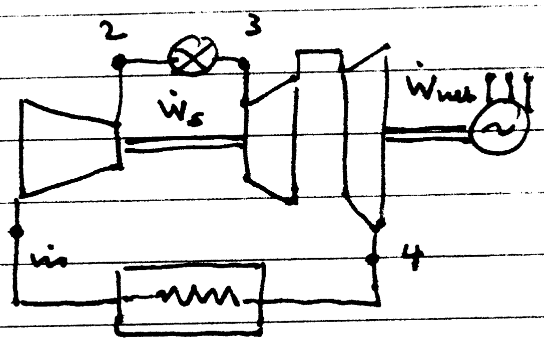
T15 16. Unified Fall 07

a)



$T_3 = 1500\,K$, $P_3 = 17\,bar$, $P_4 = 1\,bar$

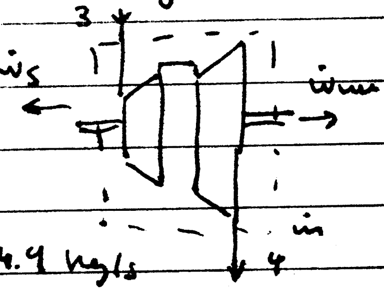
$T_1 = 280\,K$ $P_1 = 1\,bar$

$\gamma_c = 1.4$, $\gamma_T = 1.3$, $R = 287\,J/kg\text{-}K$

neglect ΔKE, ΔPE, and $\dot{m}_{fuel}$

$\dot{W}_s + \dot{W}_{net} = 470\,MW$

b) $\dfrac{T_4}{T_3} = \left(\dfrac{P_4}{P_3}\right)^{\frac{\gamma_T - 1}{\gamma_T}}$, 1st law:

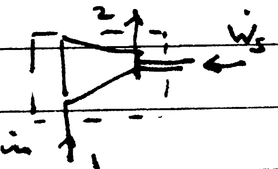


$0 = \dot{m}(h_3 - h_4) - \dot{W}_s - \dot{W}_{net}$

$c_{pT} = 1243.7\,J/kg\text{-}K$

$$\dot{m} = \frac{\dot{W}_s + \dot{W}_{net}}{c_{pT} T_3 \left(1 - \left(\frac{P_4}{P_3}\right)^{\frac{\gamma_T - 1}{\gamma_T}}\right)}, \quad \underline{\dot{m} = 524.9\,kg/s}$$

c) 1st law



$0 = \dot{m}(h_1 - h_2) + \dot{W}_s$, $\dfrac{T_2}{T_1} = \left(\dfrac{P_2}{P_1}\right)^{\frac{\gamma_c - 1}{\gamma_c}}$

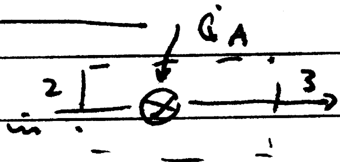
$c_{pc} = 1004.5\,J/kg\text{-}K$

$T_2 = 628.1\,K$

$$\dot{W}_s = \dot{m} c_{pc} T_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma_c - 1}{\gamma_c}} - 1\right], \quad \underline{\dot{W}_s = 184.1\,MW}$$

d) $\dot{W}_{net} = 470\,MW - \dot{W}_s$, $\underline{\dot{W}_{net} = 285.9\,MW}$

e) $\eta_{th} = \dfrac{\dot{W}_{net}}{\dot{Q}_A} = \dfrac{\dot{W}_{net}}{\dot{m}(c_{pT} T_3 - c_{pc} T_2)}$

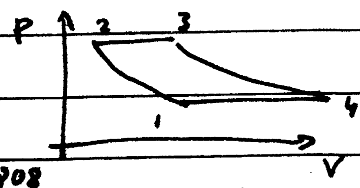


$0 = \dot{Q}_A + \dot{m}(h_2 - h_3)$

$\underline{\eta_{th} = 0.44}$

f) 1st law: $w_{net} = q_A - q_R = h_3 - h_2 - (h_4 - h_1) = c_{pT}(T_3 - T_4) - c_{pc}(T_2 - T_1)$

$\dfrac{dw_{net}}{dT_2} = 0 = -c_{pT}\dfrac{dT_4}{dT_2} - c_{pc}$ so $\dfrac{dT_4}{dT_2} = -\dfrac{c_{pc}}{c_{pT}}$



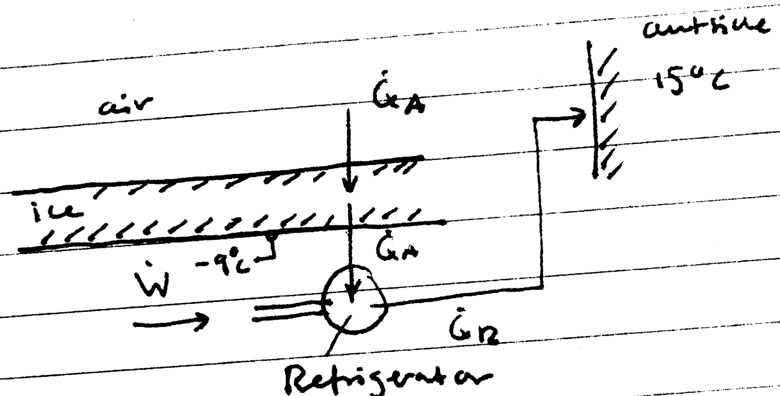
ad.-rev. processes 2-1 and 3-4 same PR

$\left(\dfrac{T_4}{T_3}\right)^{\gamma_T/(\gamma_T - 1)} = \left(\dfrac{T_1}{T_2}\right)^{\frac{\gamma_c}{\gamma_c - 1}}$ $T_4 = T_3\left(\dfrac{T_1}{T_2}\right)^{\frac{\gamma_c}{\gamma_c - 1}\frac{\gamma_T - 1}{\gamma_T}}$ $K = 0.808$

$\dfrac{dT_4}{dT_2} = -K T_3 T_1^{K} T_2^{-K-1} \Rightarrow -\dfrac{c_{pc}}{c_{pT}}$; $T_2\Big|_{\substack{max\\power}} = \left(\dfrac{c_{pT}}{c_{pc}} K T_3 T_1^{K}\right)^{\frac{1}{K+1}} = 708.6\,K$ $\underline{\Pi_{\substack{max\\power}} = \left(\dfrac{T_2}{T_1}\right)^{\frac{\gamma_c}{\gamma_c - 1}}_{\substack{max\\power}} = 25.8}$

16. Unified Fall 07

T16



$\dot{Q}_A = 400$ kW

el. power cost: \$0.02/kWh

a) minimum cost → min. required power → carnot refrig.

$$COP_R^c = \frac{\dot{Q}_A}{\dot{W}} = \frac{\dot{Q}_A}{\dot{Q}_R - \dot{Q}_A} = \frac{T_A}{T_R - T_A} = 11$$

so $\dot{W} = (COP_R^c)^{-1} \dot{Q}_A = 36.4$ kW

Cost for 24 hrs : <u>Cost</u> $= 0.02 \cdot \dot{W} \cdot 24$ <u>= \$17.5 / day</u>

b) as T_R decreases, COP_R^c increases → less work required

so expect operating cost to <u>decrease</u>
(need more cooling power for hot days)