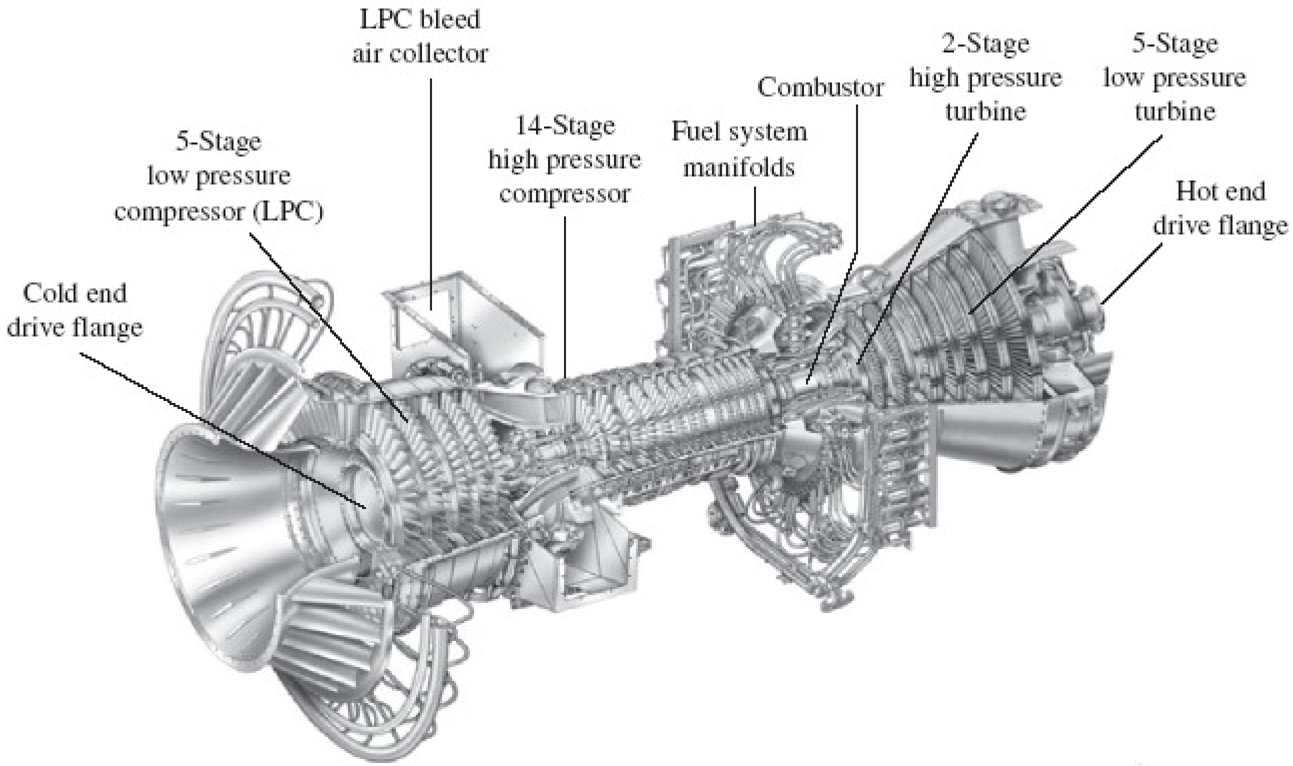
Engineering flow devices operating at steady state

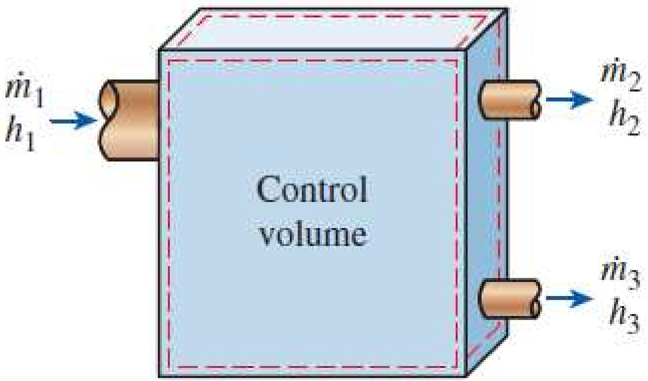
Raj Pala,
rpala@iitk.ac.in
Department of Chemical Engineering,
Associate faculty of the Materials Science Programme,
Indian Institute of Technology, Kanpur.

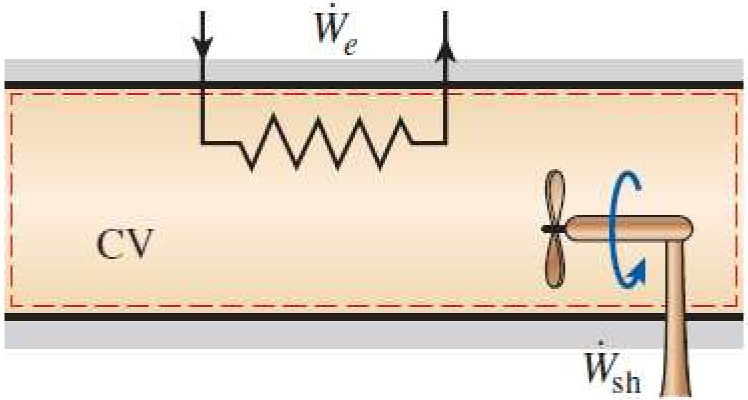
1st Law of TD for flow systems

- Mass Balance, Flow work & enthalpy; Steady State

Engineering flow devices…Turbine…CV analysis

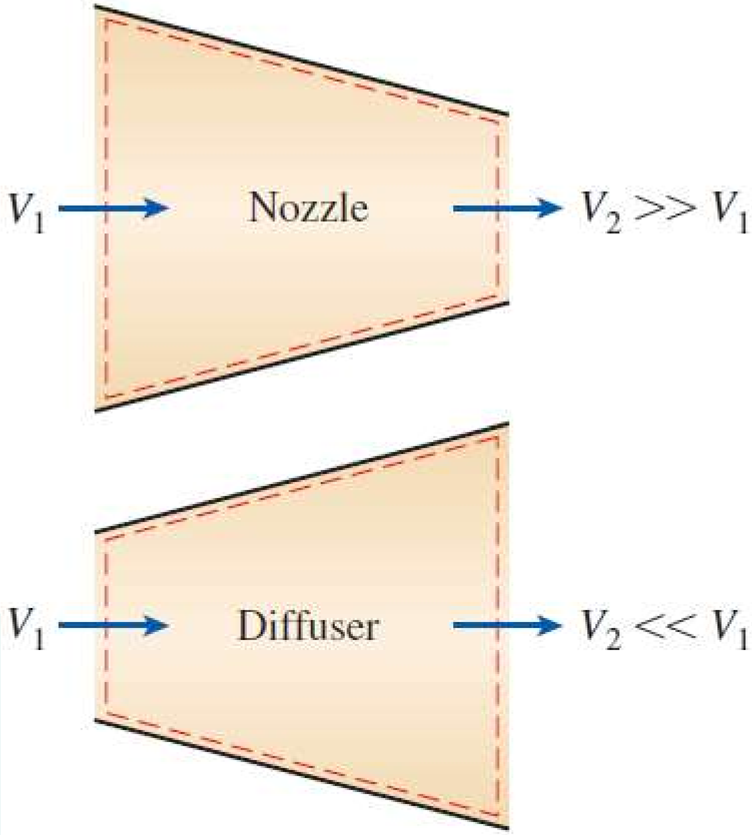






Figs: Cengel & Boles: TD

From Jets to Garden Hoses…Nozzles, Diffusers



$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{dE_{system}/dt^{\nearrow 0 \text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc., energies}}} = 0$$

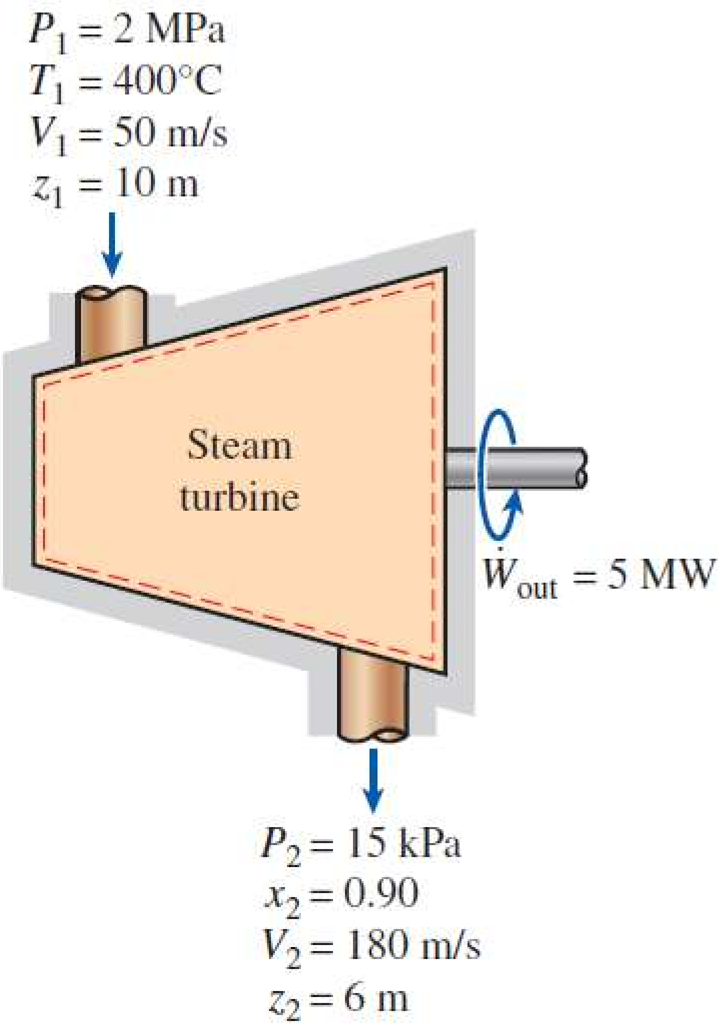
$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}\left(h_1 + \frac{V_1^2}{2}\right) = \dot{m}\left(h_2 + \frac{V_2^2}{2}\right) \quad (\text{since } \dot{Q} \cong 0,\ \dot{W} = 0, \text{ and } \Delta\text{pe} \cong 0)$$

$$h_2 = h_1 - \frac{V_2^2 - V_1^2}{2}$$

Figs: Cengel & Boles: TD

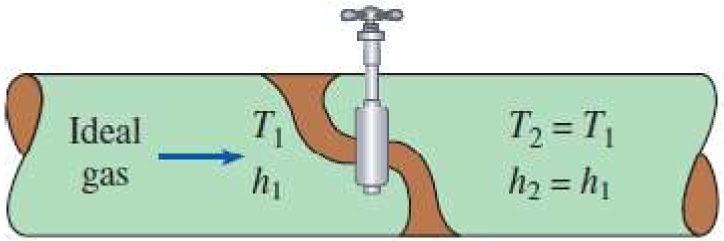
Turbines



$$w_{out} = -\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)\right] = -(\Delta h + \Delta ke + \Delta pe)$$

Figs: Cengel & Boles: TD

Throttling Value

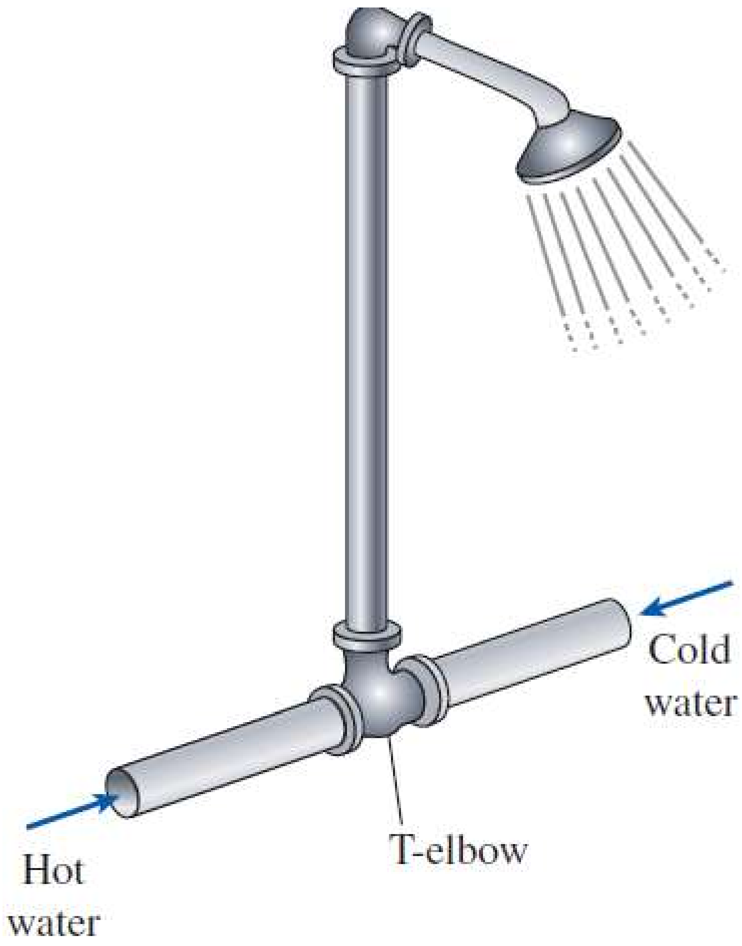


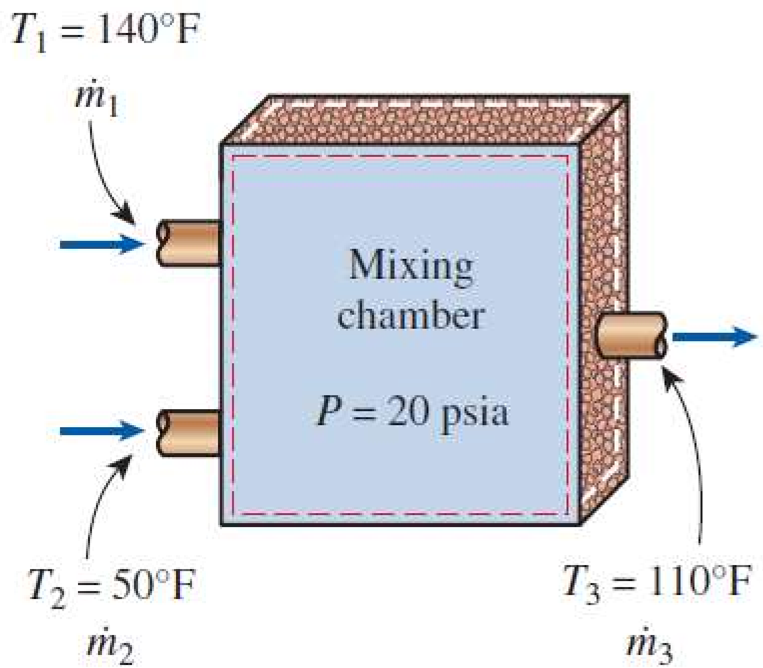
$$h_2 \cong h_1$$

$$u_1 + P_1 v_1 = u_2 + P_2 v_2$$

Figs: Cengel & Boles: TD

Bathing in Thermodynamics

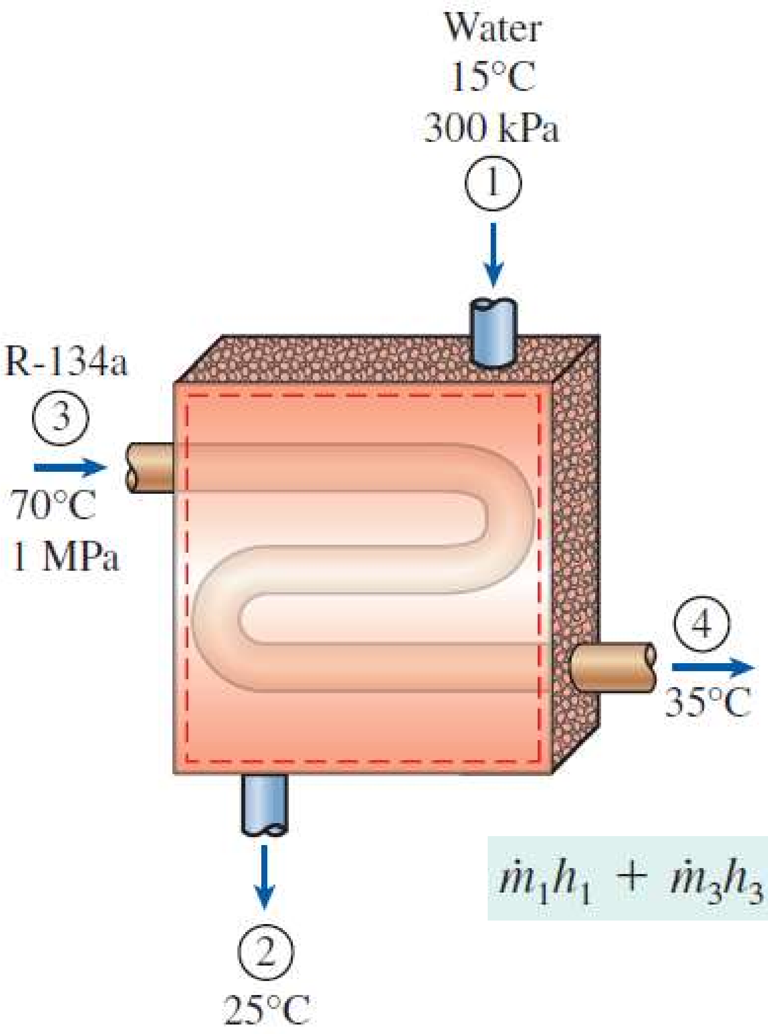




$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = (\dot{m}_1 + \dot{m}_2) h_3$$

Figs: Cengel & Boles: TD

Heat Exchangers-CV Option 1



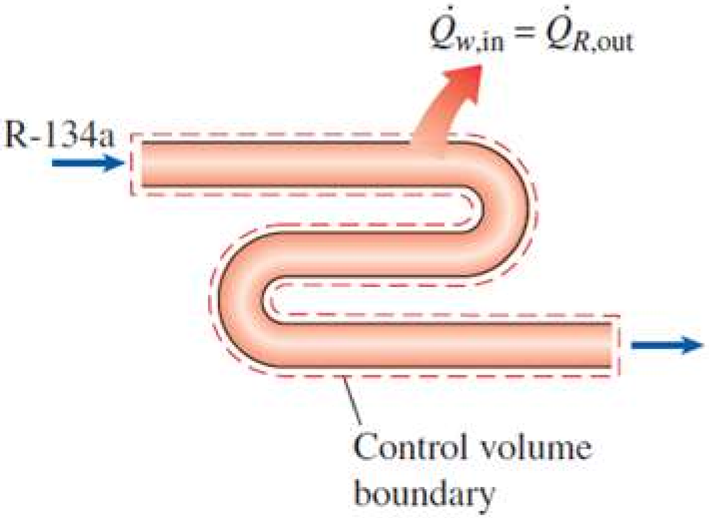
$$\dot{m}_1 = \dot{m}_2 = \dot{m}_w$$
$$\dot{m}_3 = \dot{m}_4 = \dot{m}_R$$

$$\dot{m}_1 h_1 + \dot{m}_3 h_3 = \dot{m}_2 h_2 + \dot{m}_4 h_4 \quad (\text{since } \dot{Q} \cong 0, \dot{W} = 0, \text{ke} \cong \text{pe} \cong 0)$$

$$\dot{m}_w(h_1 - h_2) = \dot{m}_R(h_4 - h_3)$$

Figs: Cengel & Boles: TD

Heat Exchangers-CV Option 2



$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{dE_{system}/dt^{\nearrow 0 \text{ (steady)}}}_{\text{Rate of change in internal, kinetic, potential, etc., energies}} = 0$$

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{Q}_{w,\,in} + \dot{m}_w h_1 = \dot{m}_w h_2$$

$$\dot{Q}_{w,in} = \dot{m}_w(h_2 - h_1)$$

Figs: Cengel & Boles: TD

What's next?

- Applying 1^{st} TD in engineering flow devices that do not operate at steady state