Chemical Engineering
Brigham Young University

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CHEN — Mass and Energy Balances

Intro

Mass and energy balances are keystone principles of chemical engineering. They are critical to evaluate changes in the system as a function of time or under steady state conditions to evaluate inlet and outlet stream composisions and flow rates.

Control Volume Inlets and Outlets

The control volume is the volume about which we evaluate the change to properties or conditions based on inlets and outlets. A control volume may be one or a collection of operational units.

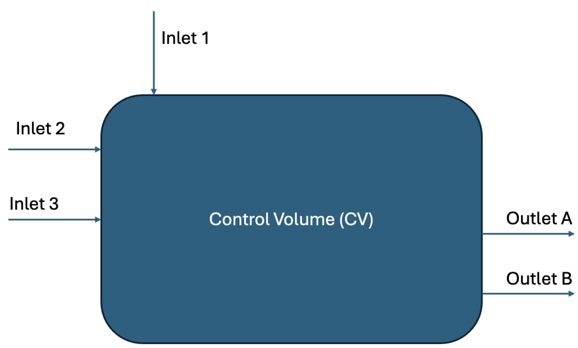

Figure 1: Image showing the control volume and inlets and outlets

The below equation is fundamental to evaluating the system.

$$\boxed{\text{accumulation}_{(CV)} = \text{in} - \text{out} + \text{generation}_{(CV)} - \text{consumption}_{(CV)}} \tag{1-1}$$

Mass (or Mole) Total Balance

$$\frac{dm_{(CV)}}{dt} = \sum_{inlets} \dot{m}_{in} - \sum_{outlets} \dot{m}_{out} + \cancel{gen_{(CV)}} - \cancel{cons_{(CV)}} \tag{1-2}$$

m is mass and that mass balance can be replaced by a total mole balance n. Assuming no nuclear conversion of mass to energy or vice-versa so total mass (or total moles) is not generated or consumed.

Species balances

$$
\begin{aligned}
\frac{dn^i_{(CV)}}{dt} &= \left(\sum_{inlets} \dot{n}^i_{in} - \sum_{outlets} \dot{n}^i_{out} \right) + gen^i_{(CV)} - cons^i_{(CV)} \\
\frac{dn^j_{(CV)}}{dt} &= \left(\sum_{inlets} \dot{n}^j_{in} - \sum_{outlets} \dot{n}^j_{out} \right) + gen^j_{(CV)} - cons^j_{(CV)} \\
\frac{dn^k_{(CV)}}{dt} &= \left(\sum_{inlets} \dot{n}^k_{in} - \sum_{outlets} \dot{n}^k_{out} \right) + gen^k_{(CV)} - cons^k_{(CV)} \\
&\text{et cetera for other species like i,j,k or l,m,n}
\end{aligned}
\tag{1-3}
$$

where n is moles, i, j, k are species, and generation (gen) and consumption ($cons$) terms inside the control volume are typically due to reactions.

Energy balance

$$
\begin{aligned}
\frac{dE_{(CV)}}{dt} &= \frac{d(U + \cancel{K} + \cancel{P})_{(CV)}}{dt} = \frac{dU_{(CV)}}{dt} \\
&= \left(\sum_{inlets} \dot{m} \cdot (h + \frac{v^2}{2} + gz) - \sum_{outlets} \dot{m} \cdot (h + \frac{v^2}{2} + gz) \right) + Q_{(CV)} + W^s_{(CV)}
\end{aligned}
\tag{1-4}
$$

where U is internal energy, K is kinetic energy (assumed zero for the control volume), P is potential energy of the control volume (also assumed to be zero). h is enthalpy (includes flow work), v is the fluid velocity, g is the gravitational constant, z is the height of the inlet or outlet, Q is the heat added (+) or removed (-), and W^s is the shaft work done on (+) or by (-) the control volume.

Submitted by on February 18, 2025.