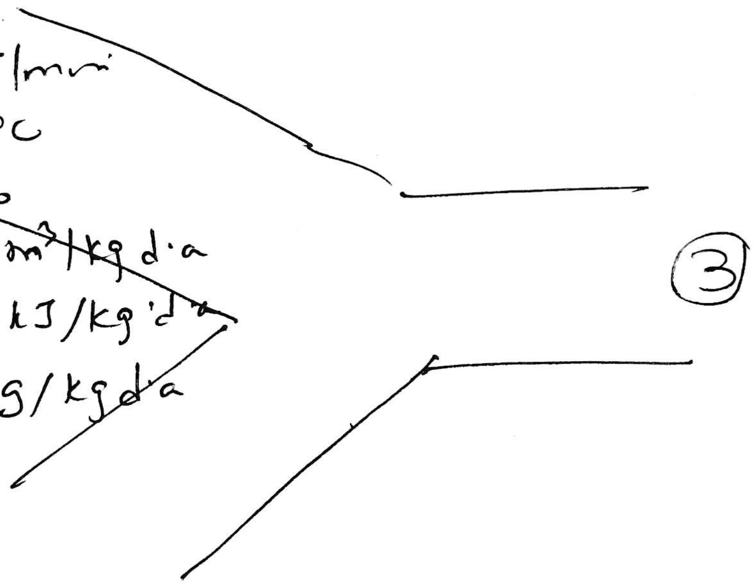
A stream of air at a flow rate of 150 m^3/min with dry bulb temperature of 24C and RH of 50% mixes with a stream of air with a flow rate of 300 m^3/min with dry bulb temperature of 40C and RH 30%. Determine the dry bulb temperature and relative humidity at the exit



1

$\dot{V}_1 = 150 \, m^3/min$

$T_d = 24°C$

$RH = 50\%$

$v_1 = 0.854 \, m^3/kg \, d.a$

$h_1 = 47.9 \, kJ/kg \, d.a$

$\omega_1 = 9.336 \, g/kg \, d.a$

2

$\dot{V}_2 = 300 \, m^3/min$

$T_2 = 40°C$

$RH = 30\%$

$v_2 = 0.907 \, m^3/kg \, d.a$

$h_2 = 76.2 \, kJ/kg \, d.a$

$\omega_2 = 13.96 \, g/kg \, d.a$

Mass Balance Air : $\dot{m}_{a_1} + \dot{m}_{a_2} = \dot{m}_{a_3}$

Vapor $\dot{m}_{v_1} + \dot{m}_{v_2} = \dot{m}_{v_3}$

Energy : $\dot{H}_1 + \dot{H}_2 = \dot{H}_3$

$\dot{m}_{a_1} h_1 + \dot{m}_{a_2} h_2 = \dot{m}_{a_3} h_3$

$\cancel{\dot{m}_{a_1}}$ $\dot{m} = \dot{m}_{a_1} + \dot{m}_v$

$= \dot{m}_a (1 + \omega_1)$

$v = \frac{V}{m}$ $\dot{m}_{a_1} = \frac{\dot{V}_2}{v_1} = \frac{150 m^3/min}{0.854}$

$= 175.6 \, kg/min$

$\dot{m}_{a_2} = \frac{\dot{V}_2}{V_2} = \frac{300 m^3/min}{0.907}$

$= 330.76 \, kg/min$

$\dot{m}_{v_1} = \omega_1 \dot{m}_{a_1}$

$= (9.336)(175.6) \times 10^{-3}$

$= 1.64 \, kg/min$

$\dot{m}_{v_2} = \omega_2 \dot{m}_{a_2}$

$= (13.96)(330.76)(10^{-3})$

$= 4.5 \, kg/min$

(2)

$\dot{m}_{v_3} = \dot{m}_{v_1} + \dot{m}_{v_2} = 1.64 + 4.5 = 6.1 \text{ kg/min}$

$\dot{m}_{a_3} = \dot{m}_{a_1} + \dot{m}_{a_2} = 330.76 + 175.6 = 506.36 \text{ kg/min}$

$$\omega_3 = \frac{\dot{m}_{v_3}}{\dot{m}_{a_3}} = \frac{6.1}{506.36} = 0.01205 \text{ kg/kg d.a}$$

$\dot{m}_{a_1} h_1 + \dot{m}_{a_2} h_2 = \dot{m}_{a_3} h_3$

$\cancel{\dot{m}_a}\ (506.36)\, h_3 = (175.6)(47.9) + (330.76)\, 76.2$

$\Rightarrow \quad h_3 = 66.39 \text{ kJ/kg d.a}$

$h_3 = C_{pa} T_3 + \omega_3 [2500 + 1.9\, T_3]$

$66.39 = (1.005)\, T_3 + (0.01205)[(2500) + 1.9\, T_3]$

$$\boxed{T_3 = 35.3^\circ C}$$

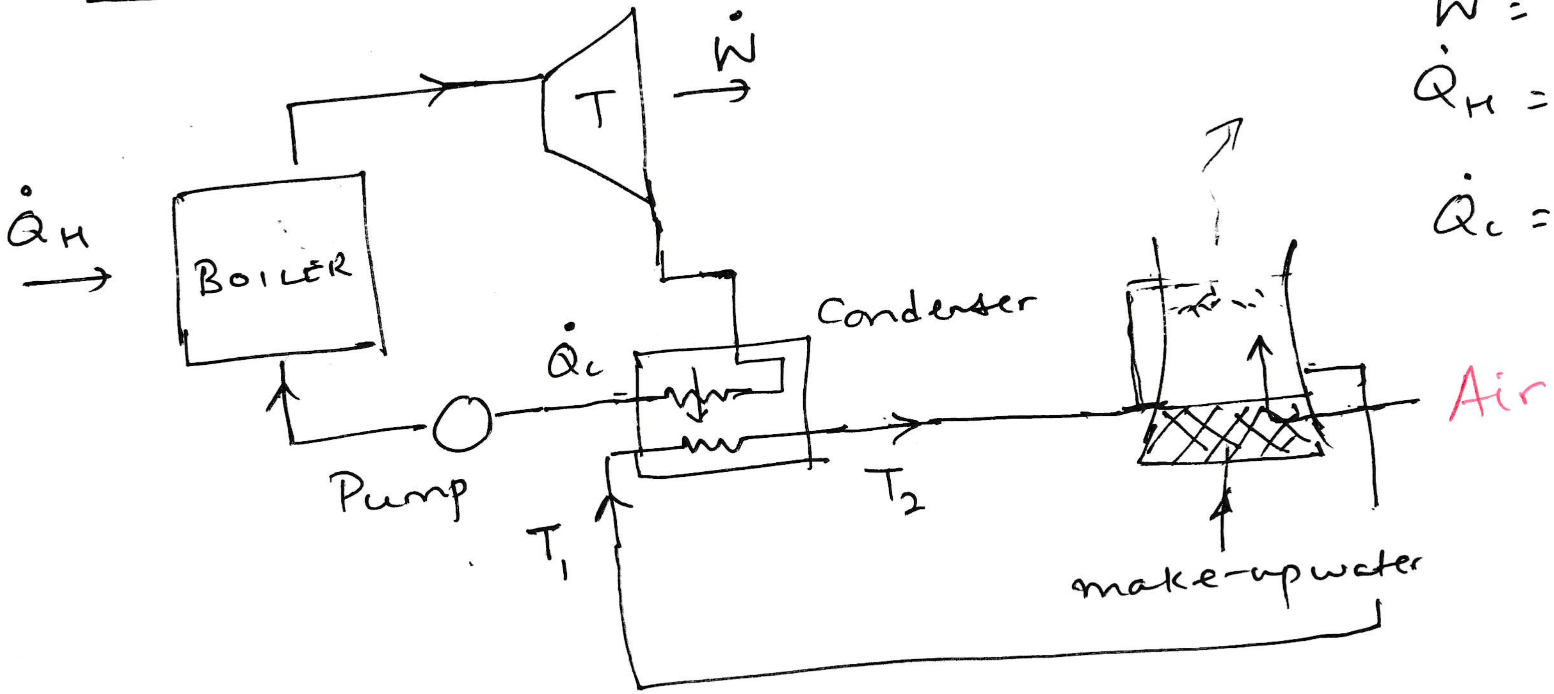
At $35.3^\circ C$, $p_{sat} = 0.0572$ bar

$$p_{v_3} = \frac{\omega p}{0.622 + \omega} = \frac{(0.01205)(101.325)}{0.622 + 0.01205} = 1.926 \text{ kPa}$$

$$= 0.01926 \text{ bar}$$

$$\phi_3 = \frac{p_{v_3}}{p_{sat}} = \frac{0.01926}{0.0572} = 33.6\%$$

Steam Power Plant (Rankine cycle)



$\eta = 40\%$

$\dot{W} = 1\,GW$

$\eta = \dfrac{\dot{W}}{\dot{Q}_H}$

$\dot{Q}_H = \dfrac{1}{0.4} = 2.5\,GW$

$\dot{Q}_c = \dot{Q}_H - \dot{W}$

$= 1.5\,GW$

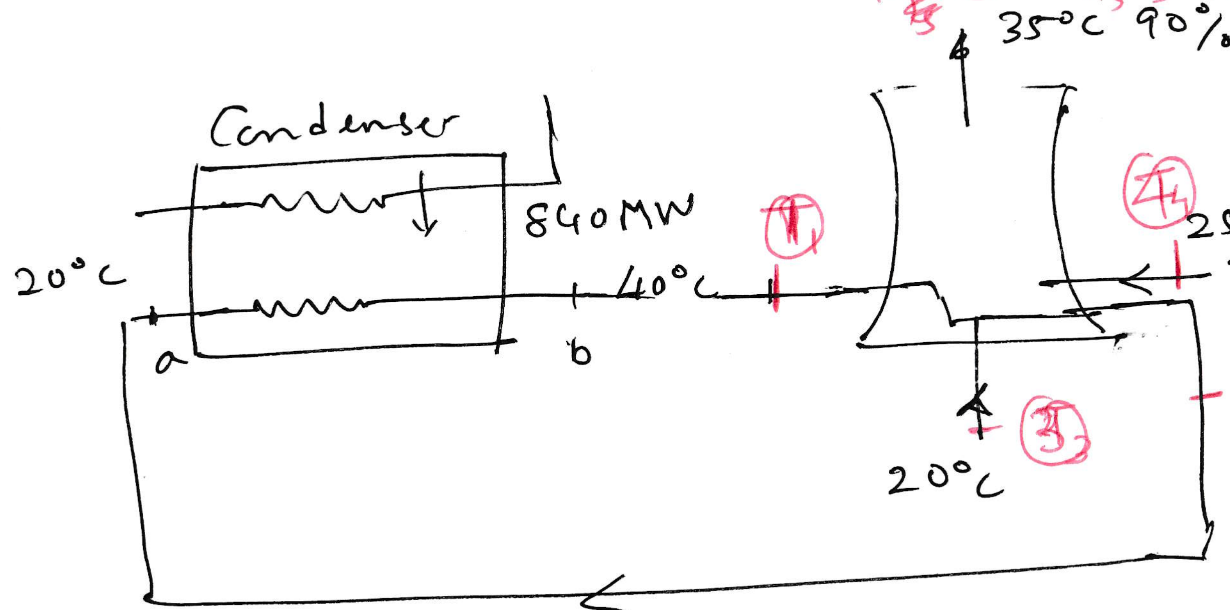
In the condenser of a power plant, energy is discharged by heat transfer at a rate of 840 MW to cooling water that exits the condenser at 40C into a cooling tower. Cooled water at 20C is return to the condenser. Atmospheric air enters the tower at 25C, 1 atm and 35% RH. Moist air exits at 35C, 1 atm and 90% RH. Make up water is added at 20C. For the operation at steady state, determine a) the mass flow rate of air, b) the makeup water

5 $\omega_5 = 32.86$ g/kg
$h_5 = 119.47$

$\dot{Q}_c = \dot{m}_w C_{pw}(T_b - T_a)$

$840 \times 10^3 = \dot{m}_w \times 4.187(40-20)$

$\dot{m}_w \approx 10,000$ kg/s



Mass

$\omega_4 = 6.912$ g/kg d.a

$h_4 = 42.74$ kJ/kg d.a.

Mass Balance for air: $\dot{m}_{4a} = \dot{m}_{5a}$

Water: $\dot{m}_1 + \dot{m}_3 + \dot{m}_{v4} = \dot{m}_{v5} + \dot{m}_2$

Since $\dot{m}_1 = \dot{m}_2 \Rightarrow \dot{m}_3 + \dot{m}_{v4} = \dot{m}_{v5}$

$\Rightarrow \dot{m}_3 = \dot{m}_{v5} - \dot{m}_{v4}$

$= \dot{m}_a(\omega_5 - \omega_4)$

$c_p T_5 + \omega(2500 + 1.9 T_5)$

Energy Balance $\dot{H}_1 + \dot{H}_3 + \dot{H}_4 = \dot{H}_2 + \dot{H}_5$

$\dot{m}_1 C_{pw} T_1 + \dot{m}_3 C_{pw} T_3 + \dot{m}_a h_4 = \dot{m}_2 C_{pw} T_2 + \dot{m}_a h_5$

$\cancel{\dot{m}_1 \, ep_1}$ $\quad \dot{m}_a (\omega_5 - \omega_4) C_{pw} T_3 + \dot{m}_a h_4 = \dot{m}_w C_{pw} (T_2 - T_1) + \dot{m}_a h_5$

$\cancel{\dot{m}_a [(119.47 - 6.97}$ $\times 10^{-3}$

$\dot{m}_a [(32.86 - 6.912)(4.187)(20)] + \cancel{\dot{m}_a}\ \dot{m}_a \, 42.74 = (10000)(4.187)(20-40)$
$+ \dot{m}_a (119.47)$

$\dot{m}_a [2.173 + 42.74 - 119.47] = (10000)(4.187)(-20)$

$\Rightarrow \quad \boxed{\dot{m}_a = 11231 \ kg/s}$

$\dot{m}_3 = \dot{m}_a (\omega_5 - \omega_4)$
$= (11231)(32.86 - 6.912) \, 10^{-3}$

$\boxed{\dot{m}_3 = 291.4 \ kg/s}$