ROSE-HULMAN Institute of Technology
Department of Mechanical Engineering

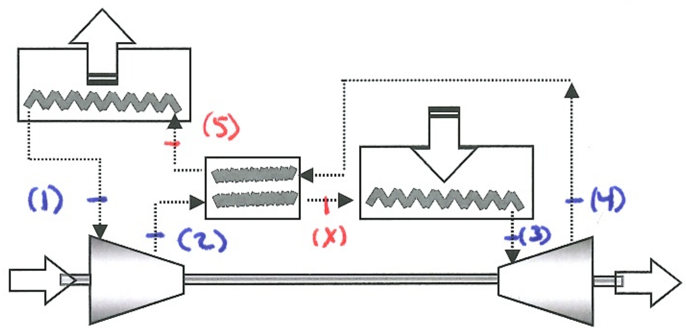
Example

Reconsider the **air-standard** Brayton cycle from the last example. The following conditions still apply: compressor inlet: 100 kPa, 300 K; turbine inlet: 1 MPa, 1300 K. Now add an **ideal regenerator** to the system.

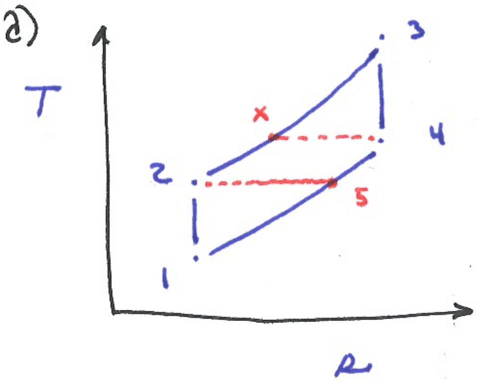
(a) Find the new heat transfer rate (per unit mass flow rate) into the high pressure heat exchanger and the new cycle efficiency.

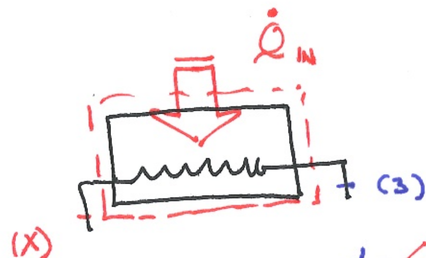
(b) Find the rate of entropy generation for the regenerator.

(c) Repeat (a) and (b) if $\eta_{regen} = 0.85$.



(a)





C.O.E. $\cancel{\frac{d}{dt}[E]} \rightarrow 0 = \dot{Q}_{IN} - 0 + \dot{m}(h_x + \ldots) - \dot{m}(h_3 + \ldots)$

$$q_{IN} = \frac{\dot{Q}_{IN}}{\dot{m}} = \overset{\checkmark}{h_3} - \overset{?}{h_x}$$

IDEAL REGENERATION $\longrightarrow h_x = h_4 \quad \therefore \quad q_{IN} = (1395.9 - 741.1)\ \frac{kJ}{kg}$

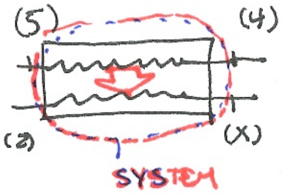
$$= \boxed{654.8\ kJ/kg}$$

$\dot{W}_c$ & $\dot{W}_T$ SAME AS BEFORE!

NOTE: SAME!

$$\eta = \frac{\dot{W}_{NET,OUT}}{\dot{Q}_{IN}} = \frac{w_{NET,OUT}}{q_{IN}} = \frac{654.8 - 279.2}{654.8} = \boxed{57.4\%}\ !!!$$

(b)

b) 

$$\frac{dS_{sys}}{dt} = \frac{\dot{Q}}{T_b} + \dot{m}(s_2) + \dot{m}_4 s_4 - \dot{m} s_x - \dot{m} s_5 + \dot{S}_{GEN}$$

$$\frac{\dot{S}_{GEN}}{\dot{m}} = (s_x - s_2) + (\overset{?}{s_5} - s_4)$$

WHAT IS s_5? C.O.E.: $\cancel{\frac{dE}{dt}} = \cancel{\dot{Q}} + \cancel{\dot{W}} + \dot{m} h_2 + \dot{m} h_4 - \dot{m} h_x - \dot{m} h_5$

$$h_2 = h_5 \Rightarrow T_2 = T_5$$

SO:

$$\frac{\dot{S}_{GEN}}{\dot{m}} = \left(s^\circ_{T_x} - s^\circ_{T_2} - R \ln \frac{P_x}{P_2} \right) + \left[\left(s^\circ_{T_5} - s^\circ_{T_4} \right) + R \ln \frac{P_5}{P_4} \right]$$

$$\frac{\dot{S}_{GEN}}{\dot{m}} = 0!$$ OF COURSE! ITS IDEAL!

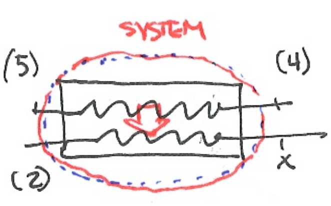
c) $$\eta_{REG} = \frac{h_x - h_2}{h_4 - h_2} = 0.85$$

$$h_x = 0.85(h_4 - h_2) + h_2 = 0.85(741.1 - 579.2) + 579.2$$

$$= 716.8 \text{ kJ/kg}$$ $\rightarrow T_x = 703.3\text{K}$ $s^\circ_{Tx} = 2.57779$

$$q_{IN} = 1395.9 - 716.8 = 679.1 \text{ kJ/kg}$$

$$\eta = \frac{-(279.2 - 654.8)}{679.1} = \boxed{55.3\%}$$ STILL NOT TO SHABBY!



$$\cancel{\frac{dE}{dt}} = \cancel{\dot{Q}} + \cancel{\dot{W}} + \dot{m}(h_2) + \dot{m}(h_4) - \dot{m} h_x - \dot{m} h_5$$

$$h_5 = h_2 + h_4 - h_x =$$

$$= 579.2 + 741.1 - 716.8 = 603.5$$

$$\Rightarrow T_5 = 596.6 \text{ K}$$

$$s^\circ_{T_5} = 2.40311$$

$$\frac{\dot{S}_{GEN}}{\dot{m}} = \left(s^{\circ}_{Tx} - s^{\circ}_{T2} - R \ln \frac{P_x}{P_2}\right) + \left(s^{\circ}_{T5} - s^{\circ}_{T4} - R \ln \frac{P_5}{P_4}\right)$$

$$= (2.57779 - 2.3615) + (2.40311 - 2.6117)$$

$$= \boxed{0.0077 \text{ kJ/kg-K}}$$

$$\dot{A}_{DES} = T_0 \dot{S}_{gen}$$

$$= 2.31 \text{ kJ/kg}$$