

Enthalpy balance

It is a generalized concept of the First theorem of thermodynamics applied to flow systems.

Total energy balance:

$$\dot{E}_1 + \dot{Q} + \dot{W} = \dot{E}_2 + \frac{dE_S}{d\tau}$$

where

$$\dot{E} = \dot{U} + \dot{E}_{kin} + \dot{E}_{pot}$$

$$\dot{W} = P + (p_1\dot{V}_1 - p_2\dot{V}_2)$$

U ... internal energy

E_{kin} ... kinetic energy

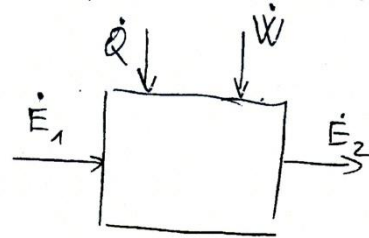
E_{pot} ... potential energy

W ... work

P ... power input

pV ... flow work done by the pressure force as it pushes the volume of the fluid through the input and output

Q ... heat



*Remark: in a closed system where kinetic and potential energies are neglected we recover the **first theorem of thermodynamics**:* $\dot{Q} + \dot{W} = \frac{dU}{d\tau}$ or $Q + W = \Delta U$

We are interested here mainly with heat and then **kinetic** and **potential** energies and power **can be neglected**, $E_{kin} = E_{pot} = P = 0$

Also we assume steady state $\rightarrow \frac{dE_S}{d\tau} = 0$

Therefore the energy balance becomes:

$$\dot{U}_1 + p_1\dot{V}_1 + \dot{Q} = \dot{U}_2 + p_2\dot{V}_2$$

$$\dot{H}_1 + \dot{Q} = \dot{H}_2$$

This equation is used to calculate the heat flow \dot{Q} which can subsequently be used to calculate heat-exchange area (see later).

Evaluation of \dot{H} :

$$\dot{H} = \dot{m}\underline{h} = \dot{n}h$$

h ... specific enthalpy (per unit of mass) [J/kg]

\underline{h} ... molar enthalpy [J/mol]

h (or \underline{h}) is calculated as follows:

$$h = \sum x_i h_i + \Delta h_{mix} \quad , x_i \dots \text{molar fraction of component } i$$

$$\underline{h} = \sum w_i \underline{h}_i + \Delta \underline{h}_{mix} \quad , w_i \dots \text{mass fraction of component } i$$

where enthalpies of pure components are:

$$h_i = \int_{t_{ref}}^t c_{p,i} dt + \sum_{\substack{\text{phase} \\ \text{changes}}} \Delta h_{i, \text{phase change}} \doteq \langle c_{p,i} \rangle (t - t_{ref}) + \sum_{\substack{\text{phase} \\ \text{changes}}} \Delta h_{i, \text{phase change}}$$

$$\langle c_{p,i} \rangle \dots \text{average thermal capacity evaluated at } t = \frac{t + t_{ref}}{2}$$

Typical reference temperature is $t_{ref} = 0 \text{ } ^\circ\text{C}$

relation between \underline{h}_i and h_i :

$$h_i = M_i \underline{h}_i \quad , M_i \dots \text{molar mass of component } i$$

Remarks:

- 1) If chemical reactions take place, then standard molar enthalpy of formation Δh_{f0} must be added to h_i (useful for chemical reactors)
- 2) $c_{p,i}$ can be found in Tables, as well as the mixing enthalpy Δh_{mix} and the enthalpy of phase change