(1) (3) (2)

(1)	(3)	(2)
$T_d = 38^\circ C$	$T_d = 10.5^\circ C$	$T_d = 25^\circ C$
$RH = 50\%$	$RH = 100\%$	$RH = 40\%$
$\omega_1 = 0.02105$	$\omega_3 = 7.882 \times 10^{-3}$ kg/	

$\xrightarrow{\text{cooling}}$ $\xrightarrow{\text{heating}}$

$$\underbrace{\cancel{H_1 + \dot{m}_f}}_{h_1} \; \dot{m}_a(C_p T_1 + \omega_1 h_g(T_1)) + \dot{Q} = \underbrace{\dot{m}_f}_{\dot{m}_a(\omega_2 - \omega_1)} h_f(10.5^\circ C) + \dot{m}_a(\underbrace{C_p T_3 + \omega_3 h_g(T_3)}_{h_3})$$

$$\dot{m}_a = \frac{\dot{V}}{v} \qquad v = \frac{T(1+\omega)}{\frac{P_a}{R_a} + \frac{P_v}{R_v}} = \frac{(311)(1 + 0.02105)}{\left[\frac{1.01325 - 0.03316}{0.287} + \frac{0.03316}{0.462}\right] 100}$$

100 bar $\rightarrow$ kPa

$$R_v = \frac{\bar{R}}{MW_{H_2O}} = \frac{8.314}{18}$$

$$= 0.9107 \text{ m}^3/\text{kg d.a.}$$

$$\dot{m}_a = \frac{75 \text{ m}^3/\text{min}}{0.9107 \text{ m}^3/\text{kg d.a}} = 82.35 \frac{\text{kg d.a}}{\text{min}} = 1.373 \frac{\text{kg}}{\text{s}} \text{ d.a.}$$

$$h_1 = \underset{(38^\circ C)}{C_p T_1 + \omega_1 h_g(T_1)} = (1.005)(38) + (0.02105)(2570.7) = 92.3 \text{ kJ/kg d.a}$$

$$h_3 = C_p T_3 + \omega_3 h_g(T_3) = (1.005)(10.5) + (0.00788)(2476.5) = 30.1 \text{ kJ/kg d.a.}$$

$$h_f(10.5^\circ C) = 4.182 \times 10.5 = 43.91 \text{ kJ/kg d.a}$$

$$(1.373)(92.3) + \dot{Q} = (1.373)(0.02015 - 0.00788)\overset{43.91}{\wedge} + (1.373)(30.1)$$

$$\boxed{\dot{Q} = -84.7 \text{ kW}}$$

Power required for AC unit = $COP = \frac{\dot{Q}}{\dot{W}}$

$$\Rightarrow \dot{W} = \frac{\dot{Q}}{COP} = \frac{+84.7}{3} = 28.2\ kW.$$

From 3 $\rightarrow$ 2 heating.

$$h_2 = C_p T_2 + \omega_2 h_g(T_2) = (1.005)25 + (0.00788)(2547.2)$$

$$= 45.2\ kJ/kg\ d.a.$$

$$\dot{H}_3 + \dot{Q} = \dot{H}_2$$

$$\dot{m}_a h_3 + \dot{Q} = \dot{m}_a h_2 \Rightarrow \dot{Q} = \dot{m}_a(h_2 - h_3)$$

$$= (1.373)(45.2 - 30.1)$$

$$\dot{Q} = 20.73\ kW$$

≈ adiabatic sat. temp = T_2

Moist air with dry bulb temperature of 22C and wet bulb temperature of 9C enters a steam-spray humidifier. It is desired to bring the humidity to 50% with the same dry bulb temperature. Saturated steam at 100C and 1 atm is available. How much steam needs to be sprayed per kg of d.a. in the moist air stream?

$$\omega_1 = \frac{C_{pa}(T_w - T_d) + \omega_w h_{fg}(T_w)}{h_g(T_d) - h_f(T_w)} \qquad \omega_1 = \frac{C_{pa}(T_2 - T_1) + \omega_2 h_{fg}(T_2)}{h_g(T_1) - h_f(T_2)}$$

$T_d = 22^\circ C$

$T_w = \cancel{90}\ 9^\circ C$

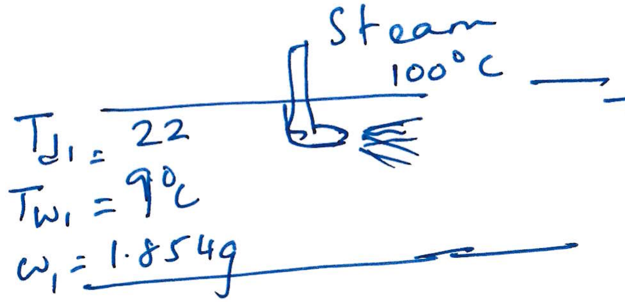
$p_{sat}(9^\circ C) = 0.01115$ bar

$\omega_w = (0.622)\dfrac{0.0115}{1.01325 - 0.0115} = 7.14\times10^{-3}$

$h_{fg}(9^\circ C) = \cancel{2480.85}\ 2480.1$

$h_f(9^\circ C) = 37.805$

$$\omega_1 = \frac{(1.005)(9-22) + (0.00714)(2480.1)}{2541.7 - 37.805} = 1.854\times10^{-3} \text{ kg/kg d.a.}$$



For $22^\circ C$, $p_{sat} = 0.02645$

$p_{v_2} = (0.5)(0.02645)$

$= \cancel{0.01852}\ 0.01323$ bar

$$\omega_2 = (0.622)\frac{\cancel{0.01852}\ 0.01323}{1.01325 - \cancel{0.01852}\ 0.01323}$$

$= \cancel{0.01158 \text{ kg/kg d.a}}$

$= 0.00823$ kg/kg d.a.

Mass of steam sprayed per kg d.a $= \omega_2 - \omega_1$

$= 0.00823 - 0.001854 = 6.375$ g/kg d.a

$\dot{H}_1 + \dot{H}_{steam} = \dot{H}_2 \longrightarrow \dot{m}_a h_1 + \dot{m}_{steam} h_g = \cancel{k}.\ \dot{m}_a h_2$

$\dot{m}_{steam} \downarrow \dot{m}_a(\omega_2 - \omega_1)$

$\cancel{\dot{m}_a}\ h_1 + (\omega_2 - \omega_1) h_g = h_2$

$h_1 = C_p T_1 + \omega_1 h_g(T_1) = (1.005)(22) + (0.001854)(2541.7)$

$= 26.82$ KJ/kg d.a.

$h_g(100°C) = 2676.1$ kJ/kg

$26.82 + (0.00823 - 0.001854) 2676.1 = h_2$

$= 43.88$ KJ/kg d.a.

Find T_d corresponding to $h_2 = 43.88$ and $\omega_2 = 0.00823$

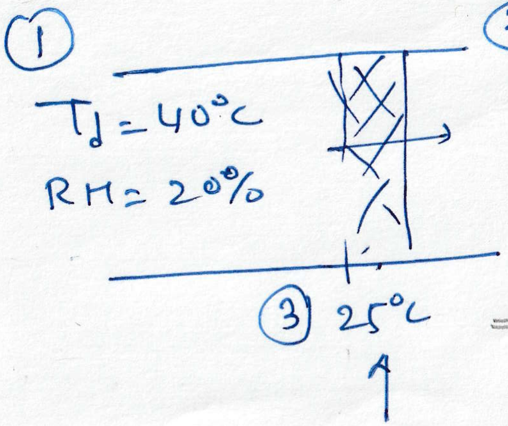
$h_2 = C_p T_2 + (2500 + 1.9 T_2)\omega_2$

$43.88 = (1.005)(\cancel{22}\ T_2) + (2500 + (1.9)\cancel{22}\ T_2)(0.00823)$

$\Rightarrow 43.88 - (2500)(0.00823) = ((1.9)(0.00823) + 1.005) T_2$

$\Rightarrow \boxed{T_2 = 22.84°C}$

Air at 40C and 20% RH enters an evaporative cooler with a flow rate of 120 kg/min. It is to be cooled down to 25C @ 25°C.
How much water is needed per minute? What is the relative humidity at the exit? → ϕ_2



$T_d = 25°C$

$* @ ①: T_d = 40°C.$

$\Rightarrow P_{sat} = 0.07384$ bar

$P_v = (0.2)(0.07384) = 0.014768$

$\Rightarrow \omega_1 = (.622)\left(\frac{0.014768}{1.01325 - .014768}\right) = 0.00920$ kJ/kg d.a.

Mass Balance: Air: $\dot m_{a_1} = \dot m_{a_2} = \dot m_a$

Water: $\dot m_{v_1} + \dot m_{f_3} = \dot m_{v_2}$

$\Rightarrow \dot m_{f_3} = \dot m_{v_2} - \dot m_{v_1}$

$= \dot m_a(\omega_2 - \omega_1)$

Energy Balance: $\dot m_a h_1 + \dot m_f h_f = \dot m_a h_2$

$h_1 + \underbrace{(\omega_2 - \omega_1) h_f}_{<< h_1 \, \& \, h_2} = h_2$

$\Rightarrow h_1 \approx h_2$

1) First find h_1 using T_{d_1} & RH_1

2) $h_2 = h_1$

$= c_{p_a} T_2 + \omega(2500 + 1.9 T_2)$

$= c_{p_a} T_2 + \omega_2 h_g(T_2)$

Solve for ω_2

$h_g(25°C) = 2547.2$

$h_g(40) = 2574.3$

$\rightarrow c_{pa} T_2 + \omega_2 h_g(T_2) = c_{pa} T_1 + \omega_1 h_g(T_1)$

$\Rightarrow \omega_2 = \frac{c_{pa} T_1 + \omega_1 h_g(T_1) - c_{pa} T_2}{h_g(T_2)} = \frac{(1.005)(40) + (0.0092)(2574.3) - (1.005)(25)}{2547.2}$

$\Rightarrow \omega_2 = 0.0152 \rightarrow P_v = \frac{\omega_2 P}{.622 + \omega_2} = \frac{(0.0152)(1.01325)}{.622 + .0152} = 0.0242$ bar $\longrightarrow$

$$\phi_2 = \frac{P_v}{P_{v,sat}} = \frac{0.0242}{0.03169} = \underline{\underline{76\%}}$$

P_{sat} @ 25C = 0.03169 bar

$\Rightarrow$ Water required? $\Rightarrow$ $w_2 - w_1 = 0.0152 - 0.0092 = 0.006$ kg/kg d.a.

* $\dot{m}_a = 120$ kg/min , $\dot{m}_{f_3} = \dot{m}_a(w_2 - w_1)$

$$= 120\,(0.006) = \boxed{0.72 \text{ kg/min}}$$