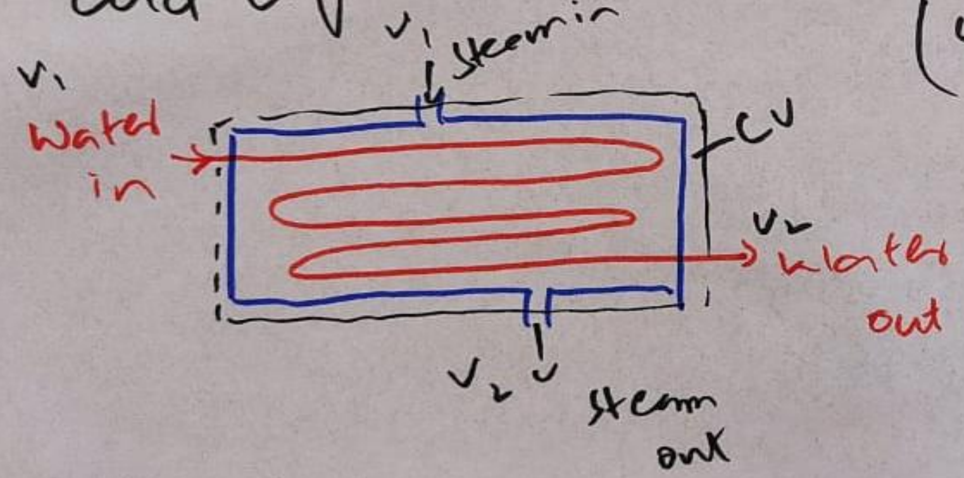
SFEE Applications and Problems

Heat Exchangers (SFEE)

2 Fluids

Liquid → Gases

Hot Liquid ↓ Cold Liquid



Condenser

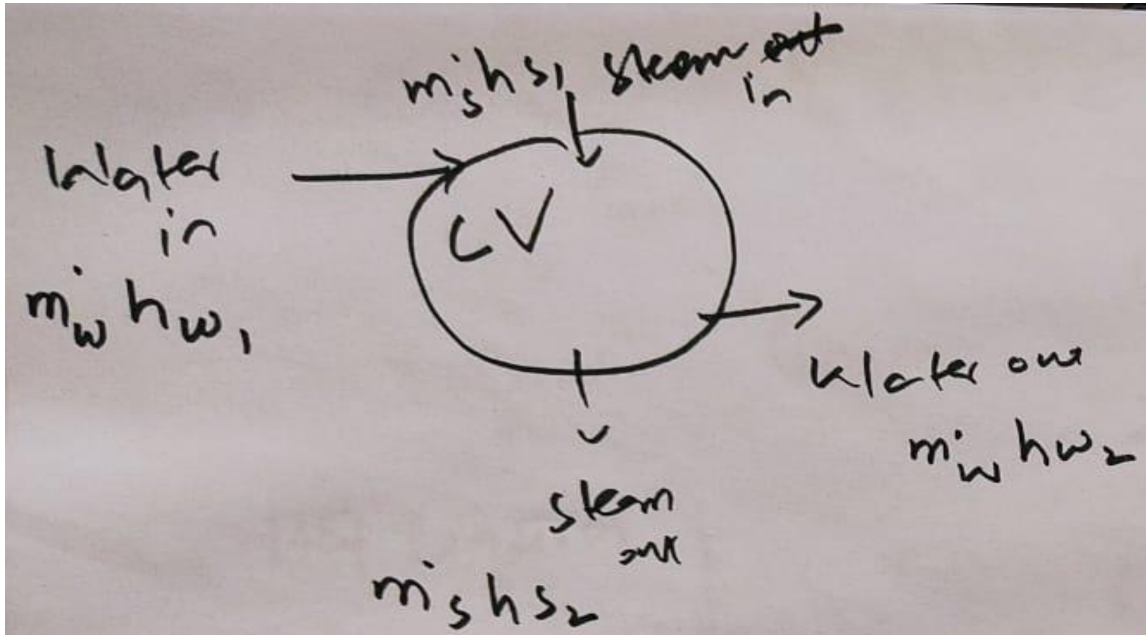
1) $W = 0$ } $dW/dm = 0$

2) $Q = 0$ } $dQ/dm = 0$

(3) ΔKE are negligible

(4) ΔPE

$v_1 = v_2$ $\quad z_1 = z_2$



Steady Flow

Mass Balance

$$\dot m_{in} - \dot m_{out} = 0$$

Energy Balance

$$\dot E_{in} - \dot E_{out} = 0$$

$\dot m_w h_{w1}$ (mass flow rate x Enthalpy) = Rate of Energy interactn.

$$kg/s \times kJ/kg = kJ/s = \dot E$$

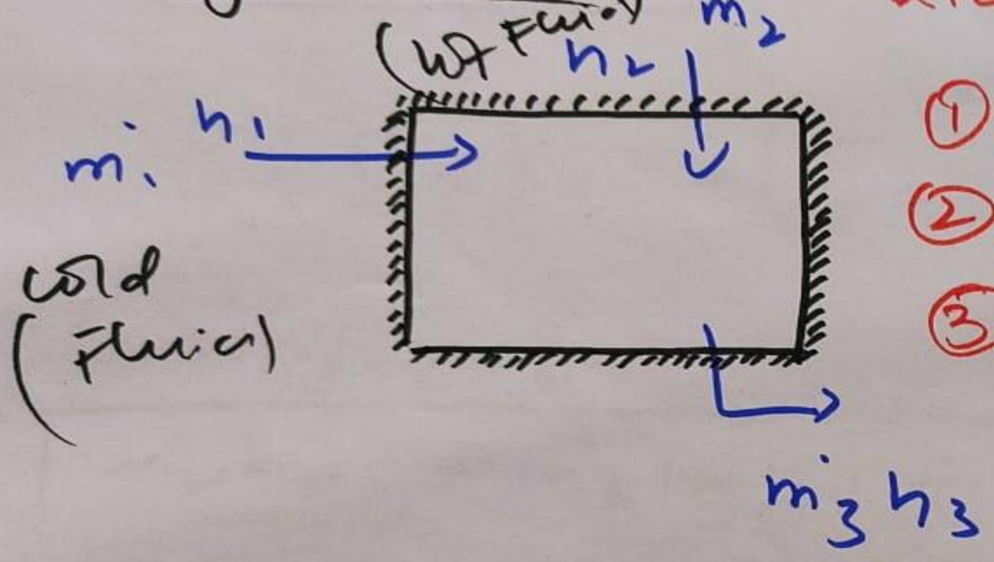
$$\underbrace{\dot{m}_w h_{w_1} + \dot{m}_s h_{s_1}}_{(E_{in})} - \underbrace{\dot{m}_w h_{w_2} + \dot{m}_s h_{s_2}}_{(E_{out})} = 0$$

$$(E_{in}) - (E_{out}) = 0$$

Energy Balance (SFEE for H·E)

$$\boxed{\dot{m}_w h_{w_1} + \dot{m}_s h_{s_1} = \dot{m}_w h_{w_2} + \dot{m}_s h_{s_2}}$$

Mixing Chamber



Well Insulated

Assumptions

1. $Q = 0$
2. $W = 0$
3. ΔKE & $\Delta PE = 0$

$v_1 = v_2$ $z_1 = z_2$

Mass Balance

(Steady Flow)

$$\boxed{\dot{m}_{in} - \dot{m}_{out} = \cancel{\Delta}\, 0}$$

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$$\dot{m}_1 + \dot{m}_2 - \dot{m}_3 = 0$$

$$\boxed{\dot{m}_1 + \dot{m}_2 = \dot{m}_3}$$

Energy Balance (Steady Flow)

$$\dot{E}_{in} - \dot{E}_{out} = 0$$

$E = $ (mass flow rate × Enthalpy)

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 - \dot{m}_3 h_3 = 0$$

$$\boxed{\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3}$$

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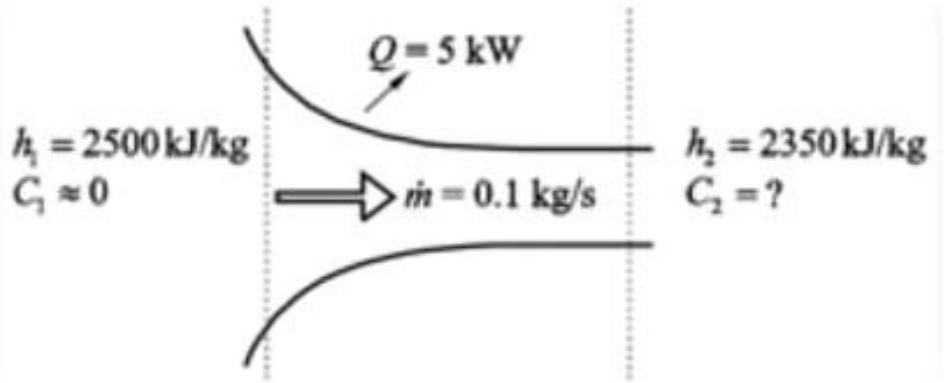
Topic : Steady Flow Energy Equation

Question

Steam flows through a nozzle at a mass flow rate of $\dot{m} = 0.1\,\text{kg/s}$ with a heat loss of 5 kW. The enthalpies at inlet and exit are 2500 kJ/kg and 2350 kJ/kg respectively. Assuming negligible velocity at inlet $(C_1 \approx 0)$, the velocity (C_2) of steam (in m/s) at the nozzle exit is ________ (correct to two decimal places).



Num II: Sol

Nozzle

$h_1 = 2500\ kJ/kg$ $\quad \dot{m} = 0.1\ kg/s$ $\quad h_2 = 2350\ kJ/kg$

$v_1 = 0$

$V_2 = ?$

$Q = 5\ kW$

$5\ kJ/s$

1) $W = 0$ 2) $\Delta PE = 0$

SFEE

$$\dot{m}\left(h_1 + \frac{v_1^2}{2} + g z_1\right) \quad J/kg$$

$$\dot{m}\left(h_1 + \frac{\cancel{v_1^2}}{2000} + \frac{\cancel{g z_2}}{1000}\right) + Q$$

$$= \dot{m}\left(h_2 + \frac{v_2^2}{2000} + \frac{\cancel{g z_2}}{1000}\right) + \cancel{W}$$

$$\cancel{0.1\,\tfrac{5}{ }\,2500\ldots}$$

$$0.1(25050) - 5 = 0.1\left[(2350) + \frac{V_2^2}{2000}\right] + 0$$

$$\boxed{\mathrm{kg/s}\ \frac{\mathrm{kJ}}{\mathrm{kg}} - \mathrm{kJ/s} = \mathrm{kJ/s}}$$

kW

Dimensional Homogeneity

$$\boxed{V_2 = 447.21\ \mathrm{m/s}}$$

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Topic : Steady Flow Energy Equation

Question

A steam turbine receives steam steadily at 10 bars with an enthalpy of 3000 kJ/kg and discharges at 1 bar with an enthalpy of 2700 kJ/kg. The work output is 250 kJ/kg. The changes in kinetic and potential energies are negligible. The heat transfer from the turbine casing to the surroundings is equal to

(A) 0 kJ (B) 50 kJ

(C) 150 kJ (D) 250 kJ

Given:

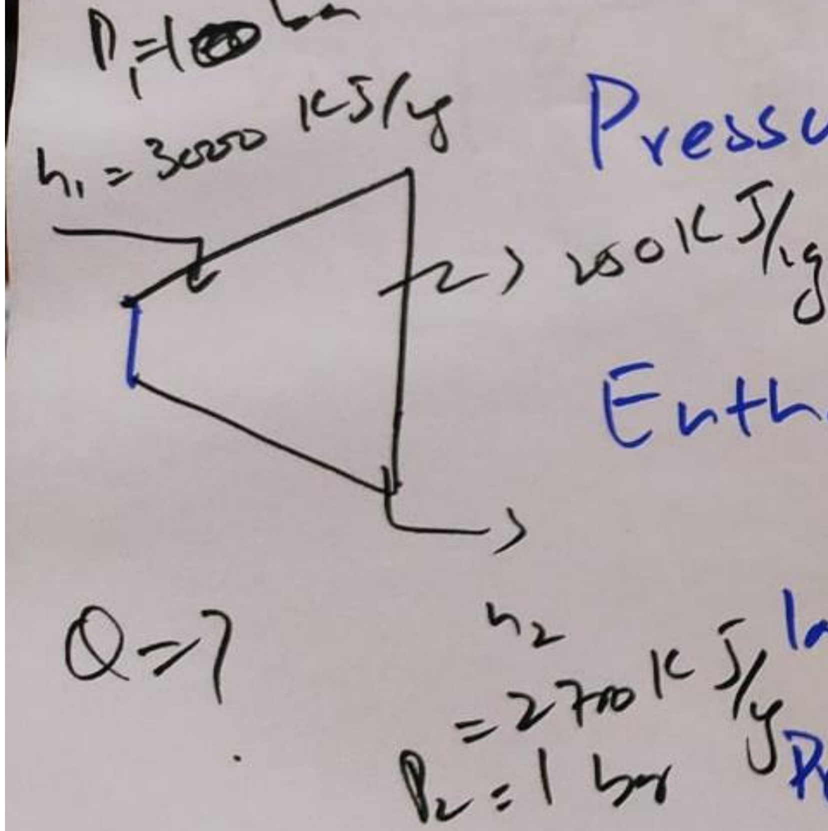
Enthalpy at Inlet $(h_1) = 3000\ KJ/kg$

Pressure for steam at Inlet $(P_1) = 10\ bar$

Enthalpy at outlet $(h_2) = 2700\ KJ/kg$

Work output $(W) = 250\ KJ/kg$

Pressure (outlet) $P_2 = 1\ bar$



SFEE

$$\dot{m}\left(h_1 + \frac{\cancel{v_1^2}}{2000} + \frac{\cancel{gz_1}}{1000}\right) + Q = \dot{m}\left(h_2 + \frac{\cancel{v_2^2}}{2000} + \frac{\cancel{gz_2}}{1000}\right) + W$$

1kg (mass basis) equation

1kg/s (time basis) equation

$$h_1 + Q = h_2 + W$$

$$3000 + Q = 2700 + 250$$

$$= 2950 - 3000$$

$$\boxed{Q = -50 \text{ KJ/kg}}$$

(a)

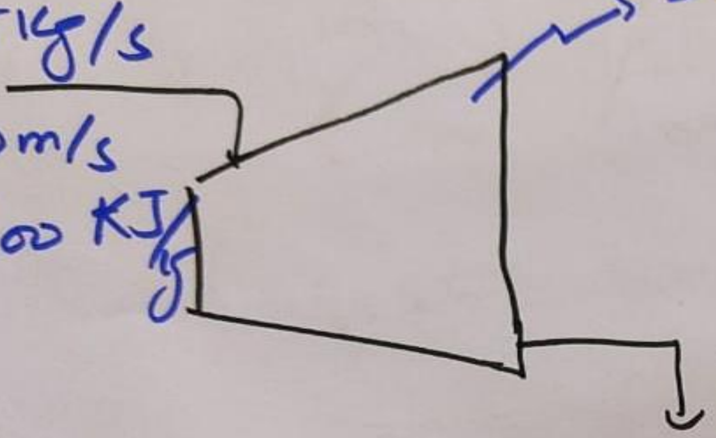
Given

$\dot{m} = 5 \, kg/s$

$v_1 = 50 \, m/s$

$h_1 = 900 \, KJ/kg$

$Q = 25 \, KJ/kg$



$v_2 = 150 \, m/s$

$h_2 = 400 \, KJ/kg$

$R = 0.285 \, KJ/kg \, K$

$C_p = 1.00 \, KJ/kg \, K$

$P_1 = 100 \, bar$

$T_1 = 27 \, °C$

(1) Power output $(\dot{W}) \, KW$

(2) Diameter of inlet pipe

$Q = 25 \, KJ/kg \times \dot{m}$

$= 25 \, KJ/kg \; 5 \times kg/s$

$\dot{Q} = 125 \, KJ/s$

$\boxed{\dot{Q} = 125 \, KW}$

$\Delta KE \neq 0$ (Special case)

SFEE

$$\dot{m}\left(h_1 + \frac{V_1^2}{2000} + \cancel{\frac{g z_1}{1000}}\right) + Q$$

$$= \dot{m}\left(h_2 + \frac{V_2^2}{2000} + \cancel{\frac{g z_2}{1000}}\right) + W$$

$$5\left(900 + \frac{(50)^2}{2000}\right) - 125 = 5\left(400 + \frac{150^2}{2000}\right) + W$$

$$\boxed{|W| = 2325\ kW}$$

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Topic : Steady Flow Energy Equation

Question

In a gas turbine the gas enters at the rate of 5 kg/s with a velocity of 50 m/s and enthalpy of 900 kJ/kg and leaves the turbine with a velocity of 150 m/s and enthalpy of 400 kJ/kg. The loss of heat from the gases to the surroundings is 25 kG/kg. Assume for gas $R = 0.285$ kJ/kgK and $c_p = 1.004$ kJ/kgK and the inlet conditions to be at 100 kPa and 27^0C. Determine the power output of the turbine and the diameter for the inlet pipe.

Diameter of Inlet Pipe

$Q = A V$

$\dot{V} = \hookrightarrow$ Volumetric Flow rate (m^3/s)

$PV = m RT$

$P\dot{V} = \underline{\dot{m}} RT$

$PQ = \dot{m} RT$

$P \frac{V^3}{s} = kg/s \, RT$

$PQ = \dot{m} RT$

$100 \times 10^2 \times Q = 5 \times 0.287 \times 300$

$100 \times 10^2 \, KPa = 100 \, bar$

$Q = 0.04305 \, m^3/s$ (1)

$T_1 = 27^\circ C = 300 \, K$

$Q = A \times V$

$$0.04305 = \frac{\pi}{4} D^2 V_i$$

$$\sqrt{\frac{\frac{4}{\pi}(0.04305)}{V_i}} = \sqrt{D^2}$$

$D = 0.0331\text{ m}$

$$\boxed{D = 33.10\text{ mm}}$$

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