$$\frac{d}{dt}\left\{U + M\left(\frac{v^2}{2} + \Psi\right)\right\} = \sum_{k=1}^{K} \dot{M}_k\left(\hat{U} + \frac{v^2}{2} + \Psi\right)_k + \dot{Q} + \underbrace{\dot{W}_s - P\frac{dV}{dt}}_{W} + \sum_{k=1}^{K} \dot{M}_k\left(P\hat{V}\right)_k$$

Note: we can have equivalent energy Balance for Molar basis

Mass	Molar
$\dot{M}\left(\frac{v^2}{2} + \Psi\right)$	$N m\left(\frac{v^2}{2} + \Psi\right)$
$\dot{M}_k\left(\hat{H} + \frac{v^2}{2} + \Psi\right)_k$	$\dot{N}_k\left(\underline{H} + m\left(\frac{v^2}{2} + \Psi\right)\right)_k$
$M\hat{U}$	$N\underline{U}$

Thus for → differential form energy balances

$$\left[U + M\left(\frac{v^2}{2} + \Psi\right)\right]_{\underline{t_2}} - \left[U + M\left(\frac{v^2}{2} + \Psi\right)\right]_{\underline{t_1}} =$$

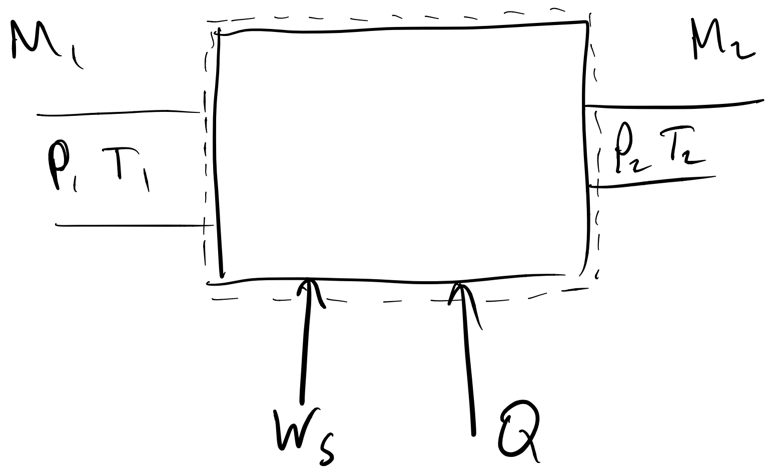
$$\sum_{k=1}^{K} \int_{t_1}^{t_2} \dot{M}_k \left(\hat{H} + \frac{v^2}{2} + \Psi\right)_k dt + \underline{Q} + \underline{W}$$

$$\underline{Q = \int_{t_1}^{t_2} \dot{Q}\, dt} \qquad W = W_s - \int_{V(t_1)}^{V(t_2)} P\, dV$$

$$W_s = \int_{t_1}^{t_2} \dot{W}_s\, dt \qquad \int_{V(t_1)}^{V(t_2)} P\, dV = \int_{t_1}^{t_2} P \frac{dV}{dt}\, dt$$

For BME's — LVAD

For ABE's → Compressor



Do open system analysis →

1) Mass balance

2) Energy balance

To show that

$$Q + W_s = (\hat{H}_2 - \hat{H}_1)\,\Delta M$$

where ΔM is flow in a small time interval. t to $t+\Delta t$

1) Take system as compressor

Mass balance on compressor itself,

$$M(t+\Delta t) - M(t) = \int_t^{t+\Delta t} \dot{M}_1 \, dt + \int_t^{t+\Delta t} \dot{M}_2 \, dt = 0$$

lets choose Δt so $\dot{M}_1 \sim$ constant

$\dot{M}_2 \sim$ constant.

$$\dot{M}_1 \Delta t + \dot{M}_2 \Delta t = \Delta M_1 + \Delta M_2 = 0$$

$$\boxed{\Delta M_1 = -\Delta M_2 = \Delta M}$$

Energy Balance

$$\cancel{\left[U + M\left(\frac{v^2}{2} + \Psi\right)\right]_{t_2}} - \cancel{\left[U + M\left(\frac{v^2}{2} + \Psi\right)\right]_{t_1}} =$$

$$\underset{\text{2 streams}}{\longrightarrow} \sum_{k=1}^{K} \int_{t_1}^{t_2} \dot{M}_k \left(\hat{H} + \cancel{\frac{v^2}{2} + \Psi}\right)_k dt + Q + \underset{W_s}{\cancel{W}}$$

1) Steady flow - Red

2) $W = W_s - \cancel{\int_{V(t_1)}^{V(t_2)} P \, dV} = 0$ → system boundaries fixed

Blue

3) kinetic; potential $= 0$ green

$$\int_{t_1}^{t_2} \dot{M}_1 (\hat{H}_1)\, dt + \int_{t_1}^{t_2} \dot{M}_2 (\hat{H}_2)\, dt + Q + W_s$$

$\hat{H}_1$ is not changing in time

$\hat{H}_2$ is not changing in time

$$0 = \hat{H}_1 \int_{t_1}^{t_2} \dot{M}_1\, dt + \hat{H}_2 \int_{t_1}^{t_2} \dot{M}_2\, dt + Q + W_s$$

→ sub in mass balance

$$0 = \Delta M_1 \hat{H}_1 + \Delta M_2 \hat{H}_2 + Q + W_s$$

$$\Delta M_1 = -\Delta M_2 \equiv \Delta M$$

$$0 = \Delta M (\hat{H}_1 - \hat{H}_2) + Q + W_s$$

$$\boxed{\Delta M (\hat{H}_2 - \hat{H}_1) = Q + W_s}$$