Name, Surname:
No:

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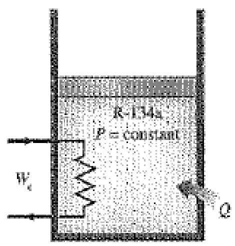
Fall 2015

Çankaya University
Faculty of Engineering
Mechanical Engineering Department
ME 211 Thermodynamics I
Closed Notes and Books

26.12.2015

Show all steps of your work to get partial credit

1)A mass of 12 kg of saturated refrigerant-134a vapor is contained in a piston–cylinder device at 240 kPa. Now 300 kJ of heat is transferred to the refrigerant at constant pressure while a 110-V source supplies current to a resistor within the cylinder for 6 min. Determine the current supplied if the final temperature is 70 °C. Also, show the process on a *T-v* diagram with respect to the saturation lines.



closed system $\Delta KE=\Delta PE=0$

$Q-W=m(u_2-u_1)$

$Q-W_e-W_b=m(u_2-u_1)$

$W_b=\int_1^2 p\,dV = mp(v_2-v_1)=m(P_2v_2-P_1v_1)$

so

$Q-W_e=m(h_2-h_1)$ $\qquad W_e=VI\Delta t$

$P_1=240\,kPa=2{,}4\,bar$, $x_1=1$ $\Big]$ $h_1=h_g=244.09\,kJ/kg$

$P_2=240\,kPa$, $T_1=70°C$ $\Big]$ $h_2=313{,}49\,kJ/kg$

$W_e=Q-m(h_2-h_1)=300-12(313{,}49-244.09)$
$=-532{,}8\,kJ$ ⇐ work done on system

$I=(532{,}8)10^3/[(110)(6min)(\frac{60s}{min})]=13{,}45\,A$

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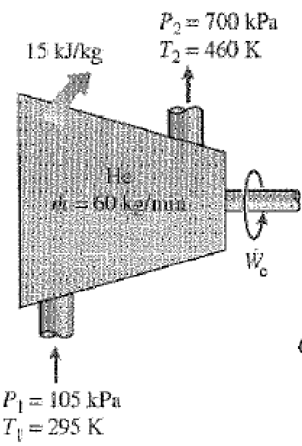
2) Helium is to be compressed from 105 kPa and 295 K to 700 kPa and 460 K. A heat loss of 15 kJ/kg occurs during the compression process. Neglecting kinetic and potential energy changes, determine the power input required for a mass flow rate of 60 kg/min. Assume that Helium is ideal gas and the constant pressure specific heat of helium is $c_p = 5.1926\,\mathrm{kJ/kg.K}$. Do not use Tables.



SSSF
$\Delta KE = 0 \quad \Delta PE = 0$
$\dot{m} = 60\ \mathrm{kg/min} = 1\ \mathrm{kg/s}$
$q = 15\ \mathrm{kJ/kg}$

$$\dot{Q}_{cv} - \dot{W}_{cv} = \dot{m}(h_2 - h_1)$$

$$\dot{W}_c = \dot{Q}_{cv} - \dot{m}(h_2 - h_1) = \dot{m}q - \dot{m}(h_2 - h_1)$$
$$= (\dot{m}q) - \dot{m}c_p(T_2 - T_1)$$
$$= \left(60\,\frac{\mathrm{kg}}{\mathrm{min}}\right)\left(\frac{\mathrm{min}}{60\,\mathrm{s}}\right)\left[-15\,\frac{\mathrm{kJ}}{\mathrm{kg}} - \underbrace{5.1926}_{\frac{\mathrm{kJ}}{\mathrm{kg\,K}}}\underbrace{(460 - 292)}_{\mathrm{K}}\right]$$
$$= -871\ \mathrm{kW}$$

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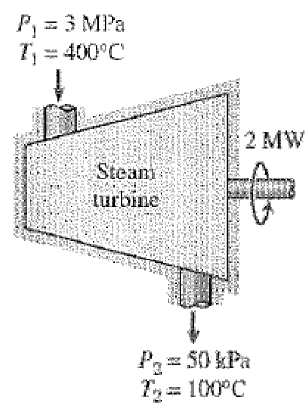
3) Steam enters an adiabatic turbine steadily at 3 MPa and 440 ^{0}C and leaves at 100 kPa and 100 ^{0}C. If the power output of the turbine is 2 MW, determine:
(*a*) the isentropic efficiency of the turbine
(*b*) the mass flow rate of the steam flowing through the turbine.
(c) entropy generation rate within the turbine
(d) show the process on a T-S diagram with respect to saturation lines



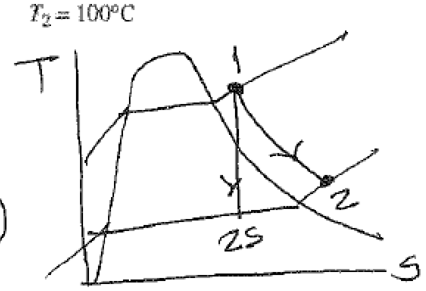
SSSF $\Delta KE = 0$ $\Delta PE = 0$

$$\left.\begin{array}{l} P_1 = 30 \text{ bar} \\ T_1 = 440°C \end{array}\right] \begin{array}{l} h_1 = 3321.5 \text{ kJ/kg} \\ s_1 = 7.0520 \text{ kJ/kg K} \end{array}$$

$$\left.\begin{array}{l} P_2 = 1 \text{ bar} \\ T_2 = 100°C \end{array}\right] \begin{array}{l} s_2 = 7.3614 \text{ kJ/kg} \\ h_2 = 2676.2 \text{ kJ/kg} \end{array}$$

(2s)

(d)



$P_{2s} = 1$ bar
$s_{2s} = s_1 = 7.052$ kJ/kg
$s_g = 7.3594$ kJ/kg
$s_f = 1.3026$ kJ/kg

$$7.052 = 1.3026 + x_{2s}(7.3594 - 1.3026) \quad x_{2s} = 0.949$$

$$h_{2s} = h_f + x_{2s} h_{fg} = 417.46 + 0.949\,(2258) = 2560.3 \ \frac{\text{kJ}}{\text{kg}}$$

$$\eta_t = \frac{(\dot{W})}{(\dot{W}_s)} = \frac{h_1 - h_2}{h_1 - h_{2s}} = \frac{(3321.5 - 2676.2)}{(3321.5 - 2560.3)} = 0.84$$

$$b)\ -\dot{W}_t = \dot{m}(h_2 - h_1) \Rightarrow \dot{m} = \frac{-(2000 \text{ kJ/s})}{2676.2 - 3321.5} = 3.09 \text{ kg/s}$$

$$c)\ \dot{\sigma} = \dot{m}(s_2 - s_1) = (3.09)(7.3614 - 7.052) = 0.95 \ \frac{\text{kJ}}{\text{K}}$$