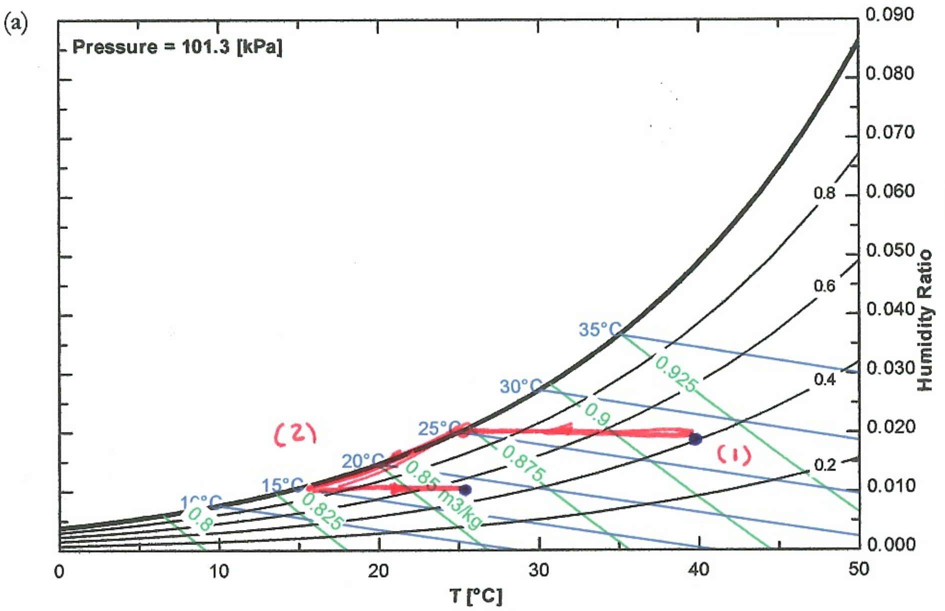
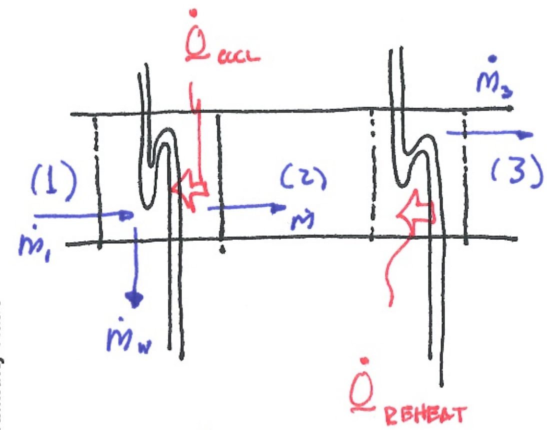
Example

A steady-flow cooling and dehumidification process with a reheat section delivers moist air at a dry-bulb temperature of 25°C and a relative humidity of $\phi = 50\%$. Air enters the cooling section at a dry bulb temperature of 40°C and $\phi = 40\%$ with a flow rate of 75 m^3/min.

(a) Draw the process on a psychrometric chart.
(b) Determine the mass flow rate of the dry air in kg/min.
(c) Determine the amount of liquid water extracted in the process, in kg/min.
(d) Determine the rate of heat transfer out of the air in the cooling section.
(e) Determine the rate of heat transfer into the air in the reheat section.

(a)





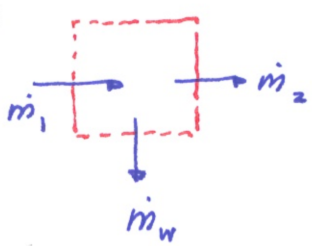
(b) $\dfrac{\dot{V}_a}{v_a} = \dot{m} = \rho_a \dot{V}_a$

$$v_a = \frac{R_a T_1}{P_a} = \frac{R_a T_1}{P - P_v} = \frac{R_a T_1}{P - \phi_1 P_g(T_1)} = \frac{(0.287 \frac{kJ}{kg \cdot K})(40 + 273)K}{(101.325\ kPa - (0.4)(7.384\ kPa))} \left\langle \frac{kPa\text{-}m^3}{kJ} \right\rangle$$

$$= 0.91318\ m^3/kg$$

$$\dot{m}_a = \frac{75\ m^3/min}{0.91318\ m^3/kg} = \boxed{82.13\ kg/min}$$

(c)



Cons of mass (water only)

$$0 = (\dot{m}_a)(\omega_1) - \dot{m}_w - \dot{m}_a \omega_2$$

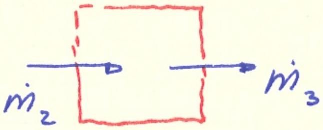
$$\dot{m}_w = \dot{m}_a(\omega_1 - \omega_2)$$

$$\omega_1 = \omega(T_1, \phi_1)$$

Cons of mass (air only)

$$0 = \dot{m}_{a1} - \dot{m}_{a2}$$

$$\dot{m}_{a1} = \dot{m}_{a2} = \dot{m}_a$$



Cons of mass (air)

$$0 = \dot m_{a,2} - \dot m_{a,3}$$

$$\dot m_{a2} = \dot m_{a3} = \dot m_a$$

Cons of mass (vapor)

$$0 = \dot m_a \omega_2 - \dot m_a \omega_3$$

$$\omega_2 = \omega_3$$

$$\omega_3 = \omega(T_3, \phi_3)$$

$$\omega_1 = 0.622 \frac{\phi_1 P_g(T_1)}{P - P_g(T_1)} = \frac{(0.622)(0.4)(7.384\text{ kPa})}{(101.325 - 7.384)\text{ kPa}} = 0.018755$$

(OR USE PSYCH CHRT, OR USE EES)

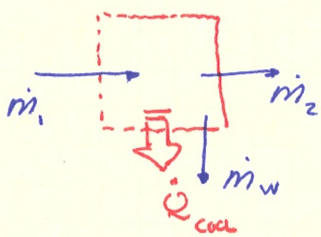
$$\omega_2 = \omega_3 = 0.622 \frac{\phi_3 P_g(T_3)}{P - P_g(T_3)} = \frac{(0.622)(0.5)(3.169\text{ kPa})}{(101.325 - 3.169)\text{ kPa}}$$

$$= 0.009881$$

FINALLY

$$\dot m_w = \dot m_a(\omega_1 - \omega_2) = \ldots = \boxed{0.722\text{ kg/min}}$$

(d)



Cons. of energy

$$0 = -\dot Q_{out} - 0 + \dot m_a h_1 - \dot m_w h_w - \dot m_a h_2$$

$$\dot Q_{out} = \dot m_a(h_1 - h_2) - \dot m_w h_w$$

$$= \dot m_a(h_{a1} + \omega_1 h_{g1} - [h_{a2} + \omega_2 h_{g2}]) - \dot m_w h_w$$

$h_{a1} = h_a(25°C) = 298.6$ kJ/kg

$h_{a2}^{\dagger} = h_a(13.7°C) = 287.2$ kJ/kg

$h_{g1} = h_g(25°C) = 2547.3$ "

$h_{g2}^{\dagger} = h_g(13.7°C) = 2526.5$ "

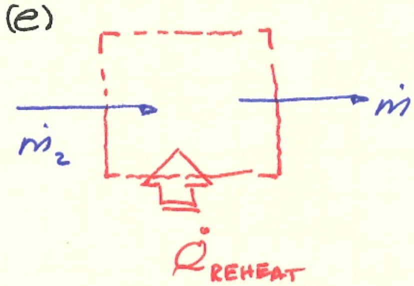
$h_w^{\dagger} \approx h_{f2} = h_f(13.7°C) = 57.48$ "

$$\ldots \boxed{\dot Q = \ldots = 4071\text{ kJ/min}}$$

OR USE PSYCH CHART TO FIND h_1 & h_2 (OR EES)

$\dagger$ $T_2 = T_{DEW}(P = P_{v,3} = \phi_3 P_g) = T_{SAT}((0.5)(3.169\text{ kPa})) = T_{SAT}(1.584\text{ kPa}) = 13.7°C.$

(e)



Cons of energy

$$0 = \dot{Q}_{REHEAT} - \quad + \dot{m}_a(h_2) - \dot{m}_a(h_3)$$

$$\dot{Q}_{REHEAT} = \dot{m}_a(h_3 - h_2)$$

$$= \dot{m}_a\left[h_{a,3} + \omega_3 h_{g,3} - h_{a,2} - \omega_2 h_{g,2}\right]$$

RECALL $\omega_2 = \omega_3$

$$\therefore \dot{Q}_{REHEAT} = \dot{m}_a\left[h_{a,3} + \omega_3 h_{g3} - (h_{a2} + \omega_3 h_{g2})\right]$$

$h_{a,3} =$

$h_{g3} =$

$$\therefore \boxed{\dot{Q}_{REHEAT} = \ldots = 951 \text{ kJ/min}}$$

(AGAIN, CAN USE CHART or EES)

HOW IS IT THAT THIS IS <u>DE</u>HUMIDIFICATION & ϕ GOES <u>UP</u>?!