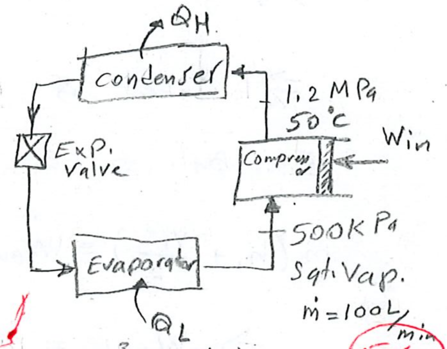
SFU

MSE-321 – Thermodynamics and Heat Transfer

Quiz 2- Nov.,10th, 2017

Student Name: **Student Number:**

1- An air-conditioner with refrigerant-134a as the working fluid is used to keep a room at 26°C by rejecting the waste heat to the outdoor air at 34°C. The room gains heat through the walls and the windows at a rate of 250 kJ/min while the heat generated by the computer, TV, and lights amounts to 900 W. The refrigerant enters the compressor at 500 kPa as a saturated vapor at a rate of 100 L/min and leaves at 1200 kPa and 50°C. Determine:
(a) the actual COP,
(b) the maximum COP, and
(c) the minimum volume flow rate of the refrigerant at the compressor inlet for the same compressor inlet and exit conditions. (Score 50) (7-113)



Given: R134-a, $T = 26°C = 299\,°K$,
$\dot Q = 250\ \text{kJ/min}$, $\dot Q_{equipment} = 0.9\ \text{kW}$, $\dot m_{in} = 100\ \text{L/min}$

(a) Table A-12 ⇒ for $P_1 = 500\ \text{kPa}$, $X_1 = 1$ ⇒ $h_g = 259.30\ \text{kJ/kg}$, $v_g = 0.041118\ \text{m}^3/\text{kg}$ 5/50

Table A-13 for $P_2 = 1.2\ \text{MPa}$, $T_2 = 50°C$ ⇒ $h_2 = 278.27\ \text{kJ/kg}$

mass flow rate for refrigerant ⇒ $\dot m_R = \dfrac{\dot V_1}{v_1} = \dfrac{(100\ \text{L/min})\left(\frac{1\ \text{m}^3}{1000\ \text{L}}\right)\left(\frac{1\ \text{min}}{60\ \text{s}}\right)}{0.041118} = 0.04053\ \text{kg/s}$ 5/50

Power Consumption of the compressor: $\dot W_{in} = \dot m_R (h_2 - h_1) = (0.04053)(278.27 - 259.30)$ kg/s, kJ/kg

$\dot W_{in} = 0.76885\ \text{kW}$ 5/50

The heat gains to the room must be rejected by the air-conditioner.

So ⇒ $\dot Q_L = \dot Q_{heat} + \dot Q_{equipment} = \left(250\ \frac{\text{kJ}}{\text{min}}\right)\left(\frac{1\ \text{min}}{60\ \text{sec}}\right) + 0.9\ \text{kW} = 5.0667\ \text{kW}$ 5/50

The actual COP ⇒ $COP = \dfrac{\dot Q_L}{\dot W_{in}} = \dfrac{5.0667}{0.76885\ \text{kW}} = 6.5899 \simeq 6.59$ Ans. a 5/50

(b) COP of a reversible Refr. operating between the same temp:

$$COP_{max} = \frac{1}{\frac{T_H}{T_L} - 1} = \frac{1}{\left(\frac{34+273}{26+273}\right) - 1} = 37.375$$ Ans. b 5/50

(c) The minimum power input to the comp. for the same refrigeration load is:
$$\dot W_{in,min} = \frac{\dot Q_L}{COP_{max}} = \frac{5.0667}{37.375} = 0.13556\ \text{kW}$$ 10/50

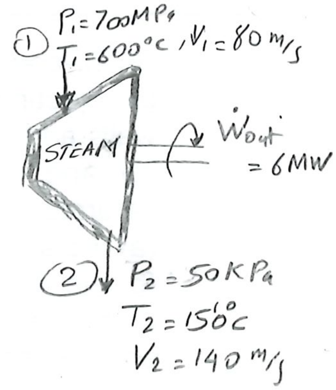
Min mass flow rate is: $\dot m_{R\,min} = \dfrac{\dot W_{in\ min}}{h_2 - h_1} = \dfrac{0.13556}{(278.27 - 259.30)} = 0.007146\ \text{kg/s}$

Min flow rate: $\dot V_{min} = \dot m_{R\,min} = (0.007146\ \text{kg/s})(0.041118)\ \text{m}^3/\text{kg} = 0.000294\ \text{m}^3/\text{s}$

10/50 $\dot V_{min} = 17.6298\ \text{L/min} \simeq 17.63\ \text{L/min}$

(See back of the page)

2- Steam enters an adiabatic turbine at 7 MPa, 600°C, and 80 m/s and leaves at 50 kPa, 150°C, and 140 m/s. If the power output of the turbine is 6 MW, determine:
(a) the mass flow rate of the steam flowing through the turbine and,
(b) the isentropic efficiency of the turbine. (Score 50) (8-132)



Given: Fig with data indicated

Find: $\dot{m}$ & η_T , Assumption: steady, No PE,

(a) From table A-6 $\begin{cases} P_1 = 7 MPa \\ T_1 = 600°c \end{cases} \Rightarrow \begin{array}{l} h_1 = 3650.6 \, kJ/kg \\ s_1 = 7.0910 \, kJ/kg \end{array}$

Again table A-6 $\begin{cases} P_2 = 50 \, kPa = 0.05 \, MPa \\ T_2 = 150°c \end{cases} \Rightarrow h_2 = 2780.2 \, kJ/kg$ 10/50

$\Rightarrow$ 1 inlet & 1 outlet $\Rightarrow \dot{m}_1 = \dot{m}_2 = \dot{m}$

En. Bal. $\Rightarrow \dot{E}_{in} - \dot{E}_{out} = \Delta \dot{E}_{sys} = 0$ since steady. $\Rightarrow \dot{E}_{in} = \dot{E}_{out}$.

$$\dot{m}\left(h_1 + \frac{V_1^2}{2}\right) = \dot{W}_{out} + \dot{m}\left(h_2 + V_2^2/2\right) \quad \Delta PE = 0. = \dot{Q} \rightarrow \text{adiab.}$$

$$\Rightarrow -\dot{W}_{out} = \dot{m}\left(h_2 + \frac{V_2^2}{2} - h_1 - \frac{V_1^2}{2}\right) = \dot{m}\left(h_2 - h_1 + \frac{V_2^2 - V_1^2}{2}\right)$$

$$-6000 \frac{kJ}{s} = \dot{m}\left(2780.2 - 3650.6 + \frac{(140 \, m/s) - (80 \, m/s)^2}{2} \times \frac{1 \, kJ/kg}{1000 \, m^2/s^2}\right)$$

$\Rightarrow \dot{m} = 6.944 \, kg/s$ 10/50

Ans.

b) The isentropic exit enthalpy & the power output of the isentropic turbine are:

$$\left.\begin{array}{l} P_{2s} = 50 \, kPa \\ s_{2s} = s_1 \end{array}\right\} \Rightarrow x_{2s} = \frac{s_{2s} - s_f}{s_{fg}} = \frac{7.0910 - 1.0912}{6.5019}$$

$\rightarrow s_f$ @ $P_{2s} = 50 \, kPa$

$\rightarrow s_{fg}$ @ $P_{2s} = 50 \, kPa$

$\Rightarrow x_{2s} = 0.9228$ 5/50

$$\Rightarrow h_{2s} = h_f + x_{2s} h_{fg} = 340.54 + (0.9228)(2304.7) = 2467.3 \, kJ/kg$$ 5/50

$$\dot{W}_{s\,out} = -\dot{m}\left(h_{2s} - h_1 + \frac{V_2^2 - V_1^2}{2}\right) = -\left(6.95 \, \frac{kg}{s}\right)\left(2467.3 - 3650.9 + \frac{140^2 - 80^2}{2} \times \frac{1 \, kJ/kg}{1000 \, m^2/s^2}\right)$$ 10/50

$= 8174 \, kW$

$\Rightarrow$ Isentropic Eff of Turbine:

$$\eta_T = \frac{\dot{W}_{actual}}{\dot{W}_s} = \frac{6000 \, kW}{8174 \, kW} = 0.734 = 73.4\,\%$$ 10/50

Good Luck. Sam Behfarshad