ME/NSE 312 System Analysis Project

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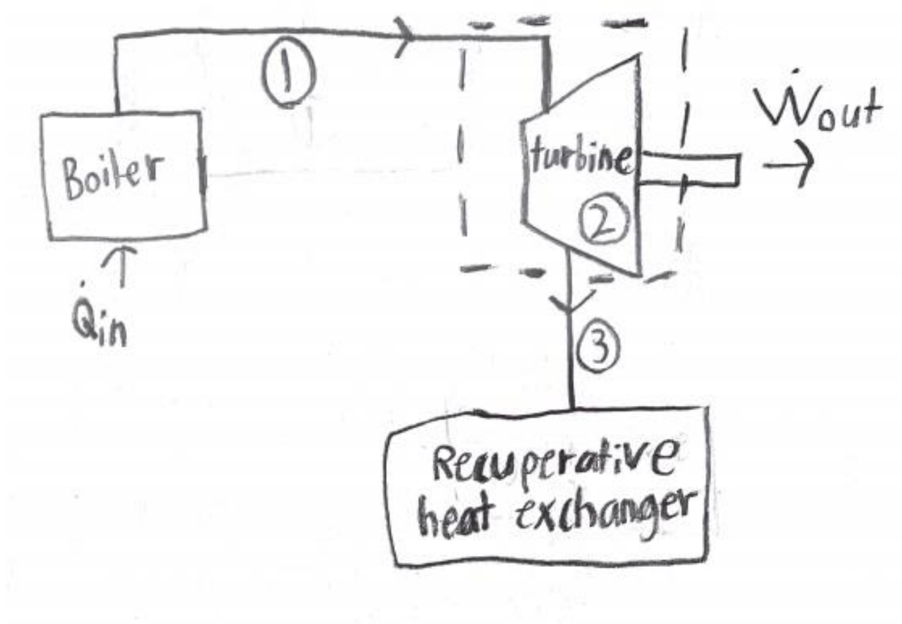
Part 1 Baseline Analysis Results [70 points total]

1. Turbine Analysis **[10 points]**
   a. Draw an appropriate control volume to calculate the turbine work out and rate of entropy generation.



   b. List all assumptions made in analyzing the turbine.

•Toluene is the working fluid (use fluid = 'toluene' in EES)
•Neglect Heat Transfer (adiabatic)
•Neglect Potential and Kinetic energy
•Steady state (mass in = mass out)
•Toluene treated as ideal gas

   c. Starting from the most general form of the 1st and 2nd law for a control volume that you know, simplify down to show the expression you will use in your code to calculate the turbine work. For the 1st law the general equation is given below:

$$\frac{dE}{dT} = \dot{Q} - \dot{W} + \sum \dot{m}i\left(hi + \frac{v^2 i}{2} + gzi\right) - \sum \dot{m}e\left(he + \frac{v^2 e}{2} + gze\right)$$

Simplify the 1st law:

$$\frac{dE}{dT} = \dot{Q} - \dot{W} + \dot{m}(h1 - h2)$$

To get isentropic turbine efficiency:

$$\eta = \frac{A}{S} = \frac{h1 - h3}{h1 - h2}$$

With given assumptions of steady state and adiabatic we can simplify the general form of the 1st law by crossing out kinetic, potential energy, and the change in energy get the simplified equation for the actual work of the turbine as.

$$\dot{W} = \dot{m}(h1 - h2) * \eta$$

Simplified equation for actual work of the turbine:

$$\dot{W} = \dot{m}(h1 - h2) * \frac{h1 - h3}{h1 - h2} = \dot{m}(h1 - h3)$$

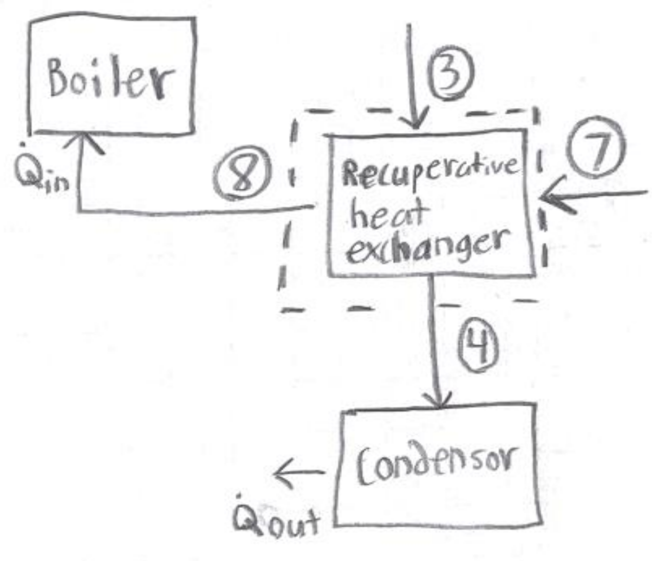
For the 2nd law the general equation is given below:

$$\frac{dS}{dT} = \sum_j \frac{Q}{T} + \sum_j \dot{m}isi - \sum_j \dot{m}ese + \dot{\sigma}$$

The simplified form of the second law to solve for entropy produced is given below:

$$\dot{\sigma} = \dot{m}(s_3 - s_1)$$

2. Regenerative HX **[10 points]**
   a. Draw an appropriate control volume to calculate the high pressure regenerative HX outlet enthalpy (State 8) and the rate of entropy generation within the regenerative HX.



b. List all assumptions made in analyzing the regenerative HX

- Steady state (mass in = mass out)
- Isothermal (adiabatic)
- Neglect pressure drop in all heat exchangers (Isobaric)
- Toluene treated as ideal gas
- Neglect Potential and Kinetic energy

c. Starting from the most general form of the 1st and 2nd law for a control volume that you know, simplify down to show the expression you will use in your code to calculate the enthalpy at state 8, and the rate of entropy generation.

Starting from the general equation of the 1st law:

$$\frac{dE}{dT} = \dot{Q} - \dot{W} + \sum \dot{m}i\left(hi + \frac{v^2 i}{2} + gzi\right) - \sum \dot{m}e\left(he + \frac{v^2 e}{2} + gze\right)$$

Simplify the 1st law:

$$\frac{dE}{dT} = \dot{Q} - \dot{W} + \dot{m}(h3 + h7) - \dot{m}(h4 + h8)$$

After simplifications are made based on assumptions the simplified equation looks like:

$$\dot{W} = \dot{m}(h3 + h7) - \dot{m}(h4 - h8)$$

The enthalpy at state 8 is equal to:

$$h8 = (h3 + h7) - h4$$

Starting from the general equation of the 2nd law:

$$\frac{dS}{dT} = \sum_j \frac{Q}{T} + \sum_j \dot{m}isi - \sum_j \dot{m}ese + \dot{\sigma}$$

Simplify the 2nd law:

$$0 = \dot{m}(s3 + s7) - \dot{m}(s4 + s8) + \dot{\sigma}$$

After simplifications are made based on assumptions the simplified equation looks like:

$$\dot{\sigma} = \dot{m}\,(s4 + s8 - s3 - s7)$$

3. Fill out following table with given units for the baseline case for quality, enter 100 if the state point is superheated vapor, and -100 if the state point is subcooled liquid. *Note, you may have negative values of enthalpy. This is OK. It is related to the reference used in EES. **[30 points]**

State	*T* (°C)	*P* (kPa)	*h* (kJ/kg)	s (kJ/kg-K)	*x*(-)
1	275	1665	612.2	1.258	100
2 (ideal)	165.7	32.82	450.4	1.258	100
3	194.1	32.82	498.9	1.365	100
4	75	32.82	314.8	0.9133	1
5	75	32.82	-68.96	-0.1883	0
6 (ideal)	75.44	1665	-66.96	-0.1883	-100
7	75.71	1665	-66.46	-0.1868	-100
8	166	1665	117.7	0.2811	-100

4. Show numerical values of following parameters in given units **[10 points]**:

1	Working fluid mass flow rate	g/s	4.514
2	Condenser heat duty	W	-1732
3	Boiler heat duty	W	2232
4	Turbine produced power	W	511.3
5	Pump consumed power	W	-11.29
6	Thermal efficiency of cycle	%	0.224
7	Rate of entropy generation in turbine	W/K	0.4837
8	Rate of entropy generation in regenerative heat exchanger	W/K	0.07317

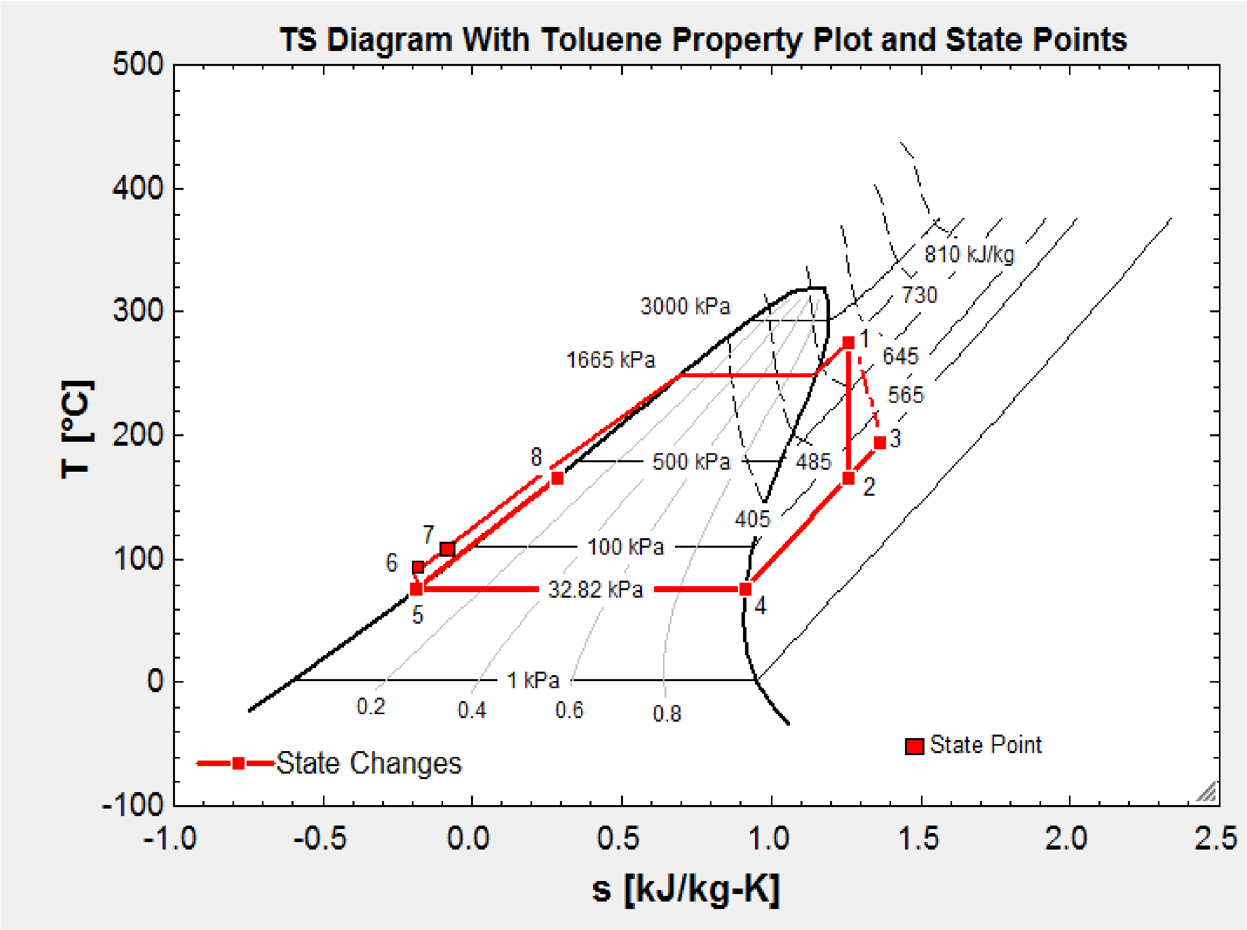
Unit Settings: SI C kPa kJ mass deg

η_P = 0.8	η_T = 0.7	$\dot{m}$ = 4.514 [g/s]	P_{high} = 1665 [kPa]	P_{low} = 32.82 [kPa]
Q_{boiler} = 2232 [W]	$Q_{condenser}$ = -1732 [W]	$\dot{\sigma}_{HX}$ = 0.07317 [W/K]	$\dot{\sigma}_T$ = 0.4837 [W/K]	$Thermal_{eff,cycle}$ = 0.224
T_{con} = 75 [C]	T_P = 250 [C]	W_{cycle} = 500 [W]	W_P = -11.29 [W]	W_T = 511.3 [W]

Click on this line to see the array variables in the Arrays Table window

No unit problems were detected.

5. Show the cycle on a *T*-*s* diagram overlaid on toluene property plot. Each state point should be labeled See the example on Canvas, as well as https://youtu.be/HRxRJU6orkE and for more information https://youtu.be/JcxX4SOjPho . It may be easier to only plot the state points, and then manually draw the connecting lines. **[10 points]**



Part 2 Parametric Analysis Results [20 points total]

6. Create a parametric table and generate a plot of the cycle thermal efficiency and condenser area versus the condenser saturation temperature varied from 0 degC to 200 degC. All other variables should be the same as the baseline analysis. Submit as a single plot, using two different y-axes to clearly show the data. The figure can be made in the plotting software of your choice. See the example on Canvas or https://youtu.be/G_xhgkAiw1Y for more information on parametric tables. **[20 points]**