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(1) H_2O 0.6 MPa SAV →

(2) H_2O 0.6 MPa 600 °C →

adiabatic mixing chamber

$\dot{S}_{gen} = ?$ → can only do specific generation

$\dot{Q} = 0$

$\dot{Q} + \dot{m}_1(h_1 + \frac{1}{2}Vel_1^2 + gZ_1) + \dot{m}_2(h_2 + \frac{1}{2}Vel_2^2 + gZ_2) = \dot{W} + \dot{m}_3(h_3 + \frac{1}{2}Vel_3^2 + gZ_3)$ (no moving parts)

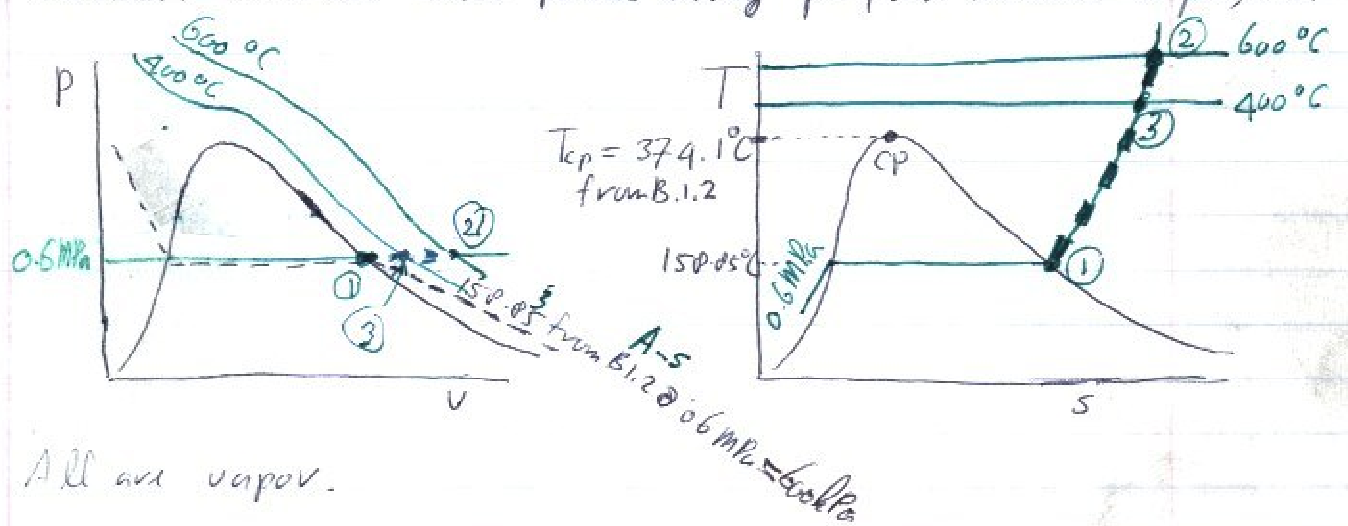
→ 0.6 MPa 400 °C

$\dot{m}_3 = \dot{m}_1 + \dot{m}_2$

$\dot{m}_3 s_3 - \dot{m}_1 s_1 - \dot{m}_2 s_2 = \frac{\dot{Q}}{T} + \dot{S}_{gen}$ $\dot{S}_{gen} = \dot{m}_{tot} s_{gen} = \dot{m}_3 s_{gen}$

4/4/16 end →

Answer: find all three phases using p-fixed method in pv, Ts:



All are vapor.

Both the 1st law and 2nd law have $\dot{m}_1$, $\dot{m}_2$, and $\dot{m}_3$, none of which I know. I can make it easier for myself by getting rid of $\dot{m}_3$ using $\dot{m}_1 + \dot{m}_2 = \dot{m}_3$. <u>Remember this trick</u>:

1st law $\dot{m}_1 h_1 + \dot{m}_2 h_2 = (\dot{m}_1 + \dot{m}_2) h_3$

2nd law $(\dot{m}_1 + \dot{m}_2) s_3 - \dot{m}_1 s_1 - \dot{m}_2 s_2 = (\dot{m}_1 + \dot{m}_2) s_{gen}$

I cannot solve the 1st law for say $\dot{m}_2$, since it has $\dot{m}_1$ too, but I can solve it for $\dot{m}_2$ <u>in terms of $\dot{m}_1$</u>, and take that to the 2nd law to get rid of $\dot{m}_2$. Then I should be able to divide out $\dot{m}_1$

A-5

Table B.1.2 @ 0.6 MPa : $h_1 = 2756.80$ kJ/kg [2] $s_1 = 6.76$ kJ/kg K [6.7593]

Table B.1.3 @ 0.6 MPa, 600°C : $h_2 = 3700.91$ kJ/kg [1.7] $s_2 = 8.2673$ kJ/kg K [95]

0.6 MPa, 400°C : $h_3 = 3270.25$ kJ/kg [8] $s_3 = 7.7078$ kJ/kg K [97]

1st law:

$$\dot m_1 h_1 + \dot m_2 h_2 = (\dot m_1 + \dot m_2) h_3 \rightarrow \dot m_2 (h_2 - h_3) = \dot m_1 (h_3 - h_1)$$

$$\dot m_2 (3700.91 - 3270.25)\frac{kJ}{kg} = \dot m_1 (3270.27 - 2756.80)\frac{kJ}{kg}$$

$$\dot m_2 = \frac{3270.27 - 2756.06}{3700.91 - 3270.25}\dot m_1 = 1.1922\,\dot m_1$$

Plug into the 2nd law

$$(\dot m_1 + 1.1922\,\dot m_1) s_3 - \dot m_1 s_1 - 1.1922\,\dot m_1 s_2 = (\dot m_1 + 1.1922\,\dot m_1) s_{gen}$$

divide by $\dot m_1$:

$$2.1922\, s_3 - s_1 - 1.1922\, s_2 = 2.1922\, s_{gen}$$

$$(2.1922 \cdot 7.7078 - 6.76 - 1.1922 \cdot 8.2673)\frac{kJ}{kg\,K} = 2.1922\, s_{gen}$$

$$s_{gen} = 0.1200 \frac{kJ}{kg\,K}$$

← 0?

NOTE: more straightforward argument,

Define $s_{gen} = \dot S_{gen}/\dot m_3$, (entropy generated per kg total mass passing through)

2nd law / $\dot m_3$

$$s_{gen} = s_3 - \frac{\dot m_1}{\dot m_3} s_1 - \frac{\dot m_2}{\dot m_3} s_2 \xrightarrow[\text{conservation}]{\text{apply mass}} \frac{\dot m_2}{\dot m_3} = 1 - \frac{\dot m_1}{\dot m_2}$$

$$s_{gen} = s_3 - \frac{\dot m_1}{\dot m_3} s_1 - \left(1 - \frac{\dot m_1}{\dot m_3}\right) s_2$$

Same for 1st law

$$h_3 = \frac{\dot m_1}{\dot m_3} h_1 + \frac{\dot m_2}{\dot m_3} h_2 \longrightarrow h_3 = \frac{\dot m_1}{\dot m_3} h_1 + \left(1 - \frac{\dot m_1}{\dot m_3}\right) h_2 \xrightarrow[\text{for } \dot m_1/\dot m_3]{\text{solve}} \frac{\dot m_1}{\dot m_3}$$

$\longrightarrow s_{gen}$

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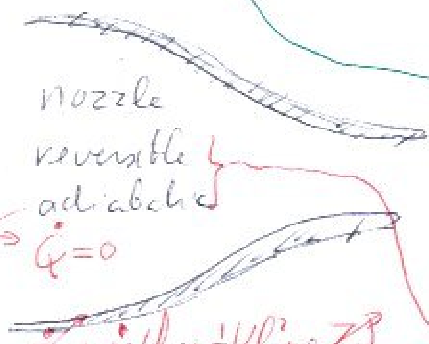
Not Cengel

choose 1 of:
a) B.6. tables
b) A-10 (A.8) table
c) A2(b) or A2(c) (A.6) cons. spec heat
d) A2(a) (A.5) cons. spec heat
e) ~~Polytropic relations~~

N_2 gas
0.15 kg/s E
① 500 kPa I
200 °C I
10 m/s Vel



$\dot{Q} = 0$

300 m/s

e

$p_e = ?$

$A_e = ?$

$\dot{m} = \frac{A_e Vel_e}{v_e}$

$s_e = s_i$ I

1st law $\dot{Q} + \dot{m}(h_i + \frac{1}{2}Vel_i^2 + gZ_i)$
$= \dot{W} + \dot{m}(h_e + \frac{1}{2}Vel_e^2 + gZ_e) \Rightarrow h_2$ I

no moving parts

Answer:

The general approach is that the 1st law gives us h_e and the second s_e. Then we should be able to find p_e and v_e, and from v_e, A_e. ~~h_e is easy: in h_i~~

not in Cengel: Now N_2 is in table B.6.2. BUT: T_i is in °C and B.6.2 uses K; also 500 kPa is not in B.6.2. → need double interpolation. Also, interpolating p_e and v_e from h_e and s_e in B.6.2 is going to be a nightmare. Forget it!

Now N_2 is also in A-10 (A.8) in I.G. approximation.

2nd: $s_e - s_i = 0 = s^o_{T_e} - s^o_{T_i} - R \ln p_e/p_i$ and $s^o_{T_2}$ from A8 @ h_e (interpolated in another)

procedure $T_i \xrightarrow[\text{interpol A-10}]{A8} h_i, s^o_{T_i} \xrightarrow{\text{1st law}} h_e \xrightarrow[\text{interpol A-10}]{A8} s^o_{T_e}, T_e \xrightarrow{\text{2nd law}} p_e \xrightarrow{pv=RT} v \rightarrow A_e$ (self)

BUT: solution manual uses polytropic relationships assuming $c_p = \text{const}$

So I will do so too:

1st law $\dot{Q} + \dot{m}(h_i + \frac{1}{2}Vel_i^2 + gZ_i) = \dot{W} + \dot{m}(h_e + \frac{1}{2}Vel_e^2 + gZ_e)$ ($\dot{Q}$: adiabatic; $\dot{W}$: no moving parts; gZ: ignore)

$h_i + \frac{1}{2}Vel_i^2 = h_e + \frac{1}{2}Vel_e^2$

$h_e - h_i = \frac{1}{2} Vel_i^2 - \frac{1}{2} Vel_e^2 = \frac{1}{2} 10^2 \frac{m^2}{s^2} \frac{1\ kJ/kg}{1000\ m^2/s^2} - \frac{1}{2} 300^2 \frac{m^2}{s^2} \frac{1\ kJ/kg}{1000\ m^2/s^2}$

$= -44.95 \frac{kJ}{kg}$

The approximate formula for h for an I.G. is

$h_e - h_i \approx c_p (T_e - T_i)$ ($T_i \to 200+273K$) $\quad c_p = $ ~~1.042~~ 1.039 $\frac{kJ}{kg\,K}$ from ~~A.5~~ A2-a (@ ~~25~~ 27 °C!)

$-44.95 \frac{kJ}{kg} = $ ~~1.042~~ 1.039 $\frac{kJ}{kg\,K} (T_e - 473K)$

$T_e = 429.06\ K = 156.06\ °C$

(Note: at $T_{ave} = \frac{429.06 + 473}{2} K$, ~~A6~~ A-2(b) at 450K gives $c_p = 1.0$~~50~~49 ≈ 1.042)

Now could use $s_2 - s_1 \approx c_p \ln \frac{T_2}{T_1} - R \ln \frac{p_2}{p_1}$ to get p_2 ($s_2 - s_1 \to 0$)

$s_2 - s_1 \approx c_v \ln \frac{T_2}{T_1} + R \ln \frac{v_2}{v_1}$ to get v_2

But the equivalent polytropic formula for $n = k$ = constant = 1.4 from A5 are easier, since you do not need to get rid of the lns,

$\frac{p_e}{p_i} = \left(\frac{v_i}{v_e}\right)^{1.4} = \left(\frac{T_e}{T_i}\right)^{\frac{1.4}{1.4-1}}$

$\to \frac{p_e}{p_i} = \left(\frac{429.06\ K}{473\ K}\right)^{\frac{1.4}{1.4-1}} = \frac{p_e}{500\ kPa} \Rightarrow p_e = \underline{357.0\ kPa}$

~~pv = RT is even easier to get~~

~~$\left(\frac{v_i}{v_e}\right)^{1.4 \cdot \frac{1}{1.4}} = \left(\frac{T_e}{T_i}\right)^{\frac{1.4}{0.4} \cdot \frac{1}{1.4}}$~~

$p_e v_e = R T_e \qquad 357.0\ kPa\ v_e = .2968 \frac{kJ}{kg\,K}\ 429.06K$

$\to v_e = 0.3566\ m^3/kg$

$\dot{m} = \frac{A_e Vel_e}{v_e} \qquad 0.15\ kg/s = \frac{A_e\ 300\ m/s}{0.3566\ m^3/kg} \qquad \underline{A_e = 0.178\ 10^{-3}\ m^2}$

9/6/6 end →

~~Skip~~

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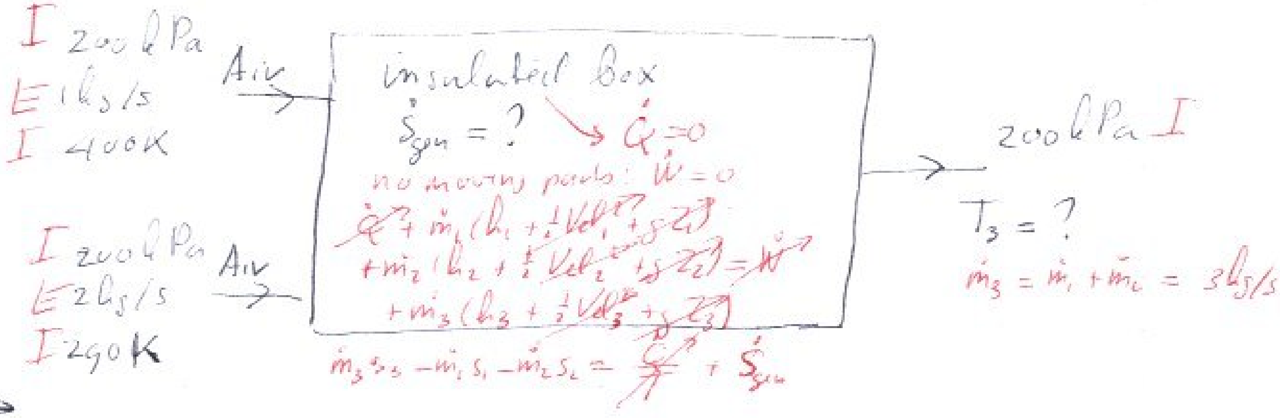

Answer:

Table A.7.1 (A-17) @ 400 K: $h_1 = 401.30\ \frac{kJ}{kg}$ (0.98) $s^0_{T_1} = 7.15926$ (1.99194) $kJ/kg\,K$

@ 290 K: $h_2 = 290.43\ \frac{kJ}{kg}$ (66) $s^0_{T_2} = 6.83521$ (1.66802) $kJ/kg\,K$

$R = 0.287\ kJ/kg\,K$

1st law $\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$

$1\frac{kg}{s}\,401.30\frac{kJ}{kg} + 2\frac{kg}{s}\,290.43\frac{kJ}{kg} = 3\frac{kg}{s}\,h_3 \rightarrow h_3 = 327.39\ \frac{kJ}{kg}$

Table A.7.1 (A-17) interpolated at $h_3 = 327.39\ kJ/kg$

$T_3 = 320K$ (325) $+ \frac{327.39 - 320.58}{340.7 - 320.58}$ (.41352) $(340-320)K$ (330 − 325) $= \underline{326.77\ K}$ (327.06)

$s^0_{T_3} = 6.53413\ \frac{kJ}{kg\,K}$ (1.78249) $+ \frac{327.39 - 320.58}{340.7 - 320.58}$ (.41352) $(6.59515 - 6.53413)$ (1.79783 1.78249) $\frac{kJ}{kg\,K}$

$= 6.95478\ kJ/kg\,K$ (1.78883)

2nd law: $\dot{m}_3 s_3 - \dot{m}_1 s_1 - \dot{m}_2 s_2 = \dot{S}_{gen}$

problem: we only have a formula for differences in s

standard solution: write $\dot{m}_3$ as $\dot{m}_1 + \dot{m}_2$:

$(\dot{m}_1 + \dot{m}_2)s_3 - \dot{m}_1 s_1 - \dot{m}_2 s_2 = \dot{S}_{gen}$

$\dot{m}_1(s_3 - s_1) + \dot{m}_2(s_3 - s_2) = \dot{S}_{gen}$

$$\dot{m}_1 \left(s^\circ_{T_3} - s^\circ_{T_1} - R \ln \frac{P_3}{P_1} \right) + \dot{m}_2 \left(s^\circ_{T_2} - s^\circ_{T_1} - R \ln \frac{P_2}{P_1} \right) = \dot{S}_{gen}$$

$$\dot{S}_{gen} = 1 \frac{kg}{s} \left(\overset{1.78883}{6.95478} \frac{kJ}{kgK} - \overset{1.99199}{7.15926} \frac{kJ}{kgK} - 0.287 \frac{kJ}{kgK} \ln \frac{200kPa}{200kPa} \right)$$

$$+ 2 \frac{kg}{s} \left(\overset{1.78883}{6.83521} \frac{kJ}{kgK} - \overset{1.66802}{7.15926} \frac{kJ}{kgK} - 0.287 \frac{kJ}{kgK} \ln \frac{200kPa}{200kPa} \right)$$

($\ln 1 = 0$)

$$= \overset{3852}{0.03466} \frac{kJ}{kgK}$$