

Conservation Balance in General: Revisiting Energy Conservation

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In general for all conserved “properties” the “*netIn*” refers to a property net-in-flow through the boundary surface of a system, while the “*netIncrease*” refers to that system property *change* (*increase* is positive change and *decrease* is negative change). The system occupies the volume within the system boundary. The *netIn* means *In* minus *Out* and *netIncrease* means *Increase* minus *Decrease*, which is often called *Change* of property. Therefore, the conservation balance law may be expressed in general as:

$$\boxed{\begin{aligned} In &= Increase + Out \text{ or} \\ netIn &= netIncrease \text{ or } In - Out = Change \end{aligned}}$$

where, *net-* is always applied, i.e. $In = -Out$, or: $In = netIn = In - Out = -Out$, $Out = netOut = Out - In = -In = -netIn$, and $Increase = netIncrease = Increase - Decrease = -Decrease = -netDecrease$

For property energy E , we have (note we use Δ for *change*):

$$\underbrace{E_{netIn}}_{SysBOUNDARY} = \underbrace{\Delta E_{netIncrease}}_{SysVOLUME} \text{ or in rate form } \underbrace{\dot{E}_{netIn}}_{SysBOUNDARY} = \frac{d}{dt} \underbrace{(E)_{Sys_in_CV}}_{SysVOLUME}$$

Furthermore, a system may be closed for any mass flow through the boundary, called *control mass* system or fixed mass system (Sys), or a system may be open for mass flow, called *control volume* system (CV), where in general the CV is allowed to deform and change. At any instant a fixed mass (Sys) occupy a given CV, but one or both may change in time. Energy is unique property since it appears in different forms and may transfer through the boundary of closed system in form of heat transfer or different types of work transfer, i.e. without any mass transfer. In addition, with any mass-flow transfer its energy property is transferred along with mass M , and in addition work is required to push mass through the boundary against system pressure P , or work is obtained when mass is leaving out of the CV under system pressure P , or (note, the specific volume $v = dV/dM$):

$$\underbrace{Q_{netIn} - W_{netOut_M} - W_{netOut_else} + E_{netIn_M}}_{E_{netIn}} = \Delta E_{netIncrease}$$

$$Q_{netIn} - \underbrace{\left(\underbrace{M_{netOut} \cdot (P \cdot v)}_{W_{netOut_M}} + W_{netOut_else} \right)}_{W_{netOut_ALL}} + \underbrace{M_{netIn} \cdot \left(u + \frac{1}{2}V^2 + gz \right)}_{E_{MnetIn}} = \underbrace{E_{Sys2} - E_{Sys1}}_{\Delta E_{netIncrease}}$$

$$\underbrace{Q_{netIn} - W_{netOut_else} + \underbrace{M_{netIn} \cdot \left(u + Pv + \frac{1}{2}V^2 + gz \right)}_m}_{\text{through Sys Boundary}} = \underbrace{M_{Sys2} \left(u + \frac{1}{2}V^2 + gz \right)}_{E_{Sys2}} - \underbrace{M_{Sys1} \left(u + \frac{1}{2}V^2 + gz \right)}_{E_{Sys1}} = \underbrace{\Delta E_{Sysin CV}}_{\substack{e=E/M \\ \Delta E_{Sysin CV}}}$$

For spatially non-uniform properties flow through the system boundary, integration of related infinitesimal quantities over the system boundary, or for spatially non-uniform properties change in control volume (CV), integration over the system CV will be needed.

For a steady-state process there is no *Change* of system properties in time (thus no *Increase* or *Decrease*). It is convenient then to consider the property balance per unit of time or in rate form. If the process is transient, i.e. non-uniform properties in time, then integration over time will be needed.