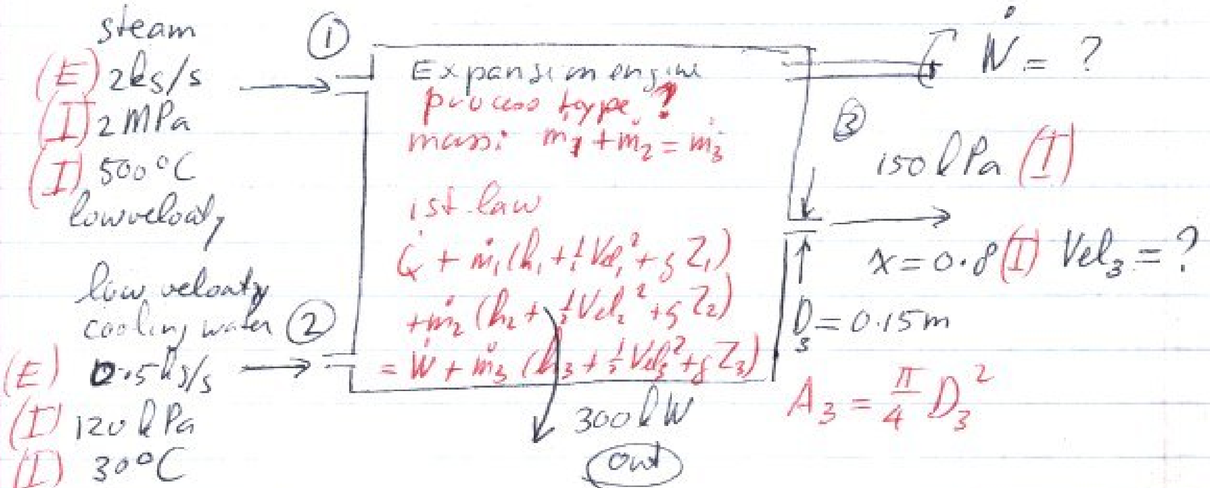
P6.81 Multiflow



Asked: $\dot W$, (Vel_3)

Answer: mass conservation: sum!

$$\dot m_1 + \dot m_2 = \dot m_3 \qquad 2\,\text{kg/s} + 0.5\,\frac{\text{kg}}{\text{s}} = \dot m_3$$

$$\dot m_3 = 2.5\ \text{kg/s}$$

Velocity / mass flow relation

$$\dot m_3 = \frac{A_3\, Vel_3}{v_3} \qquad 2.5\,\frac{\text{kg}}{\text{s}} = \frac{\frac{\pi}{4} 0.15^2\, Vel_3}{v_3}$$

To get v_3, look in saturated water table @ 150 kPa:

$$v_f = 0.001053\ \frac{\text{m}^3}{\text{kg}} \qquad v_{fg} = 1.15828\ \frac{\text{m}^3}{\text{kg}} = 1.1594 - .001053$$

$$v_3 = v_f + x\, v_{fg} = 0.001053\,\frac{\text{m}^3}{\text{kg}} + 0.8\ 1.15828\,\frac{\text{m}^3}{\text{kg}}$$

$$= 0.92767\ \text{m}^3/\text{kg}$$

$$2.5\,\frac{\text{kg}}{\text{s}} = \frac{\frac{\pi}{4}\, 0.15^2\, Vel_3}{0.92767\ \text{m}^3/\text{kg}} \Longrightarrow \underline{Vel_3 = 131.29\ \text{m/s}}$$

1st law: sum!

$$\dot{Q} + \dot{m}_1 \left(h_1 + \tfrac{1}{2}\underbrace{Vel_1^2}_{\text{low velocity}} + \underbrace{gZ_1}_{\text{ignore height differences}}\right) + \dot{m}_2 \left(h_2 + \tfrac{1}{2}\underbrace{Vel_2^2}_{\text{low velocity}} + \underbrace{gZ_2}_{\text{ignore height differences}}\right) =$$
$$\dot{W} + \dot{m}_3 \left(h_3 + \tfrac{1}{2}Vel_3^2 + \underbrace{gZ_3}_{\text{ignore height differences}}\right)$$

I need h_1, h_2, h_3:

h_1: steam, so ~~B.1.3~~ A-6 @ 2 MPa and 500°C p 685
$h_1 = 3467.55$ kJ/kg

h_2: Lowest pressure in ~~B.1.4~~ A-7 is ~~500~~ 5000 kPa, so instead use ~~B.1.1~~ A-4 @ 30°C
$h_2 = 125.77 \frac{kJ}{kg}$ (or 125.09 using $u_{sat} + p\,v_{sat}$)

h_3: Two ~~state~~ phase, so use ~~B.1.2~~ A-5 @ 150 kPa
$h_f = 467.08 \frac{kJ}{kg}$ $h_{fg} = 2226.46 \frac{kJ}{kg}$

$$h_3 = h_f + x\,h_{fg} = 467.08 \frac{kJ}{kg} + 0.8 \cdot 2226.46 \frac{kJ}{kg}$$
$$= 2248.25 \frac{kJ}{kg}$$

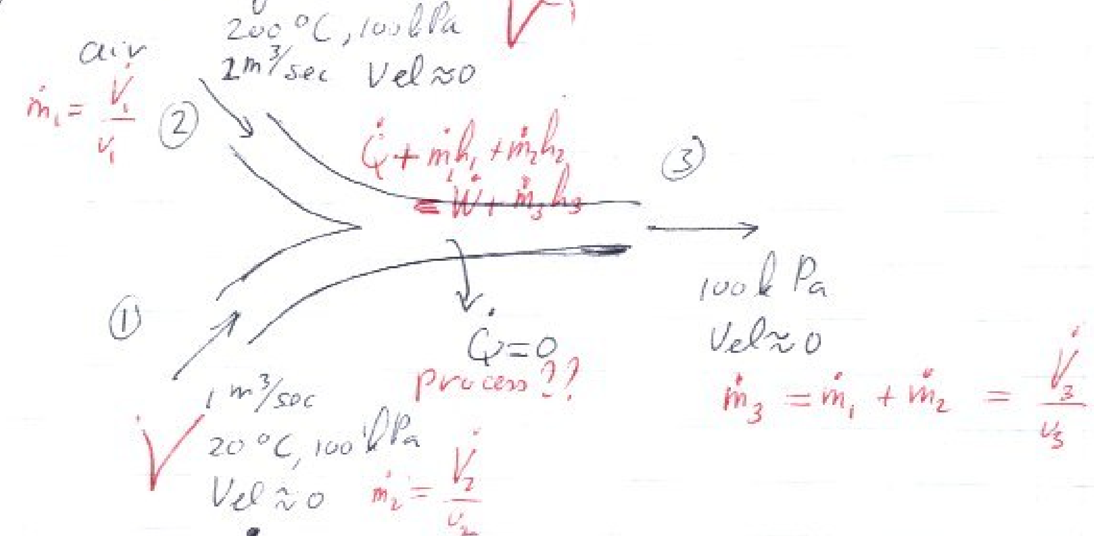
Put all numbers into 1st law:

$$\dot{Q} + \dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{W} + \dot{m}_3\left(h_3 + \tfrac{1}{2}Vel_3^2\right)$$

$$-300\,kW + 2\,\tfrac{kg}{s}\,3467.55\,\tfrac{kJ}{kg} + 0.5\,\tfrac{kg}{s}\,125.09\,\tfrac{kJ}{kg}$$
$$= \dot{W}_{out} + 2.5\,\tfrac{kg}{s}\left(2248.25\,\tfrac{kJ}{kg} + \tfrac{1}{2}(131.24)^2\,\tfrac{m^2}{s^2}\;\frac{1\,kJ/kg}{1000\,m^2/s^2}\right)$$

$$\dot{W}_{out} = 1056\,\tfrac{kJ}{s} = \underline{\underline{1056\,kW}}$$

P6.53 Mixing



Asked: T_3, $\dot{V}_3$

Answer: 1st law $\underbrace{\cancel{\dot{Q}}}_{0 \text{ given}} + \dot{m}_1 h_1 + \dot{m}_2 h_2 = \underbrace{\cancel{\dot{W}}}_{\text{no moving parts}} + \dot{m}_3 h_3$

This will give h_3 ! First need $\dot{m}_1$, $\dot{m}_2$, h_1, h_2
$\dot{m}_1 \downarrow v_1$, $\dot{m}_2 \downarrow v_2$, h_1, h_2 from A5 A-2a

v_2: $P_2 v_2 = R T_2$ $\quad 100\ kPa\ v_2 = 0.287 \frac{kJ}{kg\,K} (200 + 273) K$

$\rightarrow v_2 = 1.35751\ m^3/kg$

$\dot{m}_2 = \frac{\dot{V}_2}{v_2} = \frac{2\ m^3/s}{1.35751\ m^3/kg} = 1.4732\ kg/s$

v_1: $P_1 v_1 = R T_1$ $\quad 100\ kPa\ v_1 = 0.287 \frac{kJ}{kg\,K} (20 + 273) K$

$\rightarrow v_1 = 0.84091 \rightarrow \dot{m}_1 = \frac{\dot{V}_1}{v_1} = \frac{1\ m^3/s}{0.84091\ m^3/kg} = 1.18915\ \frac{kg}{s}$

$\dot{m}_3 = \dot{m}_1 + \dot{m}_2 = 2.6625\ kg/s$

Table A 7.1 A-17 (interpolated) $\quad @ (20 + 273) K: h_1 = 293.44\ kJ/kg$

$@ (200 + 273) K: h_2 = 475.65\ kJ/kg$

1st law was found above:

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

$$1.18915 \frac{kg}{s}\, 293.49 \frac{kJ}{kg} + 1.4732 \frac{kg}{s}\, 475.65 \frac{kJ}{kg}$$

$$= 2.6625 \frac{kJ}{kg}\, h_3 \rightarrow h_3 = 394.24\ kJ/kg$$

Table $\overset{A-17}{A.7.1}$ @ $h_3 = 394.24\ kJ/kg$ interpolated

$$T_3 = \overset{390}{\cancel{380}} + \frac{394.24 - \overset{390.88}{\cancel{381.06}}}{\underset{400.98\qquad 390.88}{401.30 - 381.06}} (400 - \overset{390}{\cancel{380}})$$

$$= 393.02\ K = \underline{\underline{120\ ^\circ C}}$$

$$P_3 v_3 = R T_3 \qquad 100\ kPa\ v_3 = 0.287 \frac{kJ}{kg\,K}\, 393.02\ K$$

$$\rightarrow v_3 = 1.1280\ m^3/kg$$

$$\cancel{\dot{V}_3 = \dot{m}_3 v_3 = 2.6625 \frac{kg}{s} 1.1280}$$

$$\dot{m}_3 = \frac{\dot{V}_3}{v_3} \Longrightarrow 2.6625 \frac{kg}{s} = \frac{\dot{V}_3}{1.1280\ m^3/kg}$$

$$\rightarrow \underline{\underline{\dot{V}_3 = 3.003\ m^3/s}}$$

2/23/06 end →

Important trick

P 6.93 again: But suppose that you do not have a table A.7.1 or A.8, i.e. suppose it was Argon. A17 – A-25

just $c_{p\,ave}$: $h_B - h_A = c_{p\,ave}(T_B - T_A)$ only, no h itself.

1st law:

$$\dot m_1 h_1 + \dot m_2 h_2 = \dot m_3 h_3 \quad \text{just like before}$$

Trick: Now use $\dot m_3 = \dot m_1 + \dot m_2$! !

$$\dot m_1 h_1 + \dot m_2 h_2 = \dot m_1 h_3 + \dot m_2 h_3 \rightarrow \underbrace{\dot m_1 (h_1 - h_3) + \dot m_2 (h_2 - h_3) = 0}_{\text{differences in } h!}$$

$$\Rightarrow \dot m_1 c_{p\,ave} (T_1 - T_3) + \dot m_2 c_{p\,ave} (T_2 - T_3) = 0$$

Can still find T_3.

Will definitely need (if no better is available): A17 – A-25

~~$du = c_v$~~

for I.G. $\begin{cases} u_2 - u_1 = c_{v\,ave}(T_2 - T_1) \ \text{(approx (better A7.1/A8))} & \longleftrightarrow \ \dfrac{du}{dt} = c_v \dfrac{dT}{dt} \ \text{(exact)} \\ h_2 - h_1 = c_{p\,ave}(T_2 - T_1) \ \text{(approx)} & \longleftrightarrow \ \dfrac{dh}{dt} = c_p \dfrac{dT}{dt} \ \text{(exact)} \end{cases}$ for I.G.

$_1Q_2 = m c_{p\,ave}(T_2 - T_1)$ ~~for I.G. at constant pressure or more generally~~, for simple liquids and solids also at nonconstant p

$_1Q_2 = m c_{v\,ave}(T_2 - T_1)$ for I.G. at constant volume

Simple liquids

$$\boxed{h_2 - h_1 \approx c_p (T_2 - T_1)} \ !$$

→ Steam powerplant cooling water is example