

SFEE for liquid nozzles, pumps and water turbine: toward the Bernoulli equation

$$\dot{V}_{cv} + \frac{V_{out}^2 - V_{in}^2}{2} + g(z_{out} - z_{in}) = \dot{Q}_{cv}$$

Assumptions:

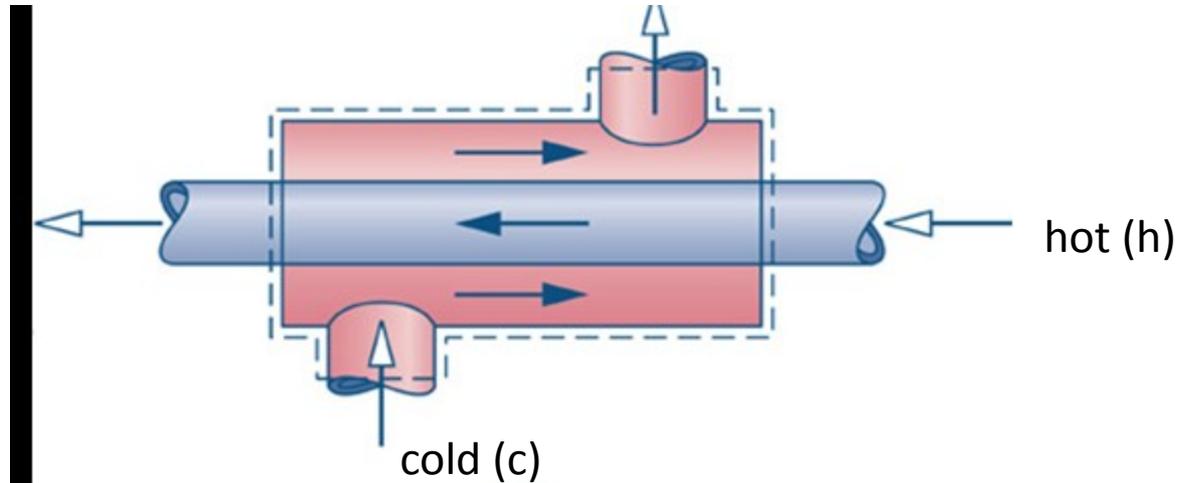
- A. Incompressible substance,**
- B. Negligible heat transfer**
- C. negligible friction despite “the rubbing liquid layers”**
- D. B and C leading to near isothermal operation.**

$$h_{out} - h_{in} = v(p_{out} - p_{in})$$

$$\dot{V}_{cv} \left[-p_{in} + \left(\frac{V_{out}^2 - V_{in}^2}{2} + g(z_{out} - z_{in}) \right) \right]$$

$$= -\dot{V}_{cv} \left[\frac{p_{out}}{\rho} + \frac{V_{out}^2}{2} + gz_{out} \right] - \left[\frac{p_{in}}{\rho} + \frac{V_{in}^2}{2} + gz_{in} \right]$$

SFEE applied to heat exchangers



$$\dot{I}_{c,out} + \dot{I}_{h,out} = \dot{I}_{c,in} + \dot{I}_{h,in}$$

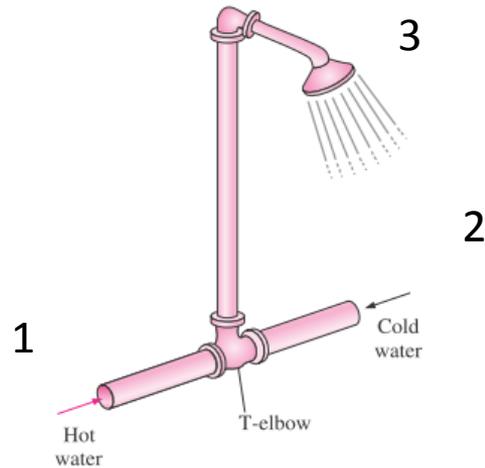
Take CV enclosing the stream that is hot at inlet

$$\dot{I}_{h,out} - \dot{I}_{h,in} = -\dot{Q}$$

Take CV enclosing the stream that is cold at inlet

$$\dot{I}_{c,out} - \dot{I}_{c,in} = \dot{Q}$$

Mixing chambers or “direct contact heat exchangers”

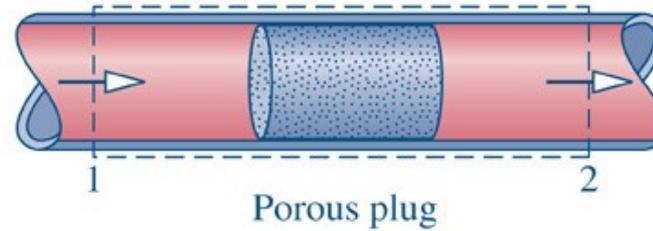
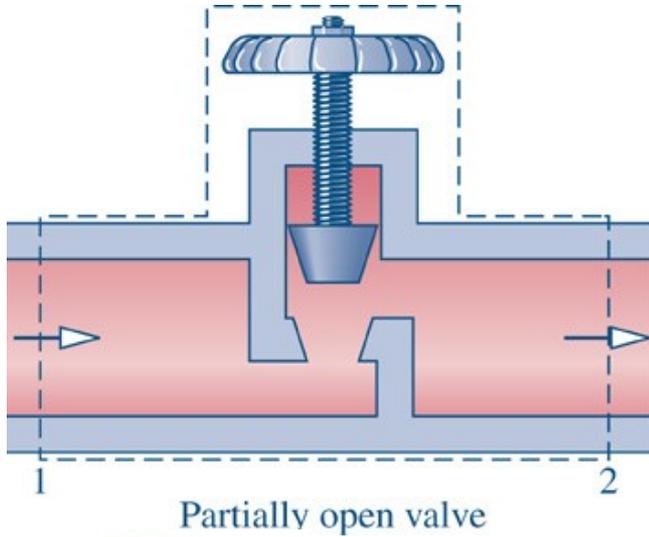


\dot{m} Conservation of mass

\dot{Q} Conservation of energy

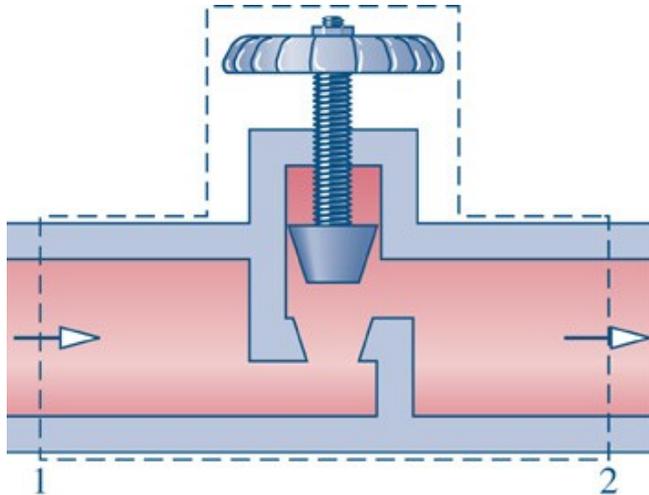
Throttling devices

Flow restriction

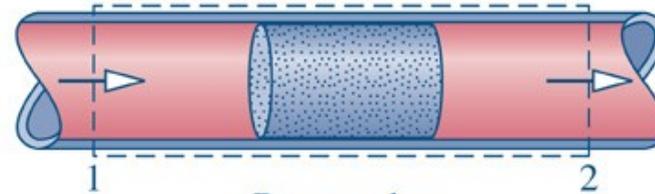


A device that causes a drop in pressure by restricting the flow passage can be termed a throttling device.

Throttling devices



Partially open valve



Porous plug

Flow restriction



Capillary tube expansion valve used to drop refrigerant pressure and temperature

Negligible heat transfer (small devices) $(\propto \text{surface area})$

$$i \cdot \left(\frac{V_2^2 - V_1^2}{2} \right) = 0$$

$$h_2 = h_1$$

- Slow flows, ΔKE effects can be neglected

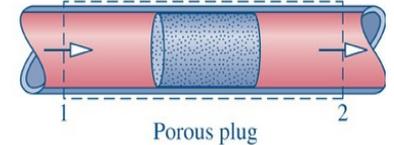
Throttling is an isenthalpic process.

Fundamentally, non-quasiequilibrium.

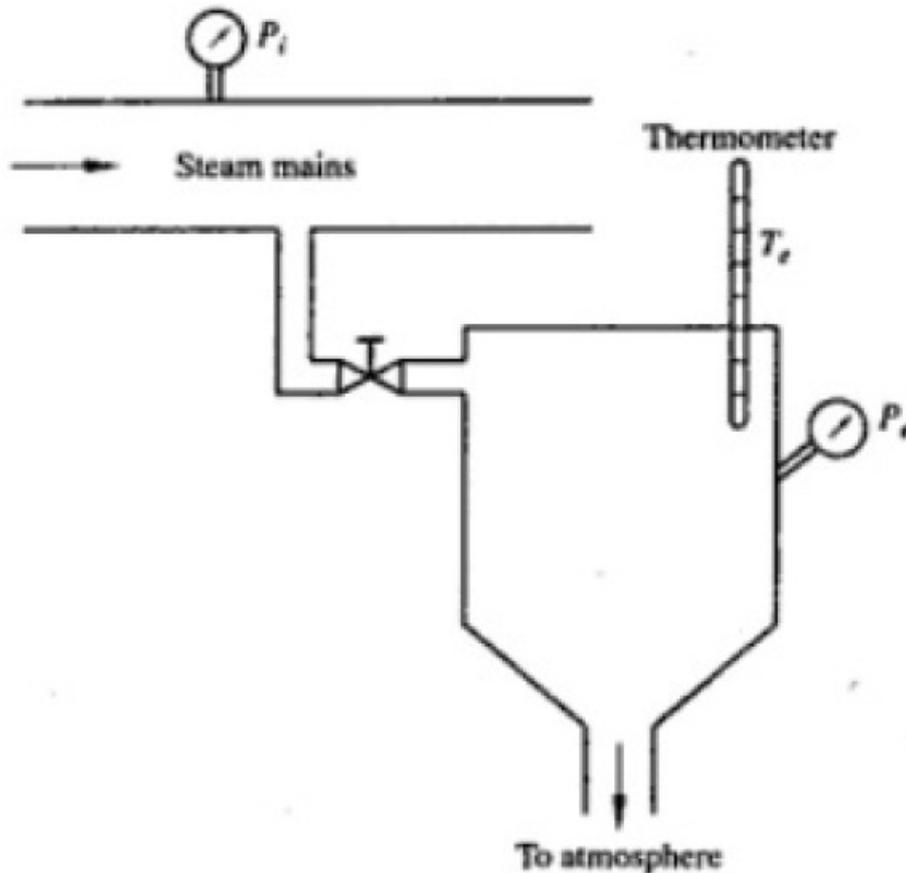
Physical effects in throttling

From upstream to downstream section:

- Pressure (P) drops (due to fluid-solid friction)
- Velocity increases slightly
- Specific volume increases
- Temperature of fluid may increase or decrease or remain same (Joule Thomson effect). **The fluids for which temperature decreases are candidates for use in refrigerators.**
 - Ideal gas \rightarrow temperature remains same.
 - Incompressible substance \rightarrow temperature increases
- Throttling of a refrigerant on T-v / P-v diagram (on board).



Throttling calorimeter to measure steam quality



P-v diagram?
Board!

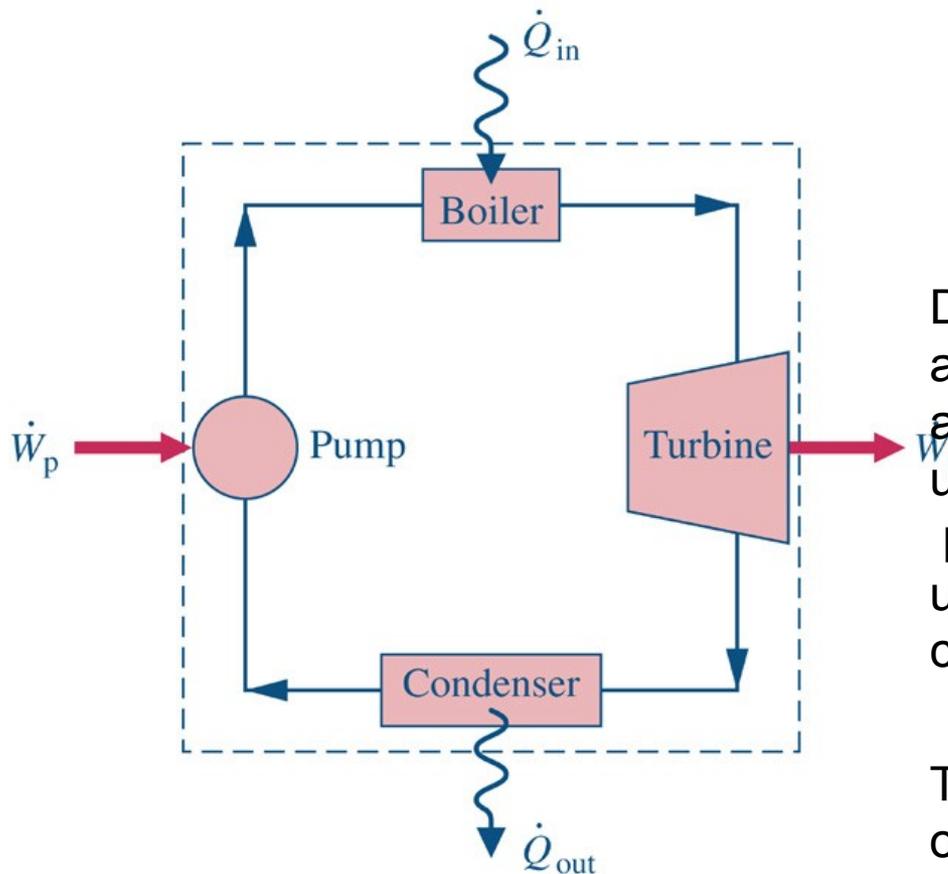
Reading assignment

- Cyclic processes in engineering: “Power cycles” and “Refrigeration cycles”. (Moran Section 2.6, next slide)
- System integration of steady flow devices to execute composite processes and power/refrigeration cycles (Subsection titled “System Integration” of Section 4.3, next slide)

Special topics (not in book, may be covered in lecture)

- Differential form of the steady flow energy equation
- The quasi-equilibrium steady flow heat transfer.

First law analysis of a simple power cycle



For the closed system shown:

$$\dot{Q}_{in} - \dot{Q}_{out} = \dot{W}_t - \dot{W}_p$$

Do *steady state* open system analysis of all components. Boilers/condensers are heat exchangers where one fluid undergoes (here the working fluid of the power plant, usually steam) undergoes vaporization/condensation

Thermal efficiency of a power plant

$$\eta = \frac{\dot{W}_t - \dot{W}_p}{\dot{Q}_{in}}$$