

6.4

(a)

first law  
 $Q = \Delta U + W \Rightarrow W_{\text{by nitrogen}} = Q - \Delta U$

$$\Rightarrow W_{\text{on nitrogen}} = -\Delta U - Q \quad \text{--- (a)}$$

$$Q_{\text{to nitrogen}} = \frac{m(s_2 - s_1)}{T}$$

from Nitrogen table,  $s_1 = 6.8418 \text{ kJ/kg K}$

$$s_2 = 5.1630 \text{ kJ/kg K}$$

$$Q_{\text{to Nitrogen}} = 2 \times (5.163 - 6.8418) \text{ kJ} \quad \text{--- (b)}$$

$$\Delta U = u_2 - u_1 = (h_2 - p_2 v_2) - (h_1 - p_1 v_1)$$

from Nitrogen table

$$u_2 - u_1 = (279.01 - 2000 \times 0.004704)$$

$$= (279.01 - 2000 \times 0.004704)$$

$$- (311.163 - 101.325 \times 0.878604)$$

from (a), (b) & (c)

$$W_{\text{on Nitrogen}} = \left( -\frac{m(s_2 - s_1)}{T} + (u_2 - u_1) \right) \quad \text{--- (c)}$$

$$= +932.864 \text{ kJ}$$

$$(b) \quad Q_{\text{to Nitrogen}} = mT(s_2 - s_1) = 2 \times 300(5.163 - 6.8418)$$

$$= -1007.28 \text{ kJ}$$

$$(c) \quad \Delta S_{\text{total}} = \Delta S_{\text{steam}} + \Delta S_{\text{HR}} \quad \text{--- heat rejected to surroundings}$$

$$= m(s_2 - s_1) + \frac{Q_{\text{HR}}}{T_{\text{HR}}}$$

$$T_{\text{HR}} = 300 \text{ K}$$

$$= \text{gas temp.} = T_{\text{gas}}$$

Hence process is overall reversible

$$= m(s_2 - s_1) + (-Q_{\text{to Nitrogen}})$$

$$= m(s_2 - s_1) + \left( -\frac{m(s_2 - s_1)T_{\text{gas}}}{T_{\text{HR}}} \right)$$

$$\Delta S_{\text{total}} = 0$$



If we consider Nitrogen gas as system, then work is being done (Compression) in quasi-static mode, hence process is internally reversible. Further temp of gas = temp of environment. so very very small amount of heat will go to surrounding throughout the process. Hence process is also externally reversible.

$$(1.01 - 1) - (1.01 - 1) = 1.01 - 1.01 = 0$$

$$W = P \Delta V$$

$$(1.01 \times 10^5 \times 0.00005 - 1.01 \times 10^5 \times 0.00005) = 0$$

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$$\Delta U = n C_v \Delta T = \frac{P_2 V_2 - P_1 V_1}{\gamma - 1}$$

$$Q = \Delta U + W = n C_p \Delta T = \frac{P_2 V_2 - P_1 V_1}{\gamma - 1}$$

$$\Delta U = 1000 \times 0.00005 = 0.05$$

$$\Delta U + W = 0.05 + 0.05 = 0.1$$

$$T_2 = 800K$$

$$T_2 = T_1 + \frac{P_2 V_2 - P_1 V_1}{n R}$$

Since process is reversible, temp of gas is equal to environment temp, hence heat rejected to environment is reversible.