3	3997	30	0	
4				
5				
6				

Thermal Mass:

D = Density

V = Volume per Node

Cp = Specific Heat

Thermal Mass = D x V x Cp

Groups of Extra Nodes

	Number of Nodes	Starting Node Number	Increment Value	Initial Temperature (C)	Thermal Mass (W-sec./C)	Comment Number
1						
2						
3						
4						
5						
6						

OK Cancel SaveAs Save Help

**Figure 12: Define Uniformly Distributed 1200Watts across Cold Plate and Power to the Heat Exchanger**

**Nonisothermal Analysis**

Analysis | Nodes | **Power** | Conductors | Arrays | Comments

☐ Use "Uniform" power
 ☒ **Constant power (Lists or Layout)**
☐ Power versus time (Lists)
 ☐ Power versus temperature (Lists)

Uniform Power

Constant Power Layout

Power Layout

Heater/Cooler

Heater

List of Powers

	Node Number	Power (Watts)	Time Array Number	Temperature Array Number	Comment Number
1	1	5.0000			
2	2	5.0000			
3	3	5.0000			
4	4	5.0000			
5	5	5.0000			
6	6	5.0000			
7	7	5.0000			
8	8	5.0000			

Groups of Powers

	Number of Nodes	Starting Node Number	Increment Value	Power (Watts)	Time Array Number	Temperature Array Number	Comment Number
1	1	3999	1	1200			
2	1	3997	1	-1200			
3	1	3998	1	1200			
4							
5							
6							
7							
8							

OK
  Cancel
  SaveAs
  Save
  Help

Figure 13: Define the Conductor Connections shown in Figure 9

**Nonisothermal Analysis**

Analysis | Nodes | Power | **Conductors** | Arrays | Comments

☒ Constant conductance
 ☐ Conductance versus time
 ☐ Conductance versus temperature

List of Extra Conductors

	"From" Node	"To" Node	Constant Conductance	Time Array No.	Temperature Array No.	Cond. Type	Comment Number
1	5001	242	0			F	
2	5001	3998	62			F	
3	4999	3998	449.7			F	
4	3997	242	449.7			F	
5	5001	3999	100			F	
6	3998	3997	449.7			F	
7						C	
8						C	

Conductor Types:  
 C - conduction  
 F - fluid flow  
 R - radiation

Conductor Units:  
 C, F - Watt/C  
 R - Watt/C^4

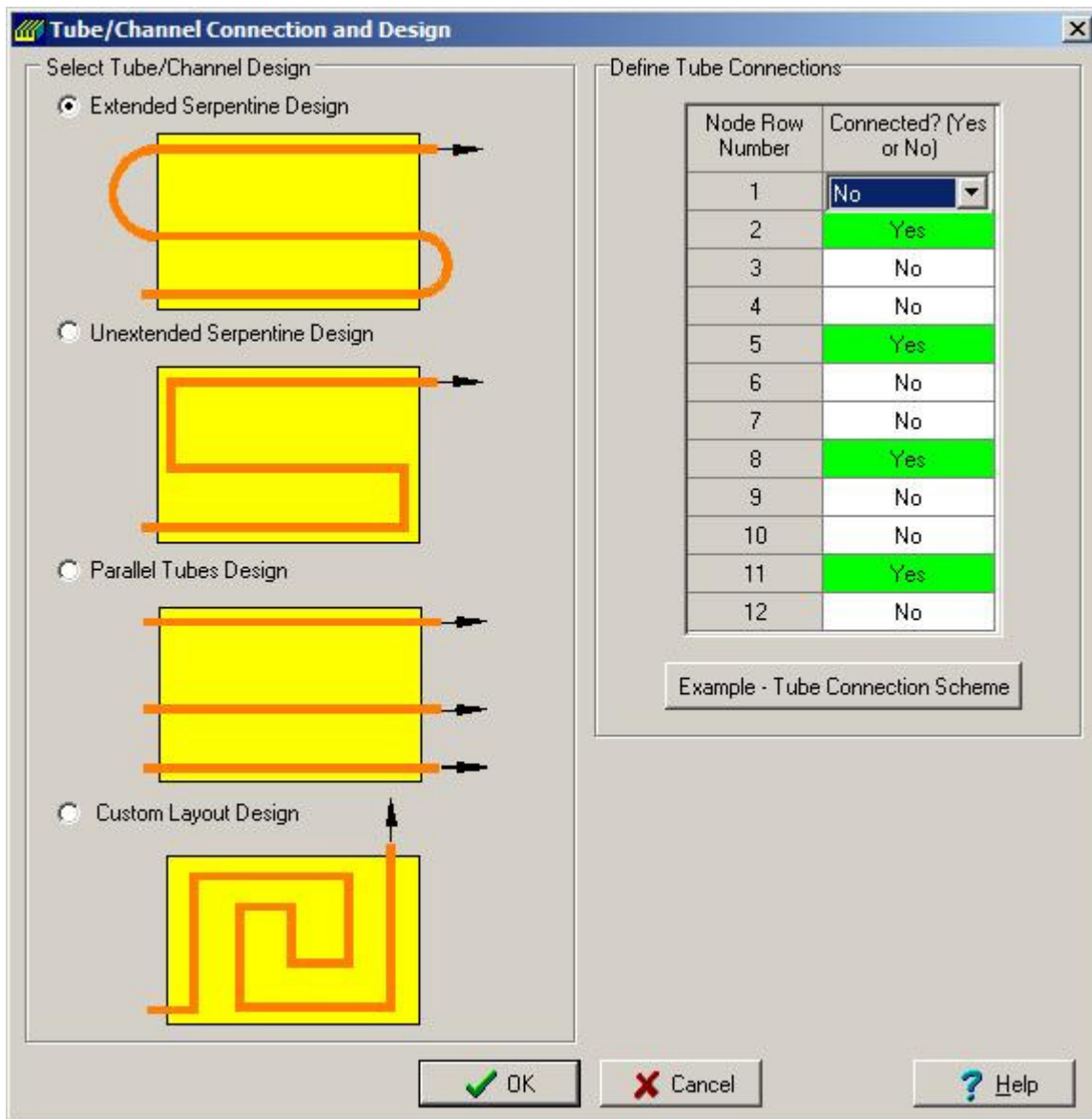
Duplicate Conductors  
☒ Over-write  
☐ Add in parallel

Groups of Extra Conductors

	No. of Conductors	Starting "From" Node	Increment Value	Starting "To" Node	Increment Value	Constant Conductance	Time Array No.	Temp. Array No.	Cond. Type	Comment Number
1									C	
2									C	
3									C	
4									C	
5									C	
6									C	
7									C	
8									C	

OK
  Cancel
  SaveAs
  Save
  Help

Figure 14: Define the Cold Plate as a 4 Pass Tube Configuration





## Results from running the Coldplate model

Figure 15 shows the results from running the model while the calculations below compare the model results with hand (explicit) analysis.

$$T_{3998} = 30\text{C} + (1200\text{W})/(62\text{W/C}) = 49.35\text{C} \text{ versus } 49.37\text{C}$$

$$T_{3997} = 49.35\text{C} - (1200\text{W})/(449.7\text{W/C}) = 46.69\text{C} \text{ versus } 46.70\text{C}$$

$$T_{3999} = 30\text{C} + (1200\text{W})/(99.9\text{W/C}) = 42.01\text{C} \text{ versus } 42\text{C}$$

**Figure 15: Results from the Coldplate model**

