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 curved used to circulate 50% ethylene glycol and water through both the cold plate and heat exchanger.

Figure 1: Cold plate and heat exchanger setup

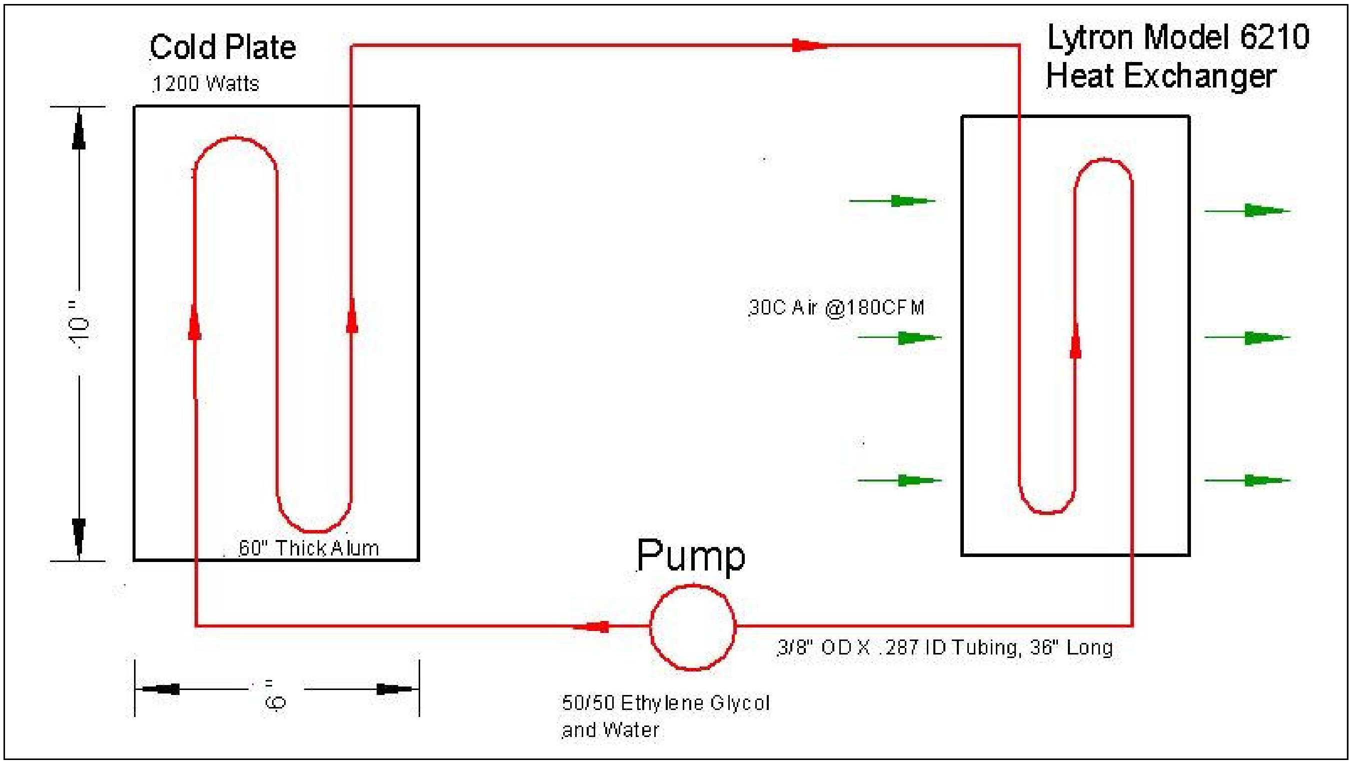
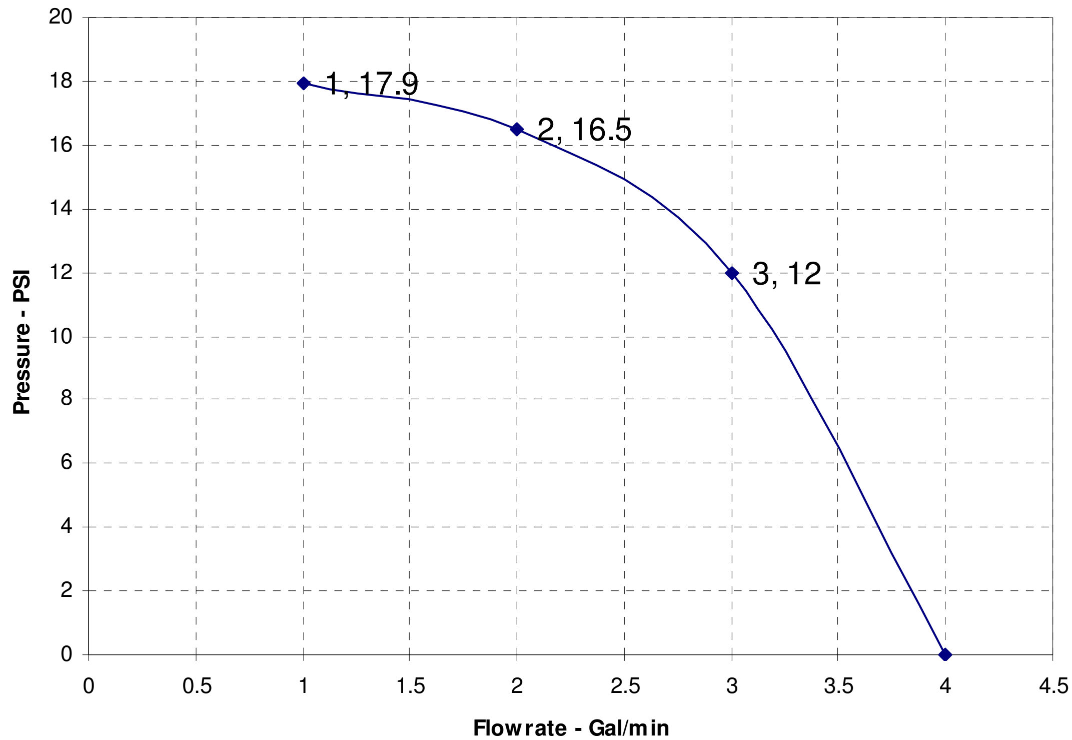


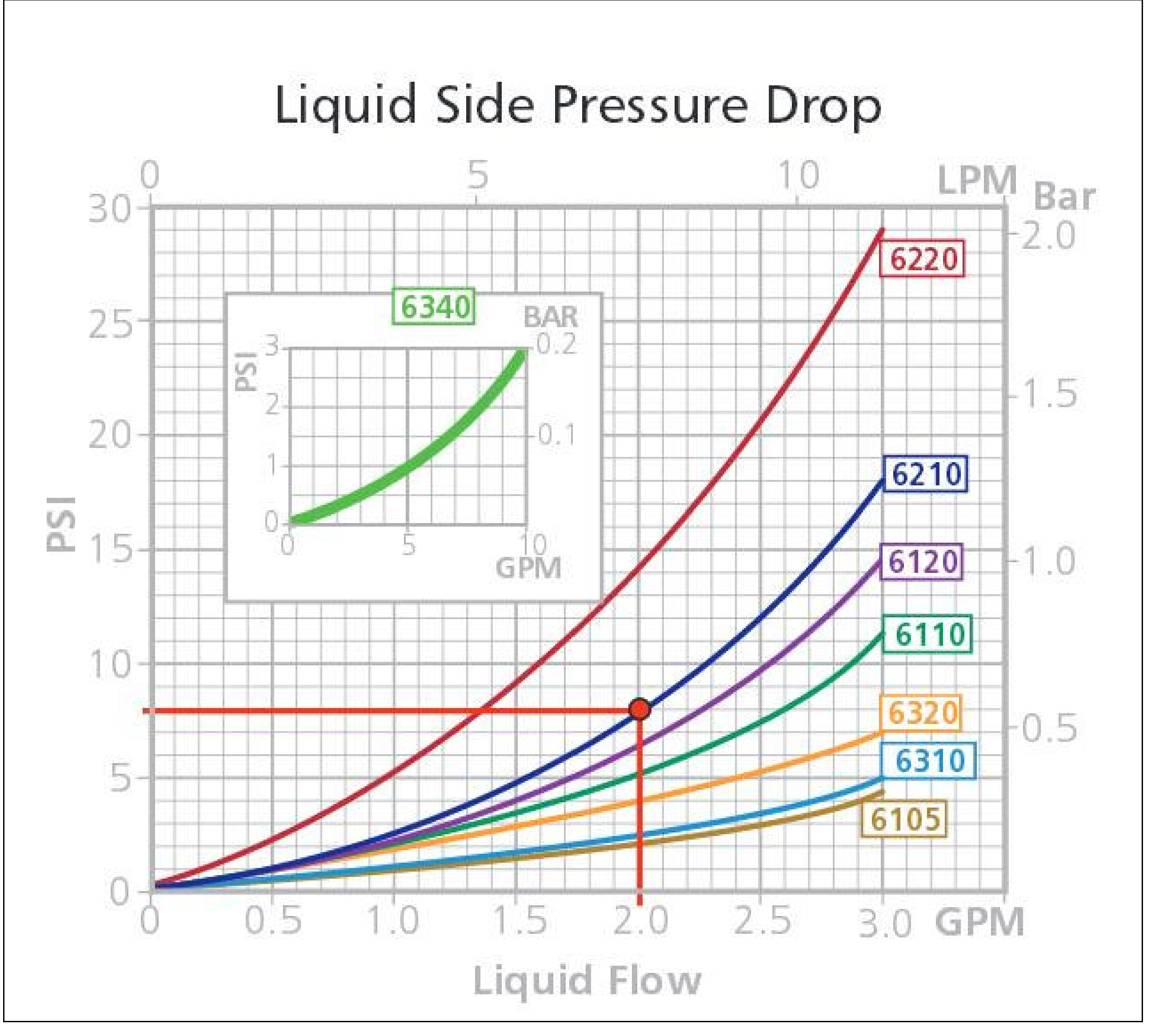
Figure 2: Pump curve used to circulate the ethylene glycol/water fluid through both the cold plate and heat exchanger



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, ΔP, through the exchanger is given by:

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

Where:

ρ = 66.4 lb/ft3, 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.

Ψ is the volume flow rate in ft3/min.

Q is the volume flow rate in gal/min.

Solving for K:

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

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

Convert flow rates:

$$Q(gal/\min) = \Psi(ft^3/\min)(7.48\,gal/ft^3)$$

$$\Psi = Q/7.48$$

Substitute into K:

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

For D = .287 in. and from the Lytron pressure drop curve at Q = 2gal/min, ΔP = 8 lb/in^2:

K = 11.33

And for D = .287 inches, at Q = 3gal/min, ΔP = 18 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

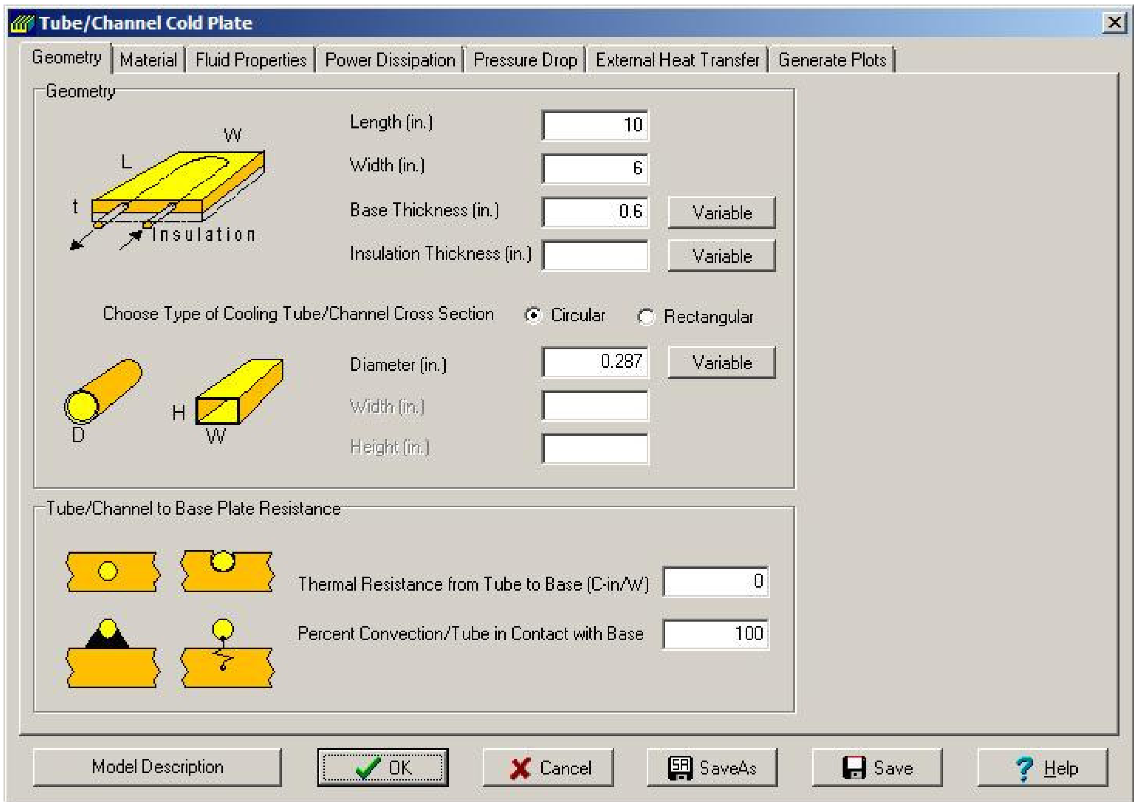


Figure 5: Fluid Properties Input

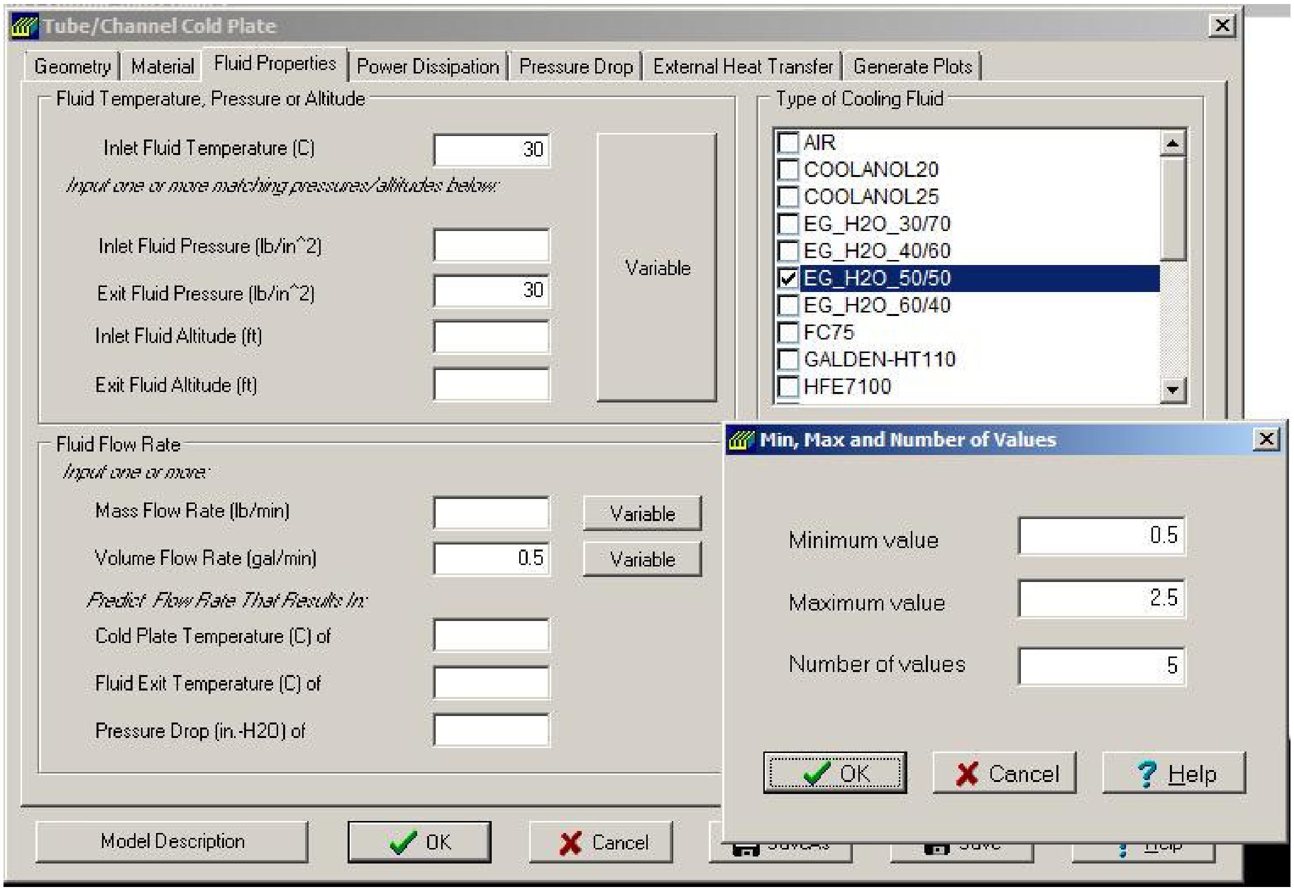


Figure 6: Pressure Drop Parameters

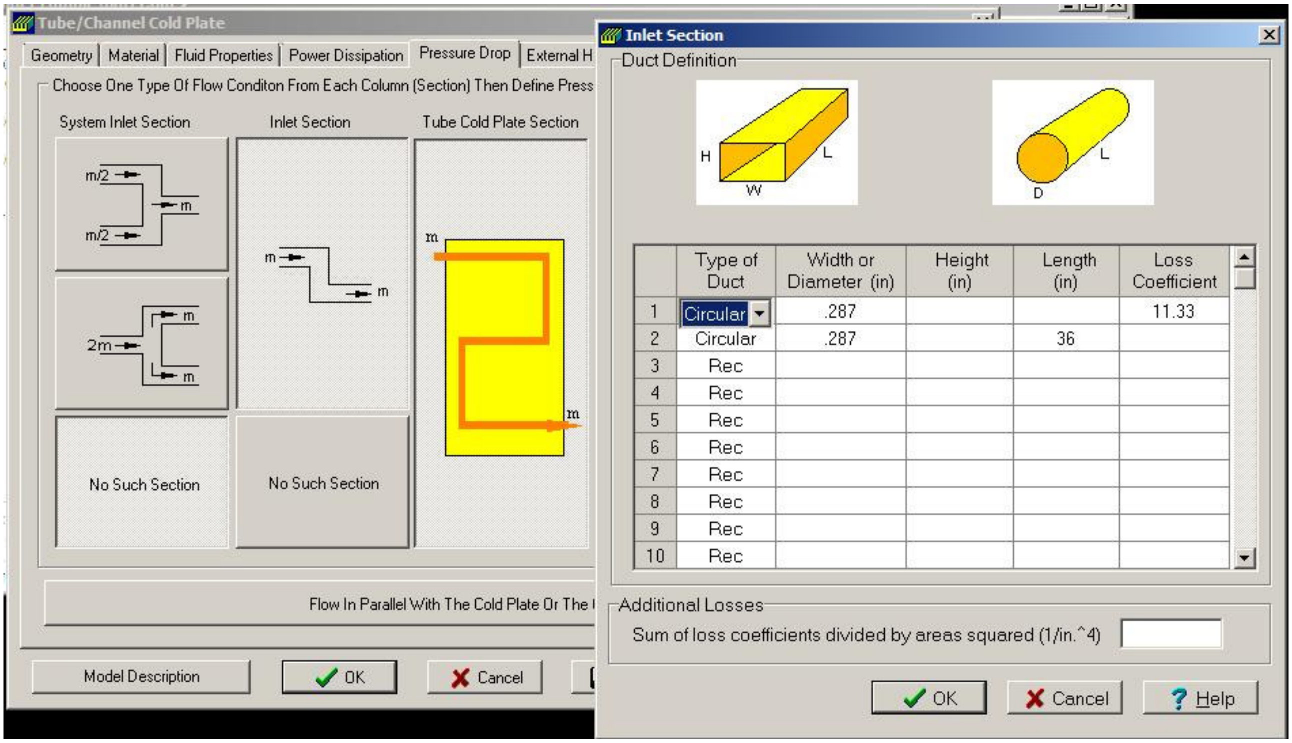
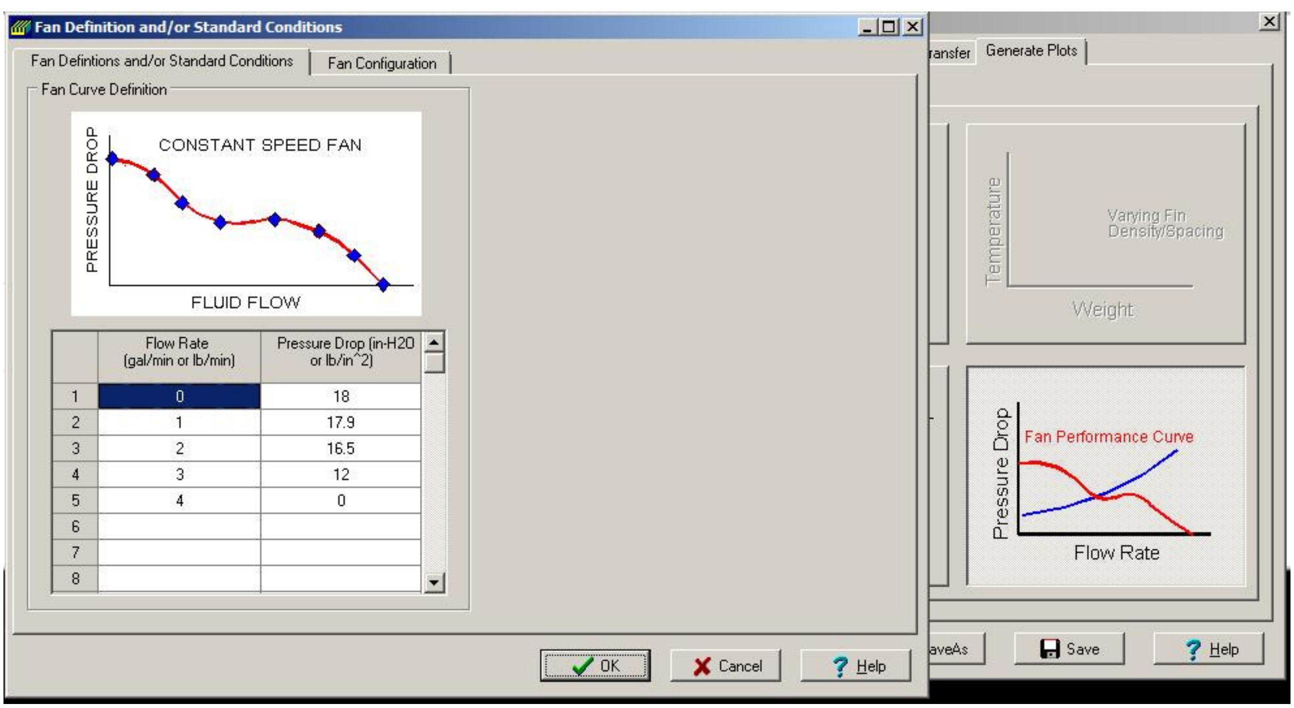
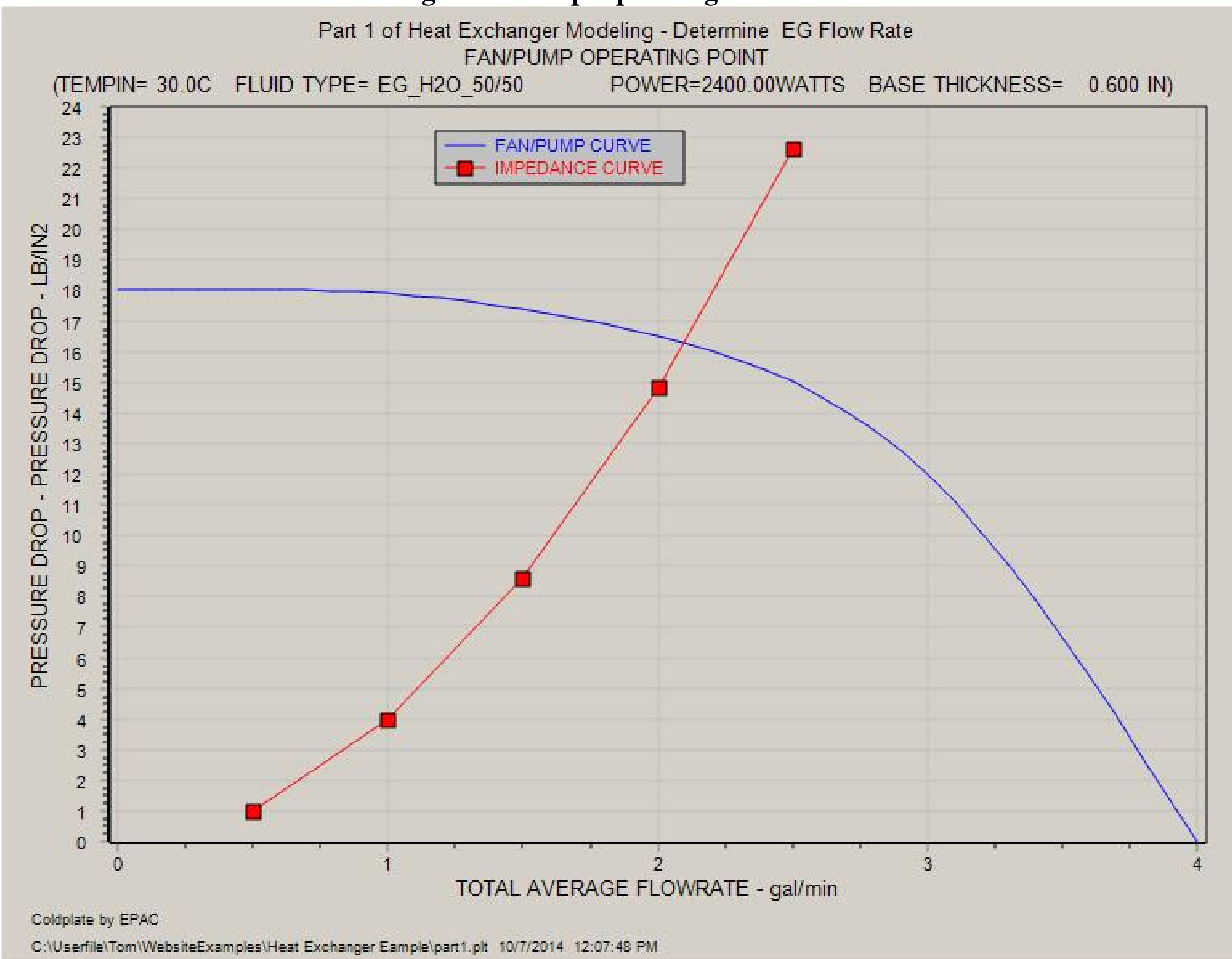


Figure 7: Pump Impedance Curve



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.

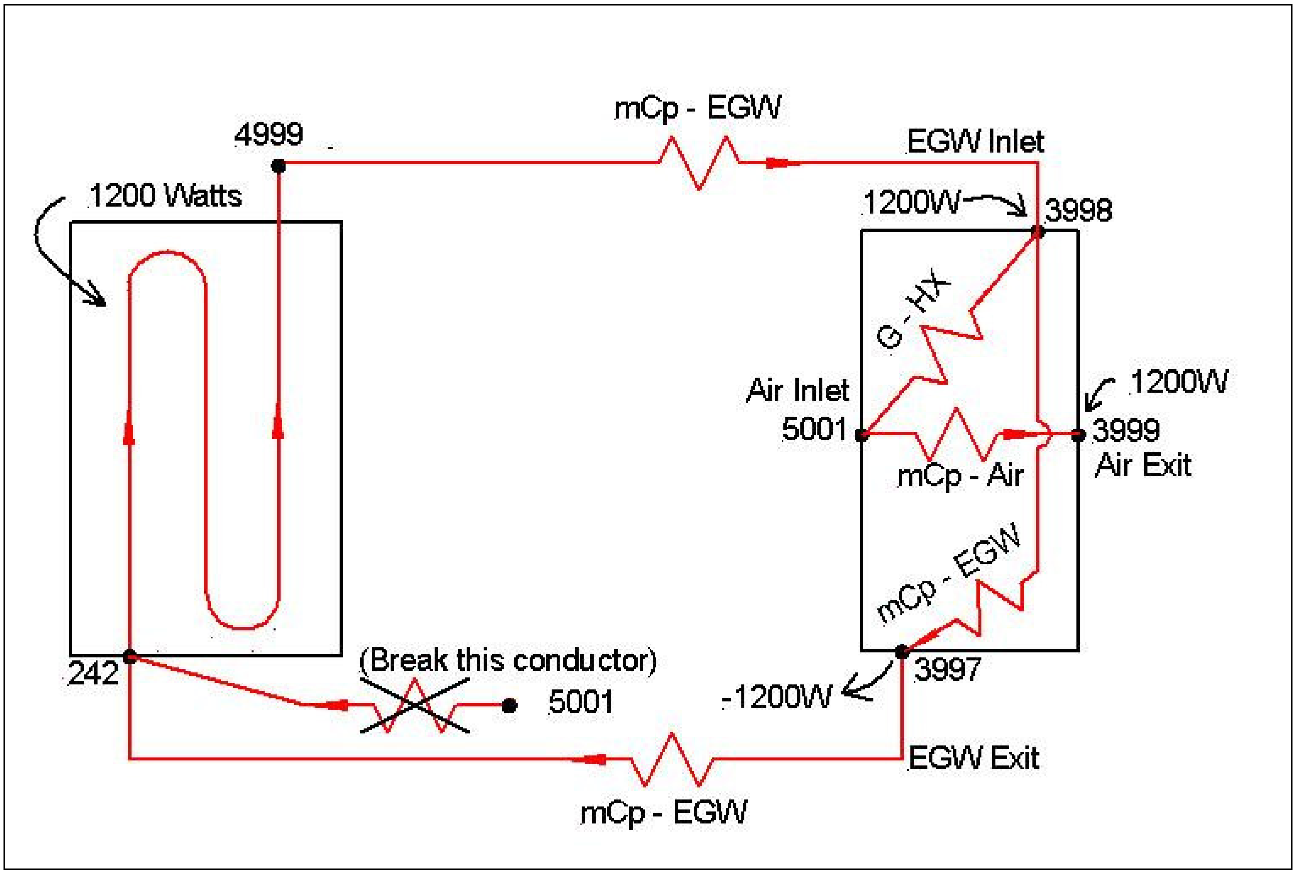
Figure 8: Pump Operating Point



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

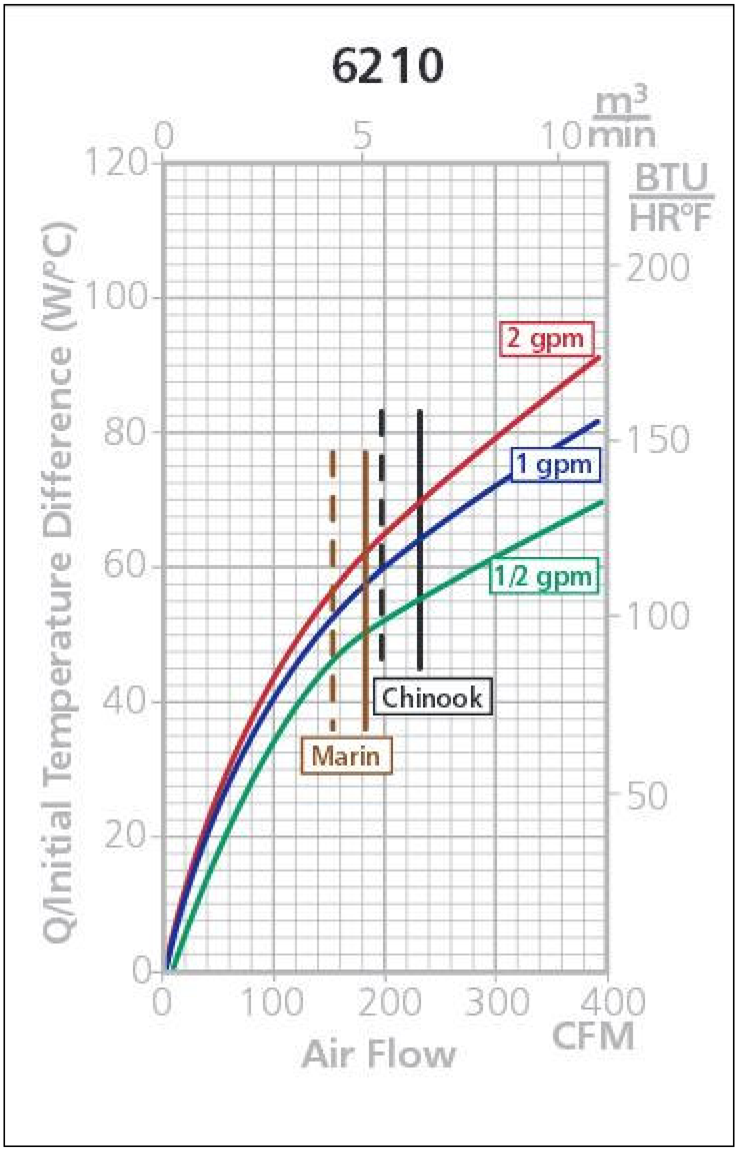


The conductor G – HX is taken from the Lytron curve for the model 6210 heat exchanger, Figure 10 at 2 gal/min and 180 CFM it is:

$$G - HX = 62\ W/C$$

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:

ρ = 65.9 lb/ft^3

Cp = 25.52 (W-min)/(lb-C)

m = ρ Ψ = (65.9 lb/ ft^3)(2gal/min)(1ft^3/7.48gal) = 17.62 lb/min

mCp – EGW = (17.62 lb/min)(25.52 (W-min)/(lb-C)) = 449.7W/C

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

ρ = P/RT

ρ = [(14.7 lb/ft^2)(144in^2/1ft^2)]/[(53.34ft/R)(30+273)K(1.8R/1.0K)]

ρ = .073 lb/ft^3

Cp = 7.6 (W-min)/(lb-C))

m = ρ Ψ = (.073 lb/ ft^3)(180ft^3/min) = 13.14 lb/min

mCp – Air = [13.14 lb/min][7.6 (W-min)/(lb-C)] = 99.9W/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

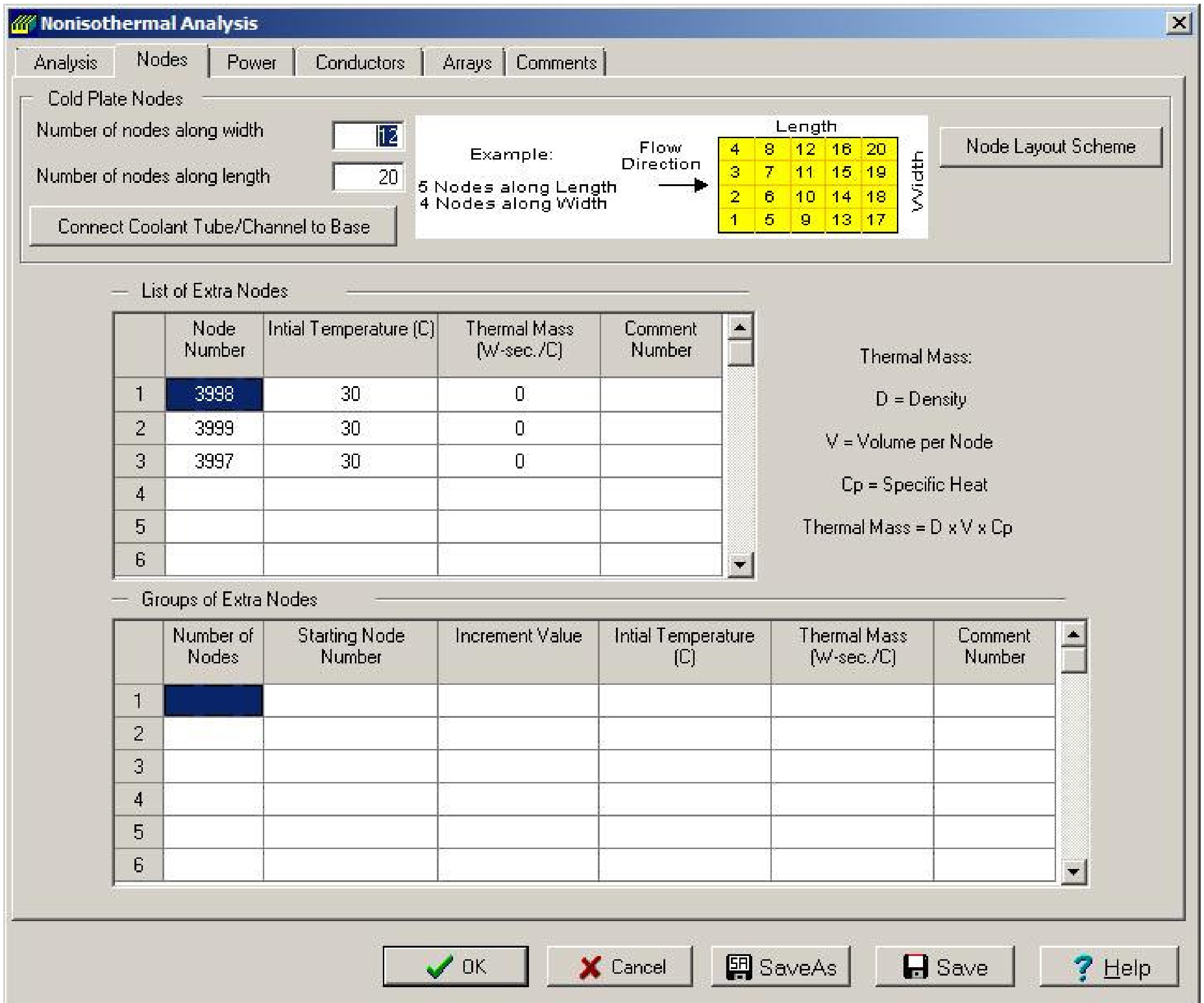


Figure 12: Define Uniformly Distributed 1200Watts across Cold Plate and Power to the Heat Exchanger

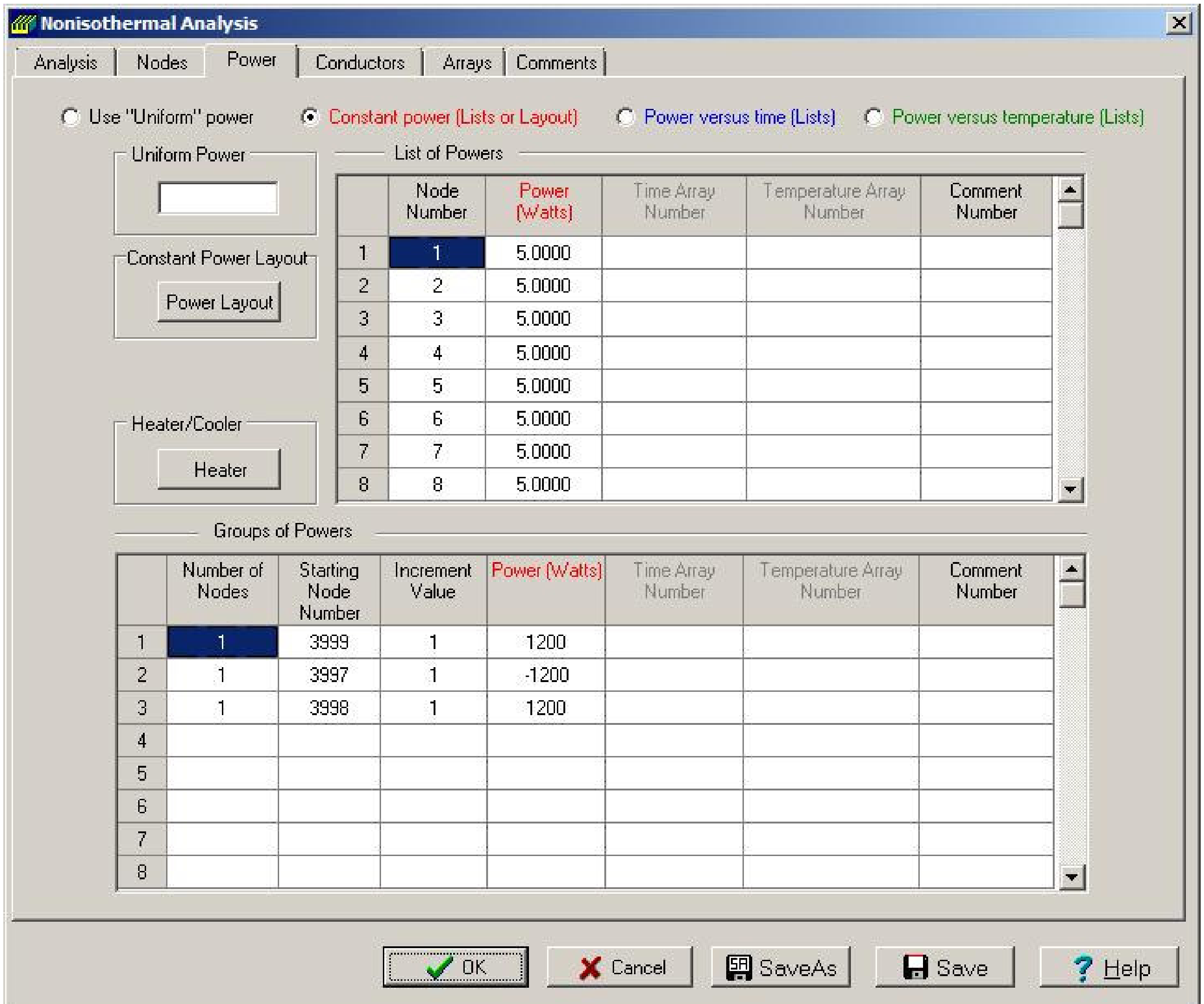


Figure 13: Define the Conductor Connections shown in Figure 9

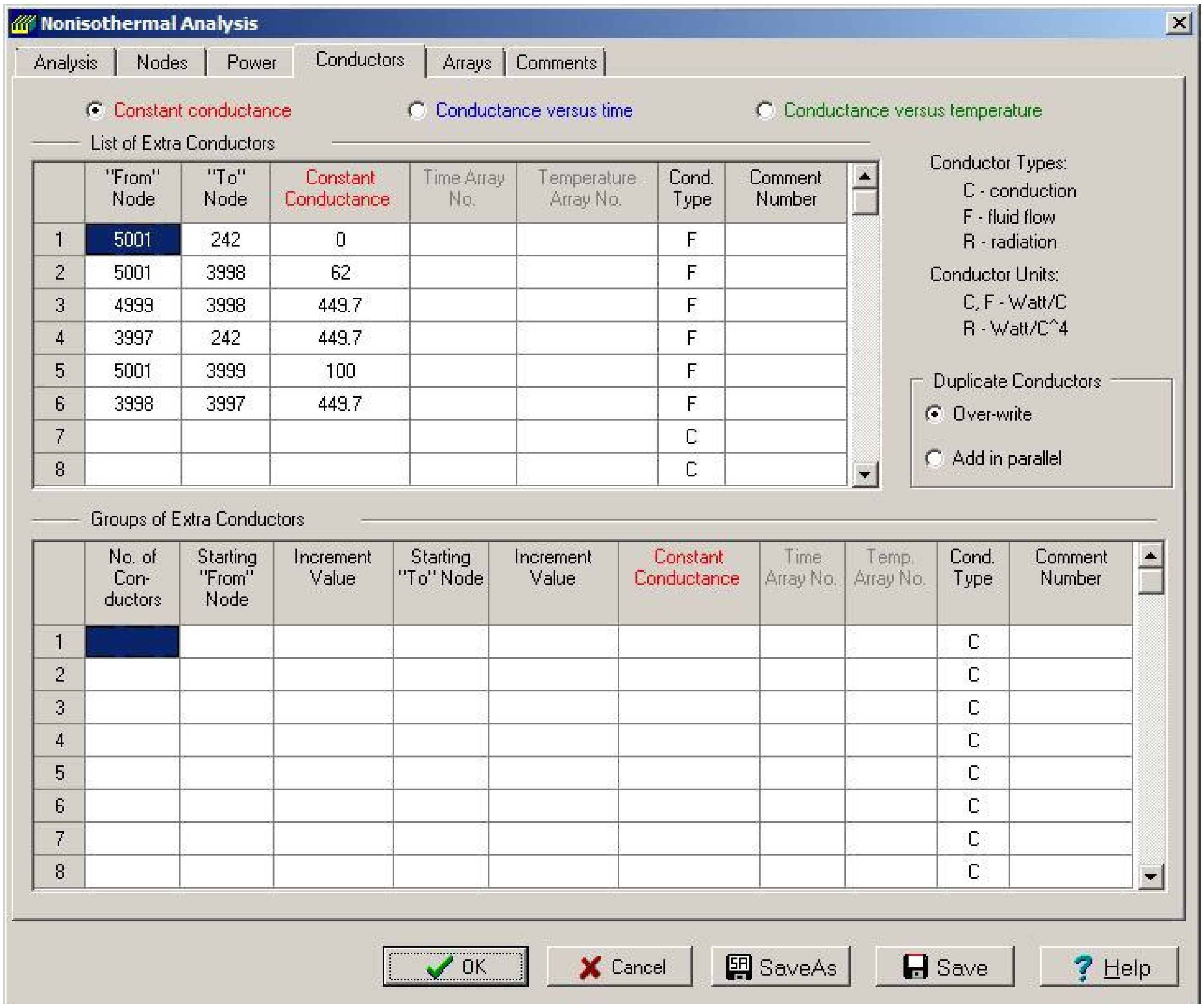
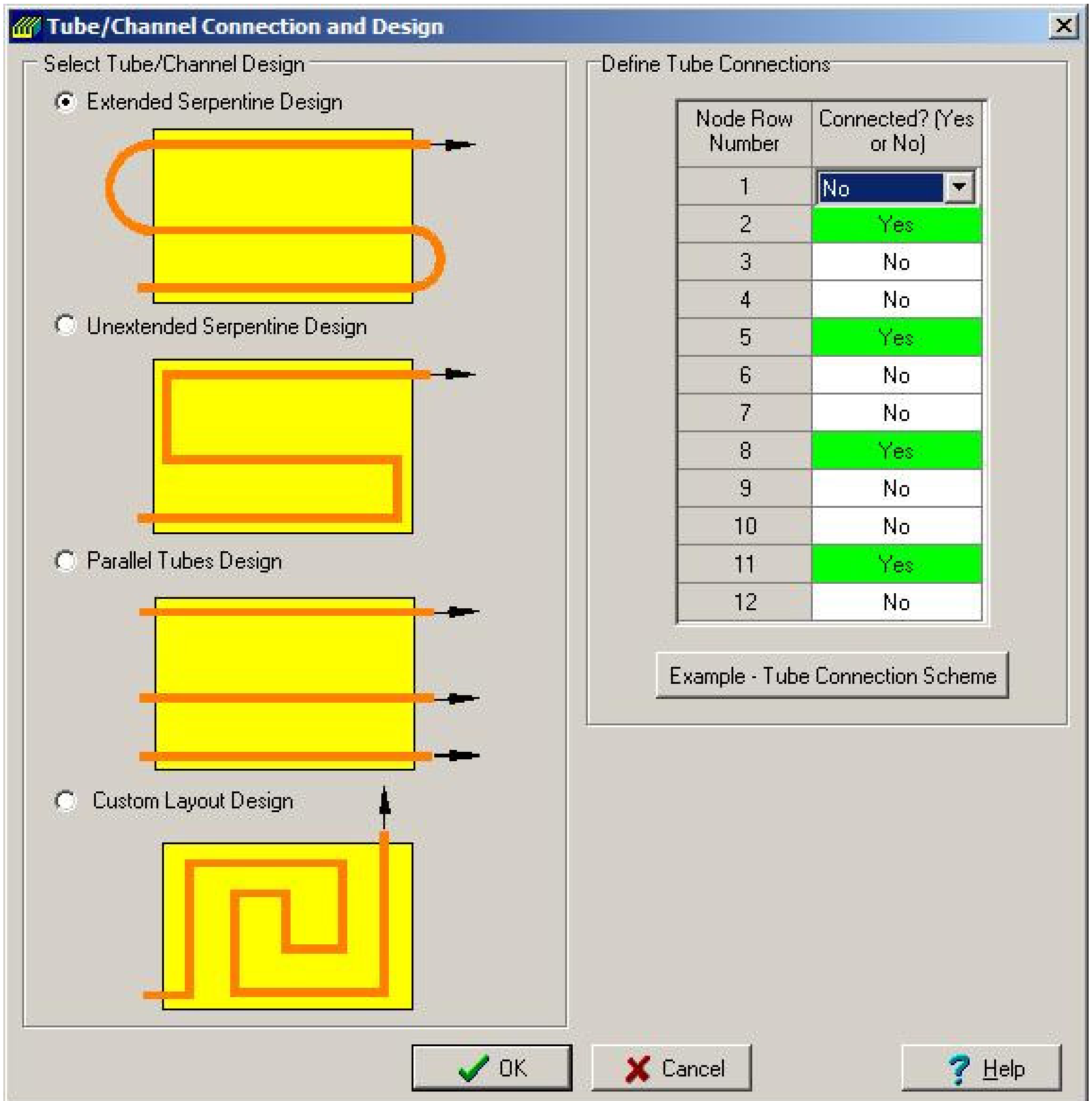


Figure 14: Define the Cold Plate as a 4 Pass Tube Configuration



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.

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

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

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

Figure 15: Results from the Coldplate model