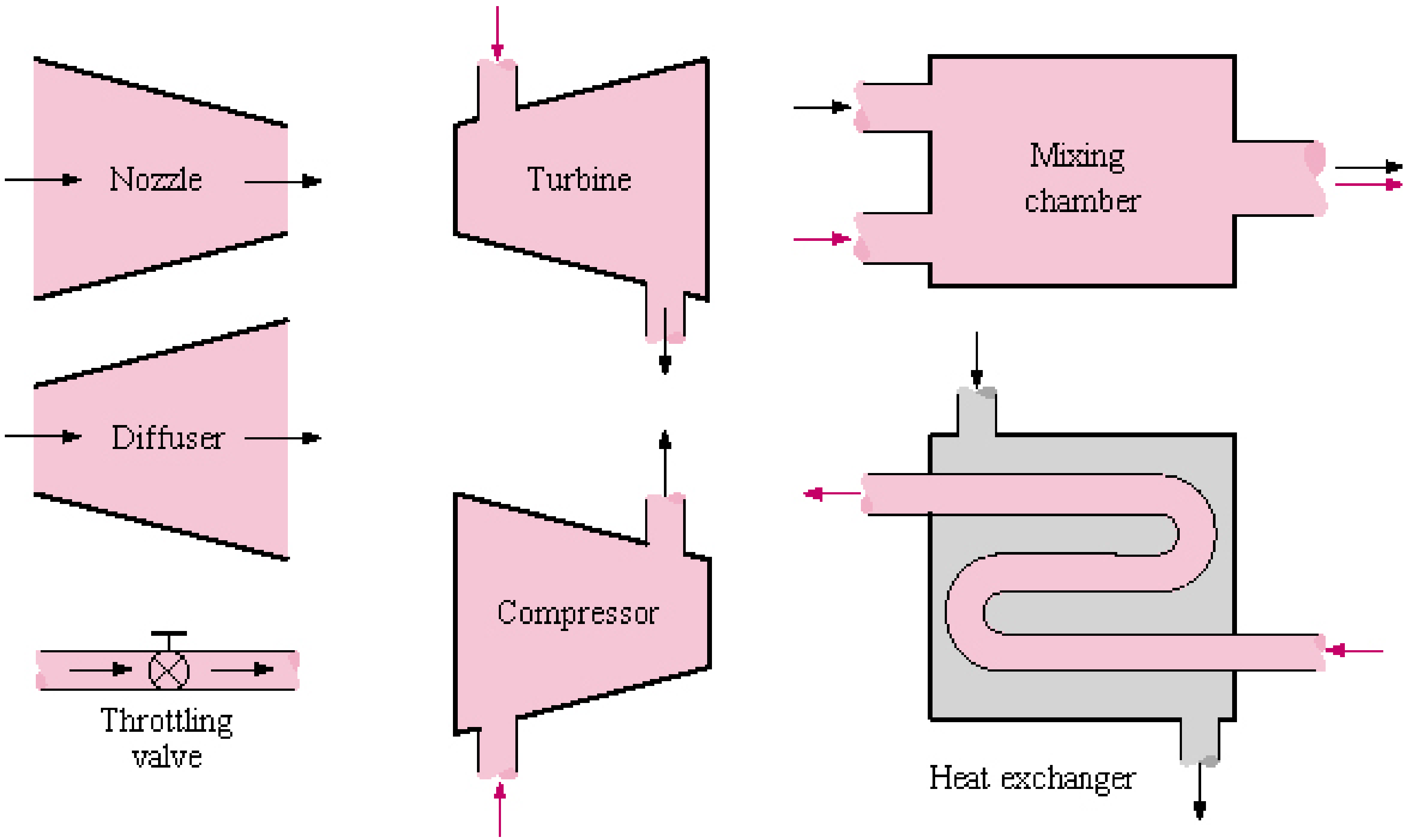
Control Volume Analysis Using Energy

Some Common Steady Flow Devices



Single Stream Steady Flow System

Nozzles

Diffusers

Turbines

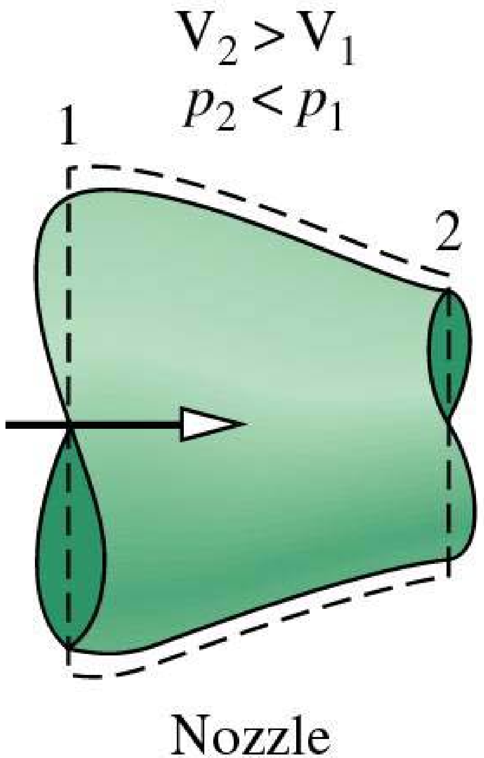
Compressors

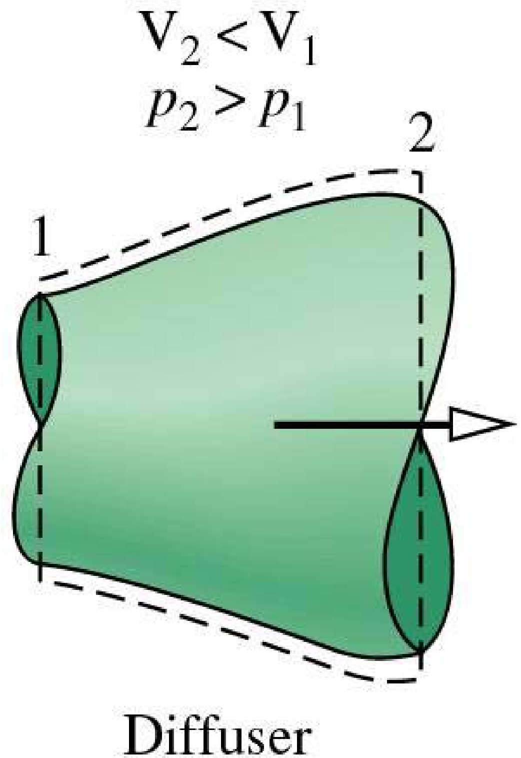
Throttling Valve

$$\dot{m}_i = \dot{m}_e = \dot{m}$$

$$\dot{Q} - \dot{W} = \dot{m}\left[h_e - h_i + \frac{V_e^2 - V_i^2}{2} + g\left(z_e - z_i\right)\right]$$

Nozzles and Diffusers





A nozzle is a device that increases the velocity of a fluid at the expense of pressure

A diffuser is a device that slows a fluid down

Nozzles and Diffusers

$$\dot{Q} - \dot{W} = \dot{m}\left[h_e - h_i + \frac{V_e^2 - V_i^2}{2} + g(z_e - z_i)\right]$$

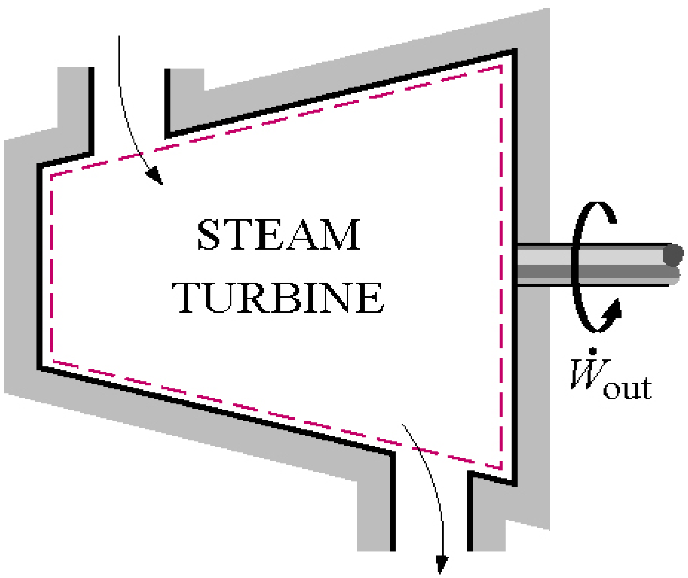
$$0 = (h_e - h_i) + \frac{V_e^2 - V_i^2}{2}$$

mass flow rate in a nozzle is

$$\dot{m} = \frac{V_i A_i}{v_i} = \frac{V_e A_e}{v_e}$$

In a nozzle, enthalpy is converted into kinetic energy

Turbines and Compressors



A turbine is a device that produces work at the expense of temperature and pressure

A compressor is a device that increases the pressure of a fluid by adding work to the system

Turbines and Compressors

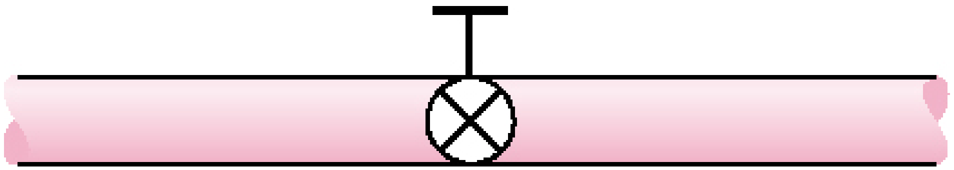
$$\dot{Q} - \dot{W} = \dot{m}\left[h_e - h_i + \frac{V_e^2 - V_i^2}{2} + g(z_e - z_i)\right]$$

or

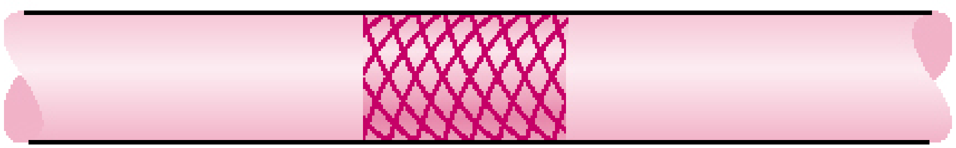
$$-\dot{W} = \dot{m}(h_e - h_i)$$

In a turbine/compressor, enthalpy is converted into work

Throttling Valve



(*a*) An adjustable valve



(*b*) A porous plug

A throttling valve reduces the fluid pressure

For example, the water that comes into your house goes through a throttling valve, so it doesn't have excessive pressure in your home.

Throttling Valve

$$\dot{Q} - \dot{W} = \dot{m}\left[h_e - h_i + \frac{V_e^2 - V_i^2}{2} + g(z_e - z_i)\right]$$

or

$$0 = (h_e - h_i)$$

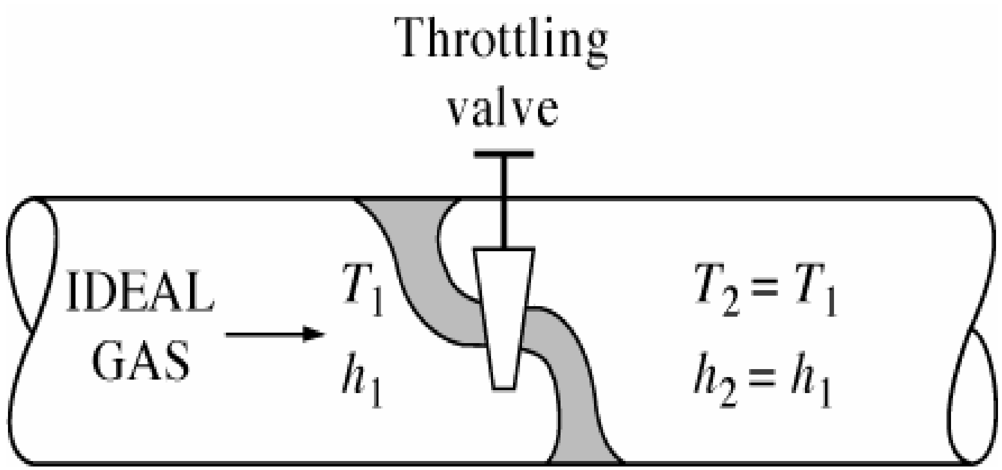
- $h_i = h_e$
- $P_{in} > P_{out}$
- For gases that are not ideal, the temperature goes down in a throttling valve

For ideal gases:

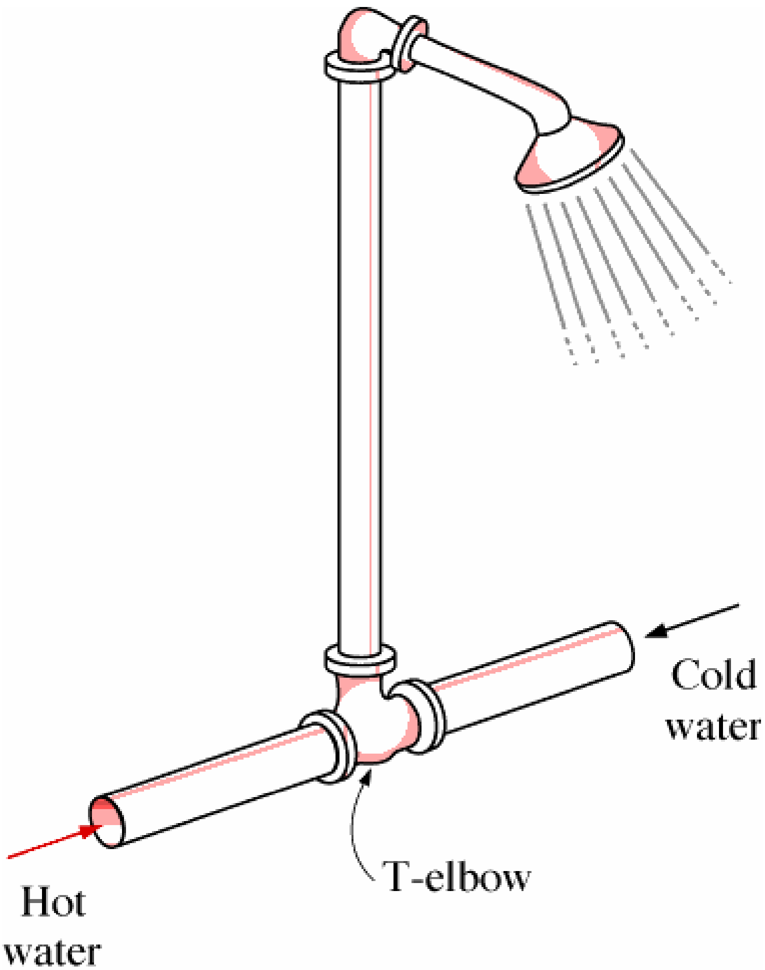
$\Delta h = C_p \Delta T$

But $\Delta h = 0 \rightarrow \Delta T = 0$

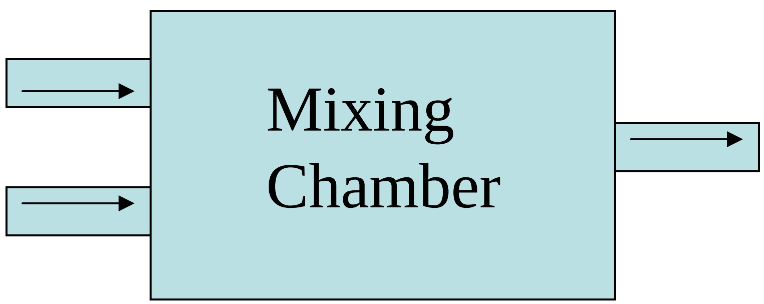
-The inlet and outlet temperatures are the same



Mixing Chamber and Heat Exchanger



Mixing two or more fluids is a common engineering process



Mixing Chamber and Heat Exchanger

$$\dot{Q}_{net} - \dot{W}_{net} = \sum \dot{m}_e \left(h_e + \frac{V_e^2}{2} + gz_e \right) - \sum \dot{m}_i \left(h_i + \frac{V_i^2}{2} + gz_i \right)$$

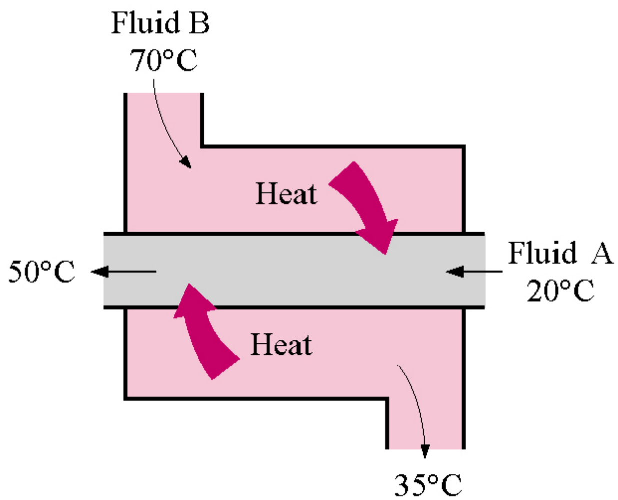
$$0 = \sum \dot{m}_e (h_e) - \sum \dot{m}_i (h_i)$$

Energy Balance

$$\sum \dot{m}_e = \sum \dot{m}_i$$

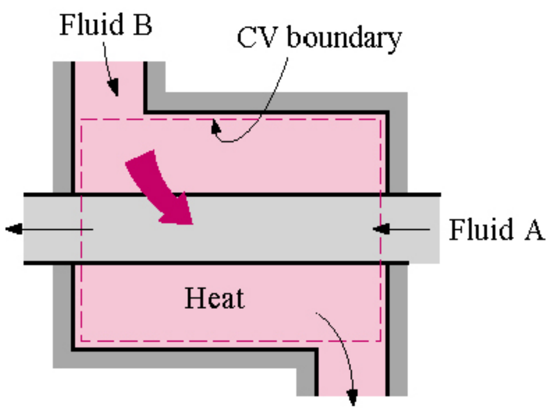
Mass Balance

Mixing Chamber and Heat Exchanger

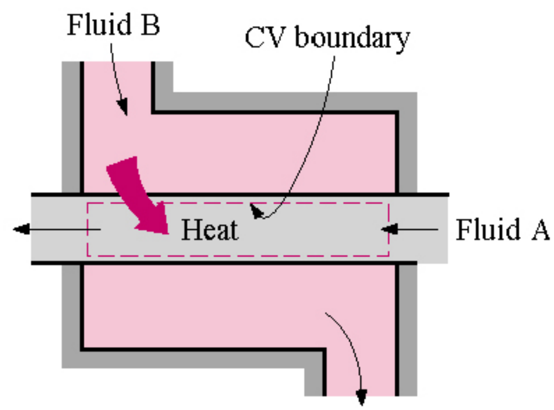


A heat exchanger is a device where two moving fluids exchange heat with or without mixing.

It is important how you define your system



(*a*) System: Entire heat exchanger ($Q_{CV} = 0$)



(*a*) System: Fluid A ($Q_{CV} \neq 0$)

Heat Exchanger

$$\dot{Q}_{net} - \dot{W}_{net} = \sum \dot{m}_e \left(h_e + \frac{V_e^2}{2} + gz_e \right) - \sum \dot{m}_i \left(h_i + \frac{V_i^2}{2} + gz_i \right)$$

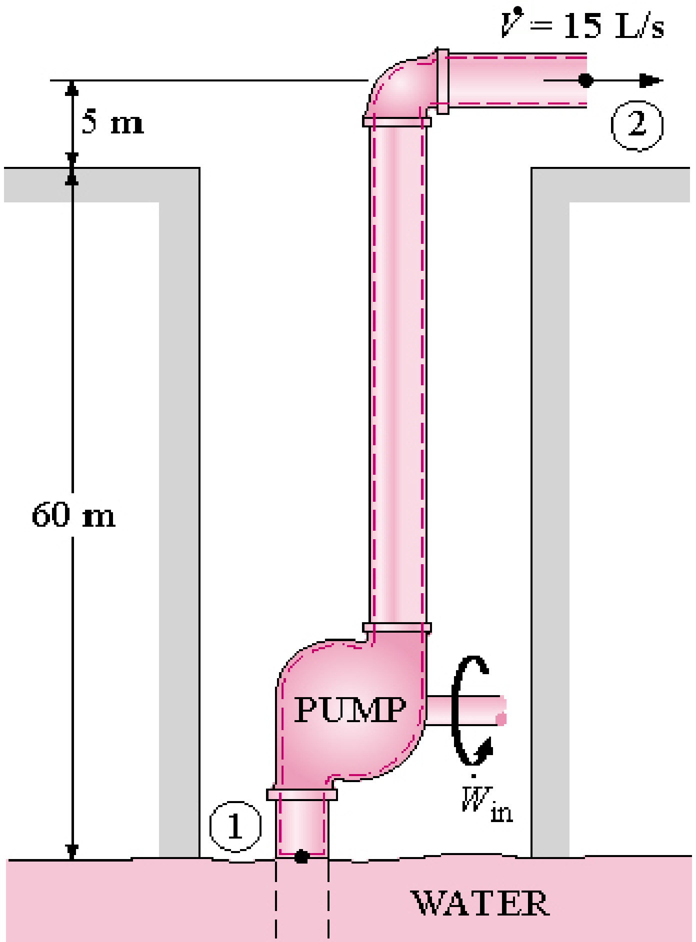
$$0 = \sum \dot{m}_e (h_e) - \sum \dot{m}_i (h_i)$$

Energy Balance

$$\sum \dot{m}_e = \sum \dot{m}_i$$

Mass Balance

Pumps



There's work going into the pump

There's an elevation change

$$\dot{Q} - \dot{W} = \dot{m}\left[h_e - h_i + \frac{V_e^2 - V_i^2}{2} + g(z_e - z_i)\right]$$

or

$$\dot{Q} - \dot{W} = \dot{m}\left[h_e - h_i + g(z_e - z_i)\right]$$

You can combine these processes to create a more complicated system