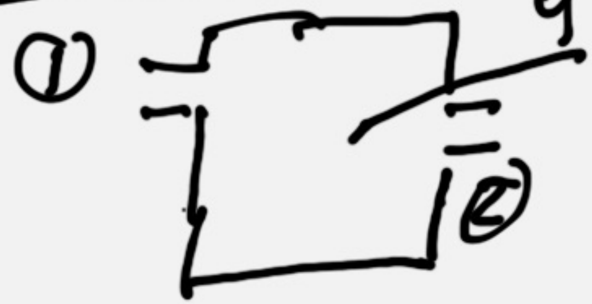
li 3002 | 2nd law for control volumes



isentropic (adiabatic and reversible) and S.E.E.

then $s_2 = s_1$

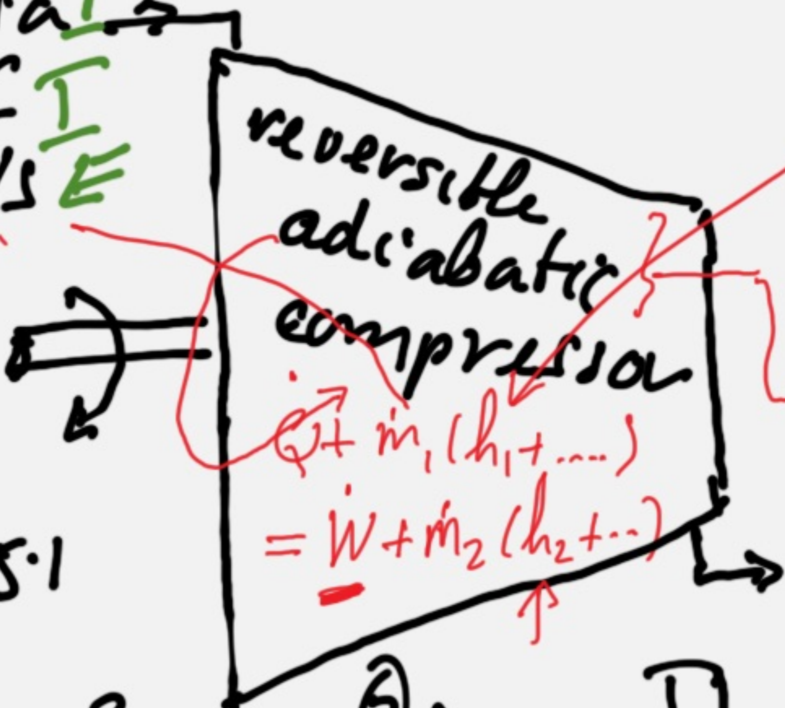
R134a ①

150kPa I

−10°C I

0.1kg/s E

$\dot{W}_{in}$?



②

$s_2 = s_1$ I

1MPa I

0.1kg/s E

→ B.5.1

Solution

phase of ①

B.5.2 @ 150 kPa, −10°C.

$h_1 = 393.84 \quad s_1 = \underline{1.7606} = s_2$

B.5.2 @ 1 MPa 1.7606 kJ/kg K

kJ/kg K $\qquad$ kJ/kg

$h = d \qquad s \qquad s_1 = 1.7494 \qquad d_1 = 431.24$

$s_2 = 1.7818 \qquad d_2 = 441.89$

$$h_2 = d = d_1 + \frac{s - s_1}{s_2 - s_1}(d_2 - d_1)$$

$h_2 = 434.92$ kJ/kg

$\dot{W} = 4.108 \frac{kJ}{s} = 4.108$ kW

2nd case : isothermal + S.E.E
+reversible

$q = T(s_2 - s_1)$

→ single enhance
single exit

$q = \dot{Q}/\dot{m}$ (heat added per kg going through)

Example

$\dot{Q} + \dot{m}(h_1 + \cancel{\frac{1}{2}Vel_1^2} + \cancel{gZ_1}) = \dot{W} + \dot{m}(h_2 + \cancel{\frac{1}{2}Vel_2^2} + \cancel{gZ_2})$

0.5 kg/s E
2000 kPa (1) I
300 K I

air expander
isothermal
reversible
ΔPE, ΔKE ~ 0

$\dot{W}$

(2) 400 kPa I
0.5 kg/s E
300 K I

asked : $\dot{Q}$, $\dot{W}$

$q = T(s_2 - s_1)$ $\dot{Q} = \dot{m} q$

Solution

$$s_2 - s_1 = \underbrace{s^o_{T_2} - s^o_{T_1}}_{c_p \ln \frac{T_2}{T_1}} - R \ln \frac{P_2}{P_1}$$

$$\dot{Q} = \dot{m}\, T\, (s_2 - s_1)$$

0.287 kJ/kg K

A.5

$$= \dot{m}\, T \left(\cancel{s^o_{T_2}} - \cancel{s^o_{T_1}} - R \ln \frac{P_2}{P_1} \right)$$

P_2 = 400 kPa

P_1 = 2000 kPa

$\dot{m}$ = 0.5 kg/s

T = 300 K

$$= 69.29 \text{ kJ/s} = 69.29 \text{ kW}$$

$$\dot{W} = \dot{Q} + \dot{m}\,(\cancel{h_1} - \cancel{h_2}) = 69.29 \text{ kW}$$

3th case : general S.E.E. (with heat addition at a single temperature)

$$\boxed{\underbrace{\dot{m}(s_2 - s_1)}_{\text{net entropy out}} = \frac{\dot{Q}}{T_{surr}} + \dot{S}_{gen}}$$

$\dot{S}_{gen}$ ↓

$\dot{S}_{gen} > 0$ irreversible

$\dot{S}_{gen} = 0$ reversible

Example $\dot{Q}_{in} = -8.5\,kW$

1.5 kg/s SHV
2MPa
350°C (1)
50 m/s
Z=6m

steam turbine

$\dot{Q} + \dot{m}\left(h_1 + \frac{1}{2}Vel_1^2 + gZ_1\right)$

$= \dot{W} + \dot{m}\left(h_2 + \frac{1}{2}Vel_2^2 + gZ_2\right)$

$\dot{m}(s_2 - s_1) = \dot{Q}/T_{surr} + \dot{S}_{gen}$

$\dot{W}$

2
$P_2 = 0.1\,MPa$
$x_2 = 100\%$ SAV
100 m/s
Z = 3 m

Asked: is this possible
↳ $\dot{S}_{gen} > 0$?

Book $\dot{W}$, (1) is SHV

B.1.3 @ 2MPa 350°C $s_1 = 6.9562$
B.1.2 @ 0.1MPa SAV $s_2 = s_g = 7.3593$

$$\dot{m}(s_2 - s_1) = \frac{\dot{Q}}{T_{surr}} + \dot{S}_{gen}$$

Temperature at which heat is added

$$\dot{S}_{gen} = \dot{m}(s_2 - s_1) - \frac{\dot{Q}}{T_{surr}}$$

$$= \underbrace{1.5\,\text{kg/s}\,(7.3593 - 6.9562) + \frac{8.5\,\text{kW}}{T_{surr}}}_{\text{always}}$$

Possible

$$du = \frac{\partial u}{\partial T} dT + \frac{\partial u}{\partial v} dv$$

$$T\,ds = du + P\,dv$$

$$ds = \frac{\partial s}{\partial T} dT + \frac{\partial s}{\partial v} dv$$

$$ds = \frac{1}{T}\frac{\partial u}{\partial T} dT + \left(\frac{1}{T}\frac{\partial u}{\partial v} + \frac{P}{T}\right) dv$$

$$\frac{\partial}{\partial v}\frac{\partial s}{\partial T} = \frac{\partial}{\partial T}\frac{\partial s}{\partial v}$$

$$\boxed{\left(\frac{\partial u}{\partial v}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_v - P}$$

for I.G.

$$\frac{\partial u}{\partial v} = 0 \rightarrow u = u(T)$$

$$h = u + Pv$$

$$\downarrow$$

$$RT$$