

Second law for a C.M. (cond. solids, liquids, T.C. (constant)) 3/31 2

$$\begin{cases} \text{isenthalpic} : s_2 = s_1 \\ \text{isothermal reversible} : q_2 = T(s_2 - s_1) \\ \text{general} : s_2 - s_1 = s_2 - s_1 - \frac{q_2}{T_{sur}} \end{cases}$$

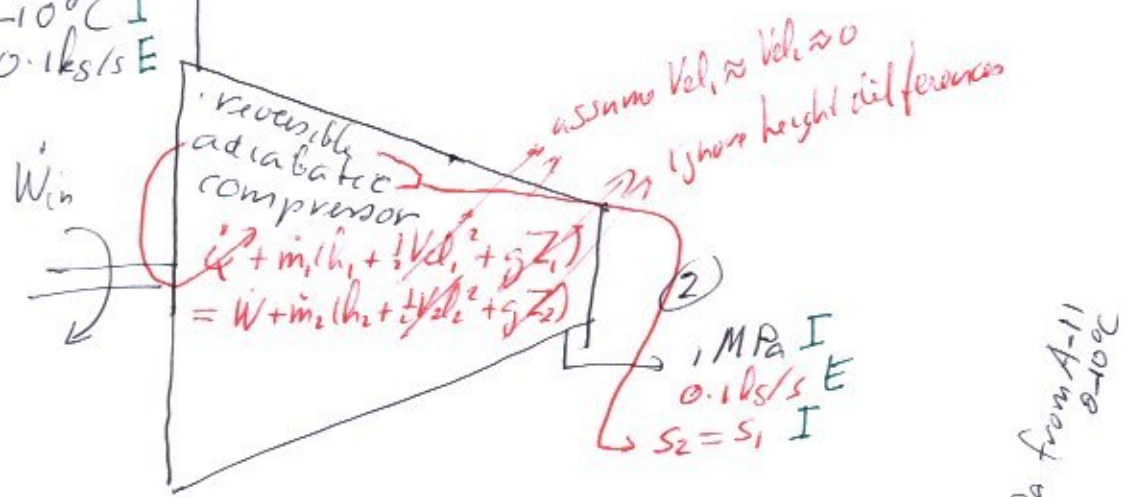
Second law for a C.V. (S.D. 12, 9.1, 9.2)

a) isentropic := adiabatic + reversible

$s_e = s_i$
if <u>adiabatic + reversible</u> + <u>single entrance and exit</u>
isentropic <span style="float: right;">SEE</span>

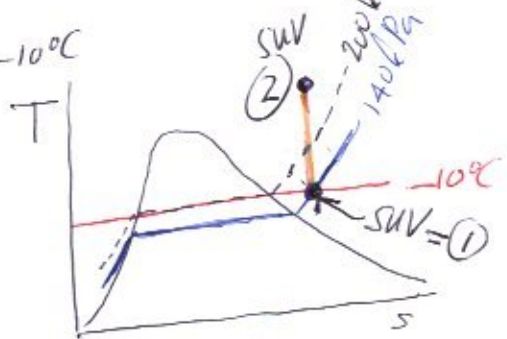
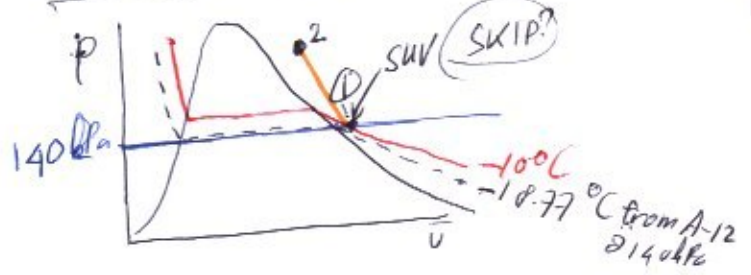
CENDEL VERSION  
 Example (Gensel) Given: in black:

R134a  
 ① 140 kPa I  
 -10°C I  
 0.1 ks/s E



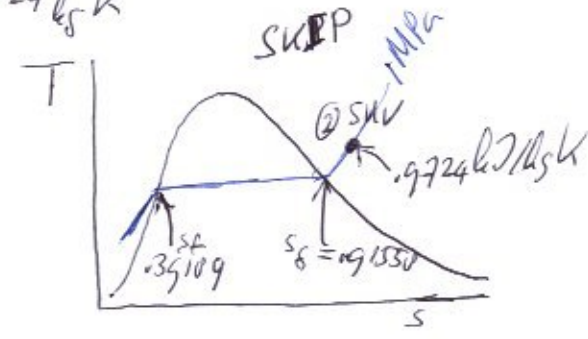
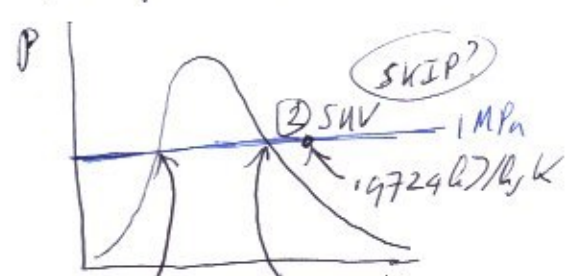
Asked:  $\dot{W}_{in}$ ,  $P_2$ ,  $T_2$

Solution: Find phase of ①, 140 kPa, -10°C



Use A-13 @ 140 kPa = 0.14 MPa and -10°C  
 $v_1 = 0.14605 \frac{m^3}{kg}$   $h_1 = 246.36 \frac{kJ}{kg}$   $s_1 = 0.9724 \frac{kJ}{kg \cdot K} = s_2$

Find phase of ②, 1 MPa,  $s_2 = 0.9724 \frac{kJ}{kg \cdot K}$



$s_f = 0.39189$   $s_g = 0.91558$   $\frac{kJ}{kg \cdot K}$  from A-17  
 @ 1000 kPa = 1 MPa

Use A-13 @ 1 MPa, and  $s = 0.9724$  (interpolated)

$g = 0.9724$   $g_1 = 0.9525$   $g_2 = 0.985$   $h_2 = d = d_1 + \frac{g_2 - g_1}{g_2 - g_1} (d_2 - d_1) = 289.25 \frac{kJ}{kg}$   
 $h = d$   $d_1 = 282.79$   $d_2 = 293.38$   
 1st law:  $\dot{W}_{in} = -\dot{W} = \dot{m}(h_2 - h_1) = 4.289 \frac{kJ}{kg} \frac{kg}{s} = 4.289 \text{ kW}$

Second law for C.V. (continued)

b) isothermal:

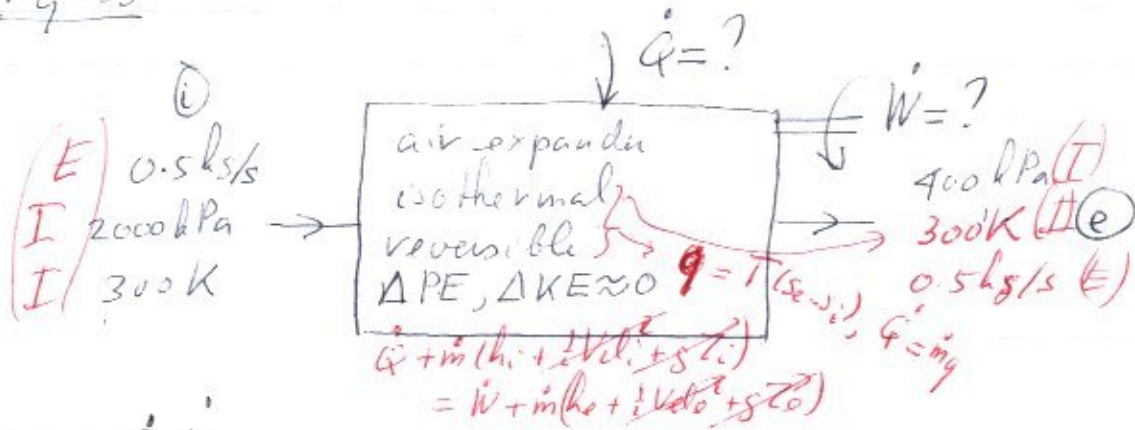
$$q = T (s_e - s_i)$$

if isothermal + reversible + SEE

↓  
Single entrance  
Single exit

$$(\dot{Q} = \dot{m}q)$$

Pg. 33



Asked  $\dot{Q}, \dot{W}$

Answer:  $\dot{Q} = \dot{m} T (s_e - s_i) = \dot{m} T (s_{T_2}^{\circ} - s_{T_1}^{\circ} - R \ln \frac{P_2}{P_1})$

$s_{T_2}^{\circ} = s_{T_1}^{\circ}$  since  $s^{\circ}$  only depends on temperature and  $T_2 = T_1$

$$\Rightarrow \dot{Q} = -\dot{m} T R \ln \frac{P_2}{P_1} = -0.5 \text{ kg/s} \cdot 300 \text{ K} \cdot 0.287 \frac{\text{kJ}}{\text{kg} \cdot \text{K}} \ln \frac{400 \text{ kPa}}{2000 \text{ kPa}}$$
$$= \underline{69.29 \text{ kJ/s}}$$

1st law:  $\dot{W} = \dot{Q} + \dot{m}(h_i - h_e)$

No need to look up  $h_i$  and  $h_e$ , since for an

I.G.  $h$  only depends on temperature and  $T_1 = T_2$ , so  $h_1 = h_2$

$$\dot{W} = \dot{Q} = \underline{69.29 \text{ kJ/s}}$$

## Second Law for a C.V (continued)

c) general process:

$$s_e - s_i = \frac{q}{T_{\text{sur}}} + s_{\text{gen}} \quad s_{\text{gen}} \geq 0$$

if SEE and heat addition at a single temperature  $T$

$$\dot{m}_e s_e - \dot{m}_i s_i = \frac{Q}{T_{\text{sur}}} + \dot{S}_{\text{gen}}$$

net entropy flowing out      entropy transferred from surroundings      entropy generated by irreversible processes

If more than one entrance, exit, or heat transfer point, sum

P 9.49,

Example 6.6 steam turbine

1.5 kg/s  
2 MPa  
350°C  
50 m/s  
 $Z_i = 6\text{m}$

$$\dot{Q} = -0.5 \text{ kW}$$



$$\text{1st law } \dot{Q} + \dot{m}(h_i + \frac{1}{2}V_i^2 + gz_i) = \dot{W} + \dot{m}(h_e + \frac{1}{2}V_e^2 + gz_e)$$

$$\dot{m}_e s_e - \dot{m}_i s_i = \frac{\dot{Q}}{T} + \dot{S}_{\text{gen}}$$

$$\left. \begin{aligned} p_e &= 0.1 \text{ MPa} \\ x_e &= 100\% \\ V_e &= 100 \text{ m/s} \\ Z_e &= 3 \text{ m} \end{aligned} \right\} T \sim 100^\circ\text{C}$$

Asked: is this possible? (is  $\dot{S}_{\text{gen}}$  positive?)

(Example 6.6  $\rightarrow$  in Sonntag already worked out what  $\dot{W}$  is, and that (1) is superheated vapor).

A-6

B 1.3 @ 2 MPa, 350°C:  $s_i = 6.5562 \frac{\text{kJ}}{\text{kg}\cdot\text{K}}$

B 1.2 @ 0.1 MPa,  $x=1$ :  $s_e = s_g = 7.3593 \frac{\text{kJ}}{\text{kg}\cdot\text{K}}$   
= 100% vapor

$$\dot{S}_{\text{gen}} = 1.5 \text{ kg/s} (7.3593 - 6.5562) \frac{\text{kJ}}{\text{kg}\cdot\text{K}} + \frac{-0.5 \text{ kW}}{T}$$

certainly positive, regardless what  $T$  is.