THERMO

SFEE

(i) Energy Balance

Work transfer is of two types

(i) External work ↓ W_x (ii) flow work ↓ pvm

Total work = $W_x - p_1v_1dm_1 + p_2v_2dm_2$

v → specific volume

e → specific energy [energy carried into or out of the control volume with unit mass of fluid]

$$e = \frac{V^2}{2} + gZ + u \cdot pv$$

$h = u + pv$

SFEE equ: $w_1\left(h_1 + \frac{V_1^2}{2} + gZ_1\right) + \left(\frac{dQ}{dm}\right) = w_2\left(h_2 + \frac{V_2^2}{2} + gZ_2\right) + \left(\frac{dW_x}{dm}\right)$

inlet (heat) = outlet (work)

(ii) mass Balance

$w_1 = w_2$

$$\frac{A_1V_1}{v_1} = \frac{A_2V_2}{v_2}$$

Specific vol. ← v_1

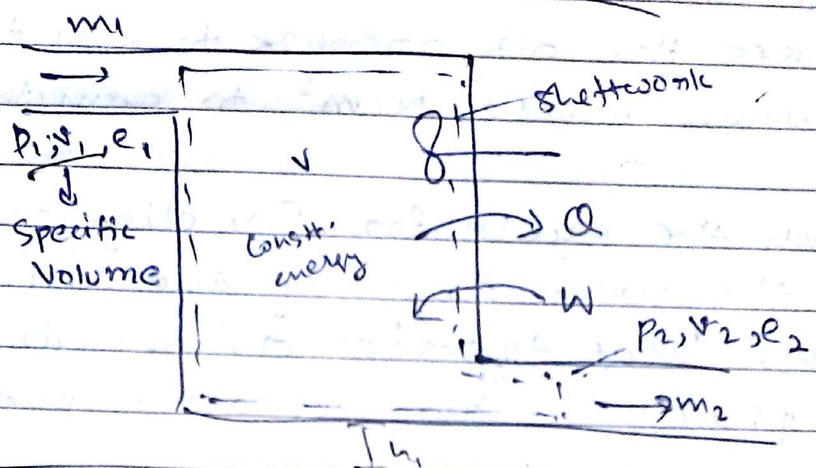
V_1 → inlet Velocity

insulated $Q = 0$
no shaft work $W = 0$

$E = me$ → specific energy; E = total energy

Steam Table

First law for Open System (Flow device)



$Q - W = \Delta E$

$$\Sigma Q - \Sigma W = \Delta E = E_2 - E_1$$ ☆☆☆

$$\Sigma W = \Sigma W_{ext} + (p_1 v_1 m_1 - p_2 v_2 m_2)$$ → Total work (flow work)

$$E_1 = E_{c,i} + e_1 m_1$$

$$E_2 = E_{c,f} + e_2 m_2$$

we consider Steady flow

Conservation of mass

$m_1 = m_2$

$$\frac{dE_{c,v}}{dt} = 0 \Rightarrow E_{c,f} = E_{c,i}$$

$$\Sigma Q - (\Sigma W_{ext} + p_1 v_1 m_1 - p_2 v_2 m_2) = e_2 m_2 - e_1 m_1$$

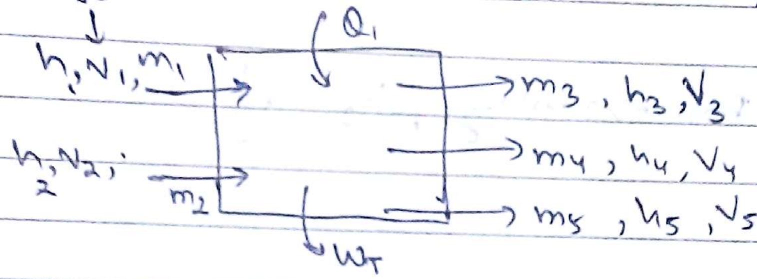
(ΣW; E_2; E_1)

$$\Sigma Q - \Sigma W_{ext} = m_2(e_2 + p_2 v_2) - m_1(e_1 + p_1 v_1)$$

$e = U + \frac{V^2}{2} + gz$ Ex

Enthalpy → $h = U + pv$ (h: specific enthalpy; U: specific internal energy)

$$\Sigma Q - \Sigma W_{ext} = \Sigma_{outlet} m \left(h + \frac{V^2}{2} + gz\right) - \Sigma_{inlet} \left(h + \frac{V^2}{2} + gz\right)$$



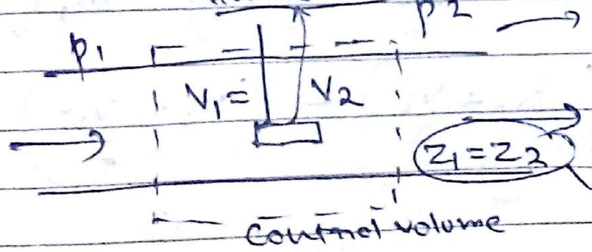
$$Q_T - W_T = m_3\left(h_3 + \frac{V_3^2}{2}\right) + m_4\left(h_4 + \frac{V_4^2}{2}\right) + m_5\left(h_5 + \frac{V_5^2}{2}\right) - m_1\left(h_1 - \frac{V_1^2}{2}\right) - m_2\left(h_2 + \frac{V_2^2}{2}\right)$$

Application of SFEE

Study

Throttling device

(1)

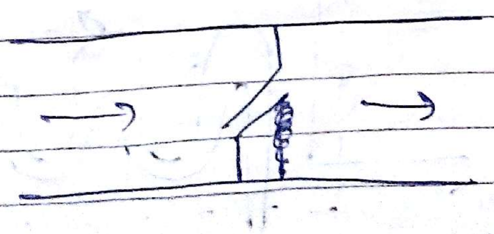


→ No external work (no shaft) $W_{ext} = 0$

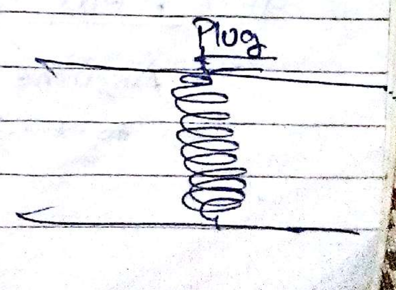
$Q = 0$

$Z_1 = Z_2$ No change in elevation

(2)

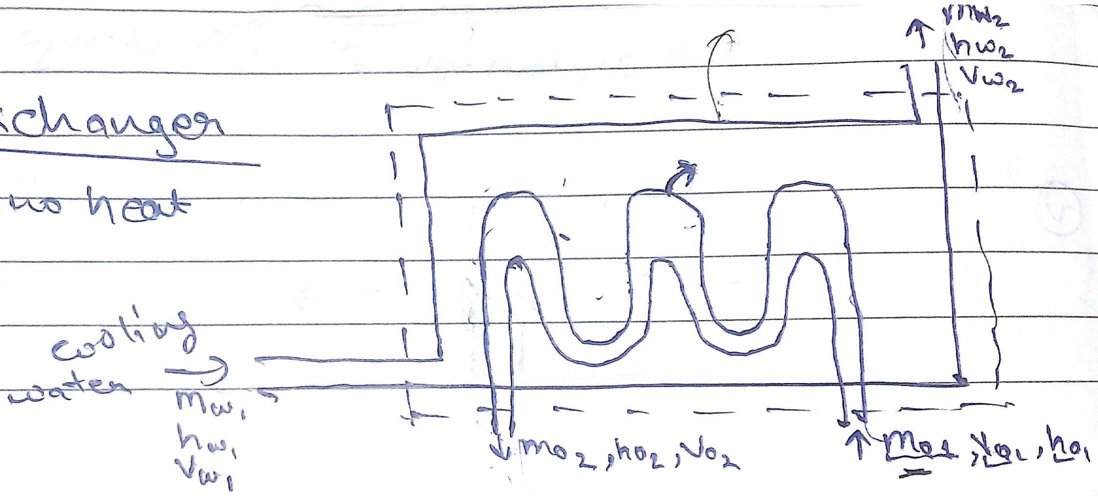


(3)



heat exchanger

(Assume no heat loss to atm.)



$$Q - W_x = \sum_{out} m\left(h + \frac{V^2}{2} + gz\right) - \sum_{in}\left(h + \frac{V^2}{2} + gz\right)$$

$$0 - 0 = m_{w_2}\left(h_{w_2} + \frac{V_{w_2}^2}{2}\right) + m_{o_2}\left(h_{o_2} + \frac{V_{o_2}^2}{2}\right)$$

(no heat exchange across control volume boundary) (no external work)

$$- m_{w_1}\left(h_{w_1} + \frac{V_{w_1}^2}{2}\right) - m_{o_1}\left(h_{o_1} + \frac{V_{o_1}^2}{2}\right)$$

* $\rho_{air} = 1.2\ kg/m^3$ ★ — standard

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Steady flow eqn (Energy balance)

$$\dot{Q} - \dot{W}_x = \Sigma m_{out}\left(h_2 + \frac{V_2^2}{2} + gZ_2\right) - \Sigma m_{in}\left(h_1 + \frac{V_1^2}{2} + gZ_1\right)$$

$$\dot{Q} = \frac{dQ}{dt} \qquad \dot{W}_x = \frac{dW_x}{dt}$$

Units:

$P = kPa$

$Q = kW$

$W_x = kW$

$m = kg/s$

$10^{-3} \times \frac{V^2}{2} = \frac{kJ}{kg}$

$h = kJ/kg$

$U + pV = kJ/kg$

$v = m^3/kg$

$$\frac{kJ}{s} = kW = \frac{kg}{s}\left[\frac{kJ}{kg}\right]$$

Mass balance

$w_1 = w_2$

$$\frac{A_1V_1}{v_1} = \frac{A_2V_2}{v_2}$$

To find mass flow

$$\dot{m}_1 = \frac{P_1 V_1}{R T_1}$$

$P_1 \to kPa,$
$V_1 \to m^3/s$
$R \to 0.287$ kJ/kg
$T_1 \Rightarrow$ K

C_p of air = 1.005

To find 'h' if 'T' is given

$$h = C_p T$$