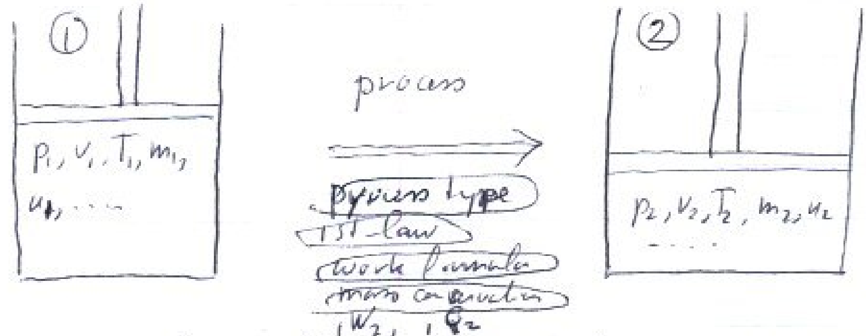
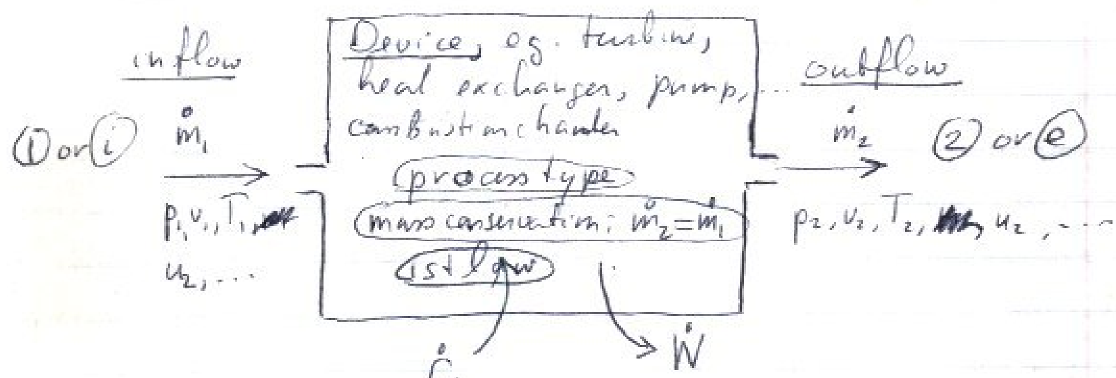
5 (In 6th edition of Çengel)

Chapter 6 : Control Volumes

The old type of problems: control mass



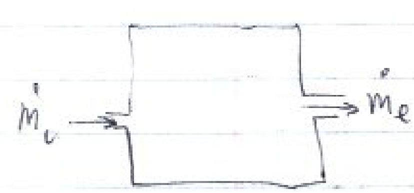
The new type of problems: control volume or S.S.S.F.



We assume steady state

Mass conservation:

$\dot{m}_i = \dot{m}_e$ $\dot{m}$: mass flow rate
if single entrance and exit: if not, sum them.

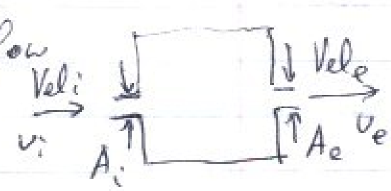


In terms of volume flow rate

$$\dot{m} = \frac{\dot{V}}{v}$$

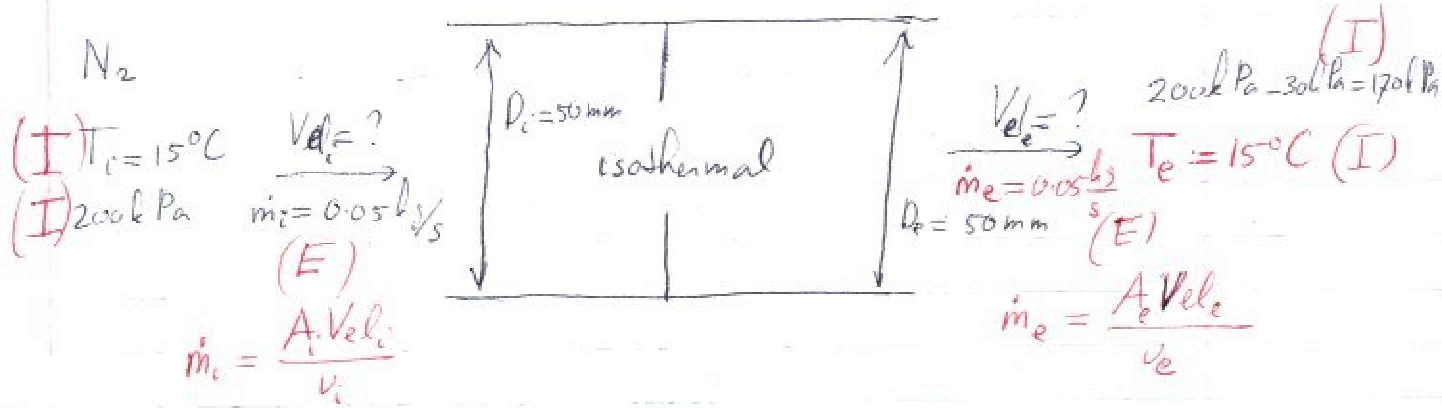
In terms of velocity and area of flow

$$\dot{m} = \frac{A \cdot Vel}{v}$$



XI 3

P6.25 (Skip in class)



Answer: N_2 is an ideal gas: Table A5: $R = 0.2968 \frac{kJ}{kg\,K}$

$p_i v_i = R T_i$ $\quad$ $200\text{ kPa}\ v_i = 0.2968 \frac{kJ}{kg\,K} (273+15)K$

$\Longrightarrow v_i = .4274\ m^3/kg$

$A_i = \frac{\pi}{4} D_i^2 = \frac{\pi}{4} (50\ 10^{-3})^2 m^2 = 0.001963\ m^2 = A_e$

$\dot{m}_i = \frac{A_i Vel_i}{v_i}$ $\quad$ $0.05\ kg/s = \frac{0.001963\ m^2\ Vel_i}{0.4274\ m^3/kg}$

$\Longrightarrow Vel_i = 10.89\ m/sec$

Same way:

$170\text{ kPa}\ v_e = 0.2968 \frac{kJ}{kg\,K} (273+15)K$

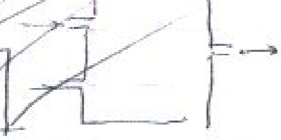
$\Longrightarrow v_e = .5028\ m^3/kg$

$\dot{m}_e = \frac{A_e Vel_e}{v_e} \Longrightarrow 0.05\ kg/s = \frac{0.001963\ m^2\ Vel_e}{0.5028}$

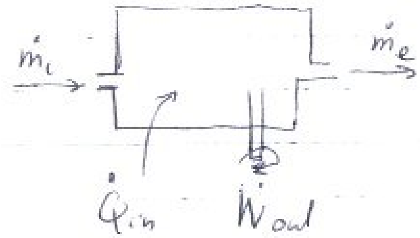
$\Longrightarrow Vel_e = 12.8\ m/sec$

If there is more than one inlet and or outlet:

(sum of all inlets) $\dot{m}_i$ = (sum of all outlets) $\dot{m}_e$



1st law



$$\dot{Q} + \dot{m}_i \left(h_i + \tfrac{1}{2} Vel_i^2 + g Z_i\right) = \dot{W} + \dot{m}_e \left(h_e + \tfrac{1}{2} Vel_e^2 + g Z_e\right)$$

If there is more than one entrance or exit, sum them

Compare control mass: ${}_1Q_2 + m_1\left(u_1 + \tfrac{1}{2} Vel_1^2 + g Z_1\right) = {}_1W_2 + m_2\left(u_2 + \tfrac{1}{2} Vel_2^2 + g Z_2\right)$

(i.e. $E_2 - E_1 = {}_1Q_2 - {}_1W_2$ rearranged)

Why h (enthalpy) for control volumes and not u (internal energy) like control masses? Well, the pressure is performing work on the entering or leaving fluid and h includes that work

$$\dot{m} u + pA\,Vel = \dot{m} u + p v \frac{A\,Vel}{v} = \dot{m} u + p v \dot{m}$$

$$= \dot{m}(u + pv) \quad \text{and } u + pv = h \text{ by definition}$$

Cengel:
- Nozzles
- Diffusers
- Throttling valves
- Mixing Chambers
- Heat exchangers
- Pipes and ducts
- Turbines
- Compressors
- Pumps and turbines in reverse
- (Expanders)

Devices and their assumptions on $\dot{Q}$ and $\dot{W}$ in table 6.1, p 154. Cengel: See class webpage for list of devices / same for isobaric

In the exams, if the device has no moving parts, $\dot{W} = 0$. But do not assume $\dot{Q} = 0$ unless I tell you so.

Specific work $w = \dot{W} / \dot{m}$

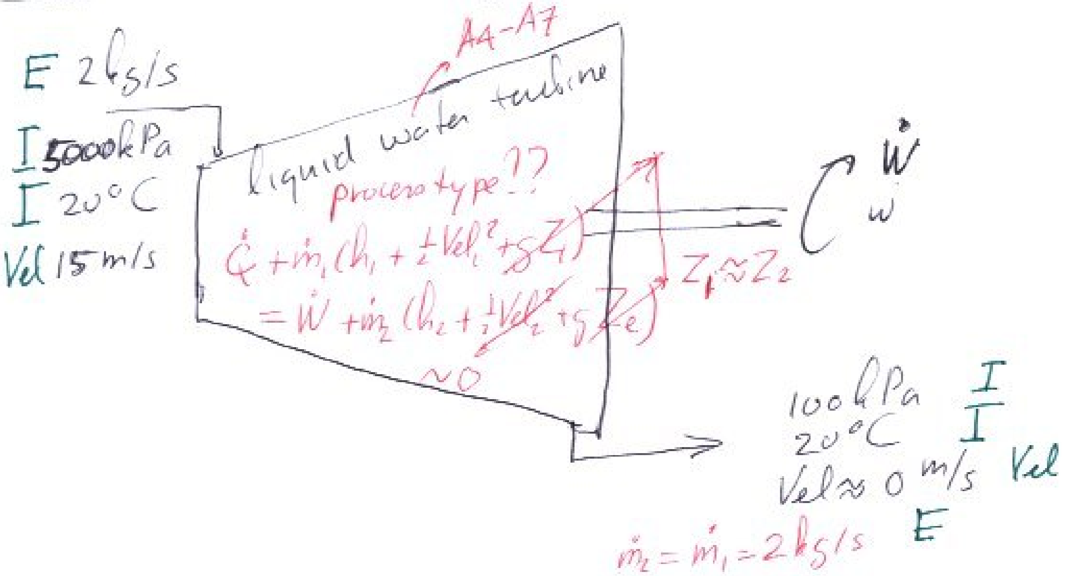
Specific heat transfer $q = \dot{Q} / \dot{m}$

Isolated → $\dot{W} = 0$ $\dot{Q} = 0$

Insulated → $\dot{Q} = 0$

Adiabatic → $\dot{Q} = 0$

Example P6.50 (Çengel) Given in black:



Asked $\dot{W}$, w

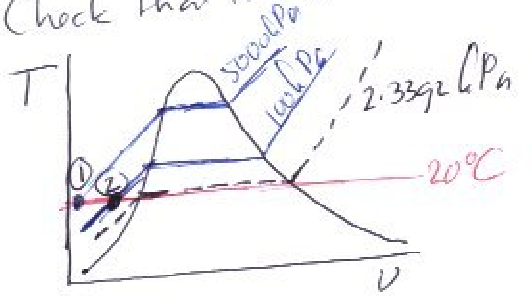
Solution $\dot{Q} + \dot{m}(h_1 + \frac{1}{2}Vel_1^2 + gZ_1) = \dot{W} + \dot{m}(h_2 + \frac{1}{2}Vel_2^2 + gZ_2)$ ($\dot{Q} \approx 0$, $Vel_2 \approx 0$)

Assume $Z_1 \approx Z_2$, so $\dot{m}gZ_1$ drops out against $\dot{m}gZ_2$

Will need to assume adiabatic, to make this solvable: $\dot{Q} = 0$

Still needed: h_1 and h_2.

Check that it is indeed liquid:



yes, both compressed liquid

Table A-7 @ 5000 kPa = 5 MPa, 20°C: $h_1 = 88.61 \frac{kJ}{kg}$

Table A-7 @ 100 kPa: No such pressure!

Table A-7 @ 100 kPa: No such pressure! (and 2.3392 kPa): $h_2 \approx 83.915 \frac{kJ}{kg}$

Can use A-4 @ 20°C (and 2.3392 kPa)

Better: interpolate between tables A-4 and A-7

$p = 100$ kPa $\quad p_a = 2.3392$ kPa $\quad p_b = 5000$ kPa

$h_a = 83.915 \quad h_b = 88.61$ kJ/kg

$$h_2 = h_a + \frac{p - p_a}{p_b - p_a}(h_b - h_a) = 84.006$$

$$\dot{W} = \dot{m}(h_1 + \tfrac{1}{2}Vel_1^2) - \dot{m}h_2$$

$$= \dot{m}(h_1 - h_2 + \tfrac{1}{2}Vel_1^2)$$

$$= 2\frac{kg}{s}\left(88.61\frac{kJ}{kg} - 84.06\frac{kJ}{kg} + \frac{1}{2}15^2\frac{m^2}{s^2}\;\frac{1\,kJ/kg}{1000\,m^2/s^2}\right)$$

$$= 9.433\frac{kJ}{s} = \underline{\underline{9.433\,kW}}$$

$$\dot{w} = 9.433\frac{kJ}{s}/2\,kg/s = \underline{\underline{47.16\frac{kJ}{kg}}}$$