Problem #2: Pick a closed system that runs at steady state. The system must involve at least two mechanisms of entropy generation. Now do a parametric study in which you change a parameter, vary it over a wide range, and see its effect on total entropy generation rate, and entropy generation due to individual mechanisms.

Suppose we have the system below:

$$\dot{W}\_{in}$$

$$\dot{Q}\_{in}$$

*Tc*

$$\dot{Q}\_{out}$$

*Th*

Figure 1. Diagram of system modeled.

The parametric study completed for this system will first vary the heat transfer into the system. Next, the heat transfer will be constant, but the boundary temperatures will be variant.

First, the energy and entropy equations must be solved:

 $\frac{dE}{dt}=0=-\dot{m}\left(∆h\right)+\dot{Q}\_{Ext}-\dot{W}\_{Ext}$ (1)

Since this is a closed steady system, this reduces to:

 $\dot{Q}\_{In}=\dot{W}\_{Ext}-\dot{Q}\_{Out}$ (2)

This is useful as the outputted heat is what will be varied for the parametric study.

Similarly, the entropy equation:

 $\frac{dS}{dt}=0=-\dot{m}\left(∆h\right)+\frac{\dot{Q}}{T\_{B}}+\dot{S}\_{Gen}$ (3)

This reduces to:

 $\dot{S}\_{Gen}=\frac{\dot{Q}\_{Out}}{T\_{B}}-\frac{\dot{Q}\_{In}}{T\_{B}}$ (4)

Now that we have an equation to calculate the entropy, it is possible to do the parametric study.

The first part of the parametric study will be to vary the heat out. This will be varied from 150kW to 720kW. The hot side is maintained at a constant 300K; the cold side is also at a constant 273K. The system has a net work input of 110kW.

After completing the calculations, the graph of the data can be seen below:

Figure 2. Entropy generation vs heat rejection.

As the chart shows, it is an extremely linear result. This is due the fact that the relationships that are changing are linear in nature. Because of this, it would be of interest to see how the entropy changes with changing boundary temperature.

The system is modeled as the same above, however the work, heat in, and heat out are all considered constant at 110kW, 150kW, and 50kW, respectively. For this parametric variance, first the hot temperature will be varied from 300 to 700K with a constant cold temperature of 273K. Then the hot temperature will be a constant 300K with the cold temperature varied from 273 to 3K.

When the hot temperature is varied:

Figure 3. Variance in the rejection temperature.

When the hot temperature side is varied, you notice that it is a nonlinear relationship between the hot side temperature and the entropy generation.

When the cold temperature is varied:

Figure 4. Variance in the inlet temperature.

Notice the difference in relationship between the temperature of the cold side and the hot side. The decrease in temperature of the cold side clearly has a huge effect on entropy generation as the temperature is decreased. This is due primarily to the inverse dependence on temperature.

The inverse dependence of the Entropy generation causes spikes in entropy generation as the temperature decreases on either side of the system. This effect is much larger than when the heat traversing the system is changing. Clearly, temperature control is of upmost importance in decreasing entropy generation.