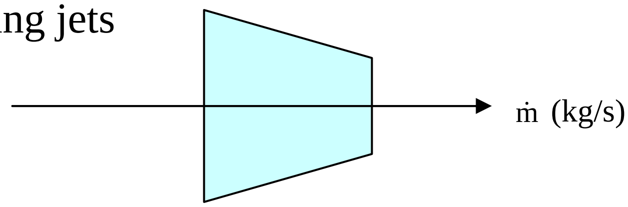
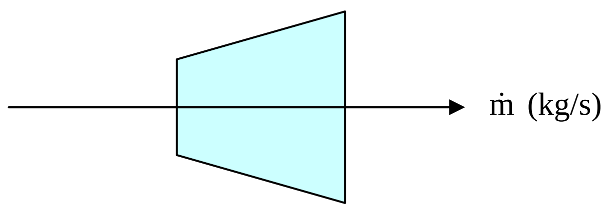
CONTROL VOLUME (OPEN SYSTEM) DEVICES ANALYZED UNDER STEADY-FLOW CONDITIONS

1) NOZZLES AND DIFFUSERS

A) **NOZZLE** is a device to **increase the velocity of a fluid while decreasing pressure** at the same time. Examples: fire hose nozzle, mixing jets



B) **DIFFUSER** is a device to **increase the pressure of a fluid while decreasing velocity** at the same time. Example: air intake to jet engine



General 1st LAW expression for both nozzles and diffusers in simple compressible open system:

$$q - w = [h_2 - h_1 + \frac{(V_2^2 - V_1^2)}{2000}] \text{ when units are (kJ/kg)}$$

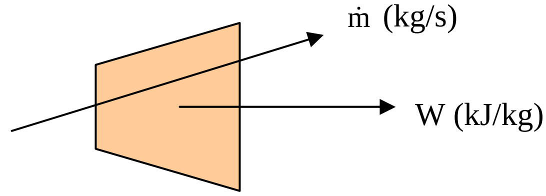
NOTE: unlike many devices we will study, nozzles and diffusers have significant changes in kinetic energy of fluid moving through CV. However, change in potential energy is usually negligible.

Nozzles and diffusers generally do not have work interactions with surroundings (w = 0). Furthermore, often nozzles and diffusers are adiabatic. **The most simplified 1st law expression: if w = 0 and q = 0** and 1st Law is stated:

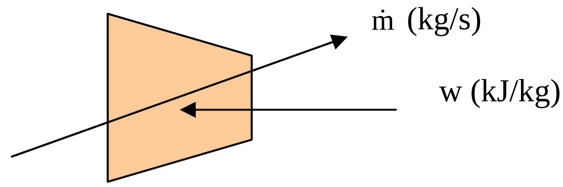
$$0 = [h_2 - h_1 + \frac{(V_2^2 - V_1^2)}{2000}] \text{ units are (kJ/kg)}$$

2) TURBINES, COMPRESSORS, PUMPS, AND FANS

A) **TURBINE** is a device to **produce mechanical (shaft) work at the same time decreasing enthalpy** (or potential energy) of fluid. Examples: steam turbines in power plant, water wheels.



B) **COMPRESSORS, PUMPS, and FANS** are devices to **increase pressure, enthalpy, kinetic energy, and/or potential energy of a fluid, at the cost of work input**. Examples: air compressor.



General 1st LAW Expression the simple compressible open system

$$q - w = [h_2 - h_1 + \frac{(V_2^2 - V_1^2)}{2000} + \frac{g(z_2 - z_1)}{1000}] \text{ (kJ/kg)}$$

TURBINE AND COMPRESSOR NOTE: often compressors and turbines are adiabatic (you would be told this on a problem). Also for steam turbines and vapor and gas compressors, the enthalpy change in the fluid is far greater than the changes in kinetic or potential energy. **If you have an adiabatic turbine/compressor with negligible changes in ke and pe (stationary system), then the simplified 1st law statement is**:

$$-w = [h_2 - h_1] \text{ (kJ/kg)}$$

3) THROTTLING VALVE:

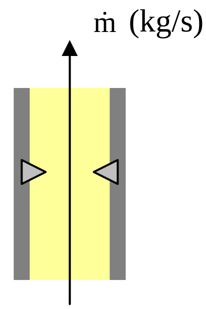
A device to lower pressure and temperature by creating a passive flow obstruction. In general, throttling valves are designed to be adiabatic and since there are no moving parts, there is no work interaction with the surroundings. Furthermore changes in kinetic and potential energy of the fluid are usually negligible.

1st Law Expression for **ISENTHALPIC** throttling valve – a simple compressible open system **(adiabatic and no work interaction)**:

$$0 = [h_2 - h_1]$$

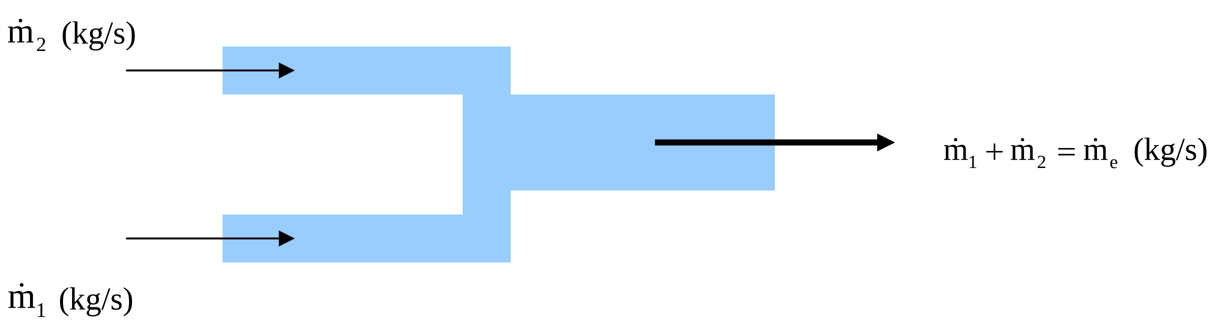
or (kJ/kg)

$$h_2 = h_1$$



4) MIXING CHAMBER

A device to mix two (or more) flows together into a single homogeneous outlet flow. They have no moving parts (no work) and typically are designed to be adiabatic with negligible changes in kinetic and potential energy.



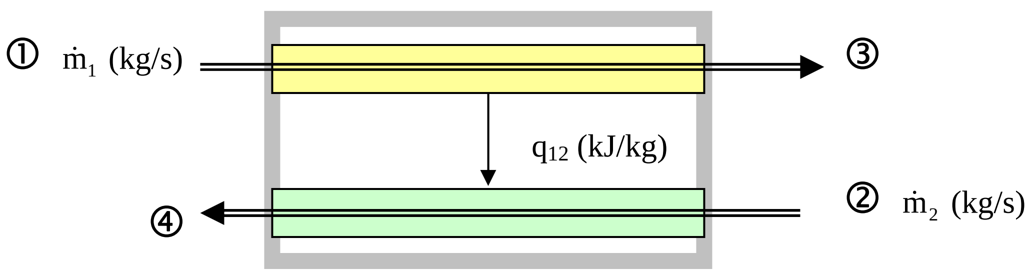
MIXING CHAMBER simplified 1st Law Expression <u>if adiabatic:</u>

$$\dot{m}_e h_e = \sum_i (\dot{m}_i h_i) \quad \text{(kJ)}$$

where $\dot{m}_e h_e =$ energy of mass leaving mixer at outlet (kJ) and $\sum_i (\dot{m}_i h_i)$ = sum of individual inputs of mass energy at each inlet (kJ).

5) HEAT EXCHANGERS

<u>Devices to transfer heat from one fluid stream to another across a solid boundary like a pipe surface.</u> Examples: boilers, condensers. Typically they are **designed to be adiabatic if the boundary encompasses BOTH fluid flows**. Changes in kinetic and potential energy are negligible. Heat exchangers generally do not have work interactions. In this case, heat exchange occurs between two fluids, but not with surroundings outside boundary.

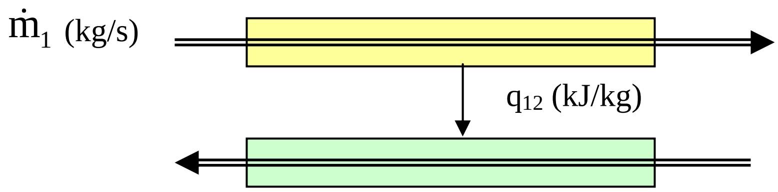


Simplified 1st Law expression for **adiabatic <u>CV with boundary encompassing both flows</u>**

$$0 = \dot{m}_1 (h_3 - h_1) + \dot{m}_2 (h_4 - h_2)$$
$$\dot{m}_1 (h_1 - h_3) = \dot{m}_2 (h_4 - h_2) \quad \text{(kJ)}$$

1st Law expression for <u>CV with one fluid analyze</u>

$$q_{12} = (h_e - h_i) \text{ (kJ/kg)}$$



<u>Glossary</u>

q = specific heat transfer (kJ/kg)
w = specific work (kJ/kg)
h_i = specific enthalpy of material i (kJ/kg)
$\dot{m}$ = mass flow rate (kg/s)
V_i = velocity of material i (m/s)
z_i = elevation of material i (m)
g = acceleration of gravity (m/s^2)
subscript "i" is for inlet state, if not otherwise numbered
subscript "e" is for outlet state, if not otherwise numbered