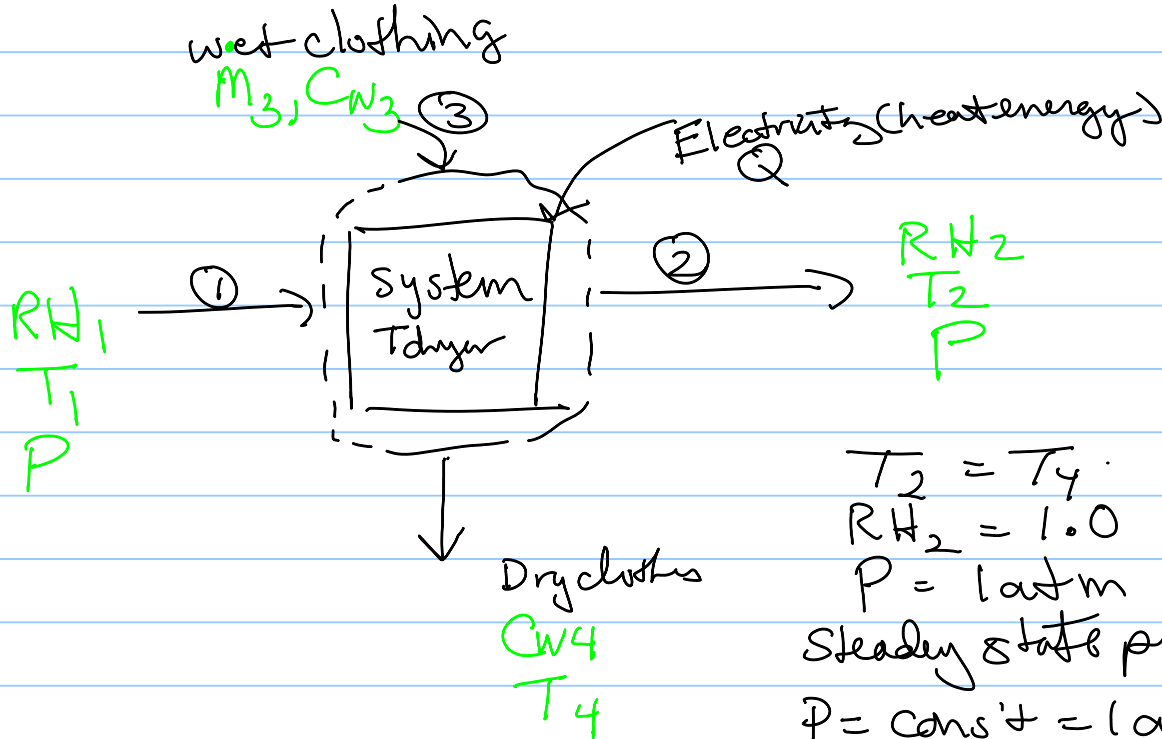

$T_2 = T_4$

$RH_2 = 1.0$

$P = 1\,atm$

Steady state process

$P_{Total} = \text{cons't} = 1\,atm$

Green parameters are known parameters

Red parameters are unknowns (turn green when defined)

$\left.\begin{array}{l} Cp_{clothes} \\ Cp_{w\,vap} \\ Cp_{w\,Liq} \\ \Delta H_{vap} \end{array}\right\}$ constants

Unknowns (in red)

mass flow rates $\Rightarrow$ (total $- \dot{m}_i$, component $- \dot{m}_{ji}$)

$\dot{m}_i \; (i = 1-4)$ and $\dot{m}_{ji} \; (j = a, w, c)$

note: $\dot{m}_3$ is known

a - air (dry)

w - water

c - clothes (dry)

$\dot{Q}$ - energy flowrate in

note: Concentration, eg. C_{ji} are mass %'s of component j in stream i

Note Title 9/23/2008

The basis for this problem is the input mass flowrate of wet clothes, $\dot{m}_3$.

This value will be used to determine all the mass flowrate of the other streams as well as the energy input.

First, setup the total and component mass balances.

3 components, w - water
a - air (dry)
c - clothing (dry)

Note that the water entering and leaving with the clothing is in the liquid state, so will need to account for vaporization in energy balance

Total Mass balance

$$\dot{m}_1 - \dot{m}_3 + \dot{m}_2 - \dot{m}_4 = \frac{dm_{sys}}{dt} = 0 \ (s.s.) \quad (1)$$

component mass balances

air $\dot{m}_{a_1} - \dot{m}_{a_2} = 0$ (2)

water $\dot{m}_{w_1} - \dot{m}_{w_2} + \dot{m}_{w_3} - \dot{m}_{w_4} = 0$ (3)

clothes $\dot{m}_{c_3} - \dot{m}_{c_4} = 0$ (4)

$\dot{m}_{a_1} + \dot{m}_{w_1} = \dot{m}_1$ $\quad \dot{m}_{a_2} + \dot{m}_{w_2} = \dot{m}_2$

$\dot{m}_{c_3} + \dot{m}_{w_3} = \dot{m}_3$ $\quad \dot{m}_{c_4} + \dot{m}_{w_4} = \dot{m}_4$

$\Rightarrow$ note: these are the same as $\sum_j y_i = 1$ (5)

Unknowns – 11
Knowns – 1
Eqn's – 8

$\Big\}$ Need 3 eqn's to solve

$$P^*_{vap} = e^{A - \frac{B}{C+T}}$$ define vapor pressure as f(T) (6)

$$P_j = RH_j \cdot P^*_{vap}$$ defines partial pressure vs RH (7)

$$\dot{n}_{w_i} = \frac{P_w \dot{V}_{Total\,i}}{RT_i}$$ defines mass as function of partial pressure and volume (8)

From definition of moles vs. mass flow rates

$$\dot{m}_{ji} = \dot{n}_{ji} \cdot MWT_j$$

[note: MWT_a is molar avg of 79% N_2, 21% O_2]

$$MWT_a = (.79)(28) + (.21)(32) = 28.84$$

From the water component mass balance,

$$\underbrace{\dot{m}_{w_1} - \dot{m}_{w_2}}_{\text{water gain by air}} = \underbrace{\dot{m}_{w_3} - \dot{m}_{w_4}}_{\text{water lost by clothing}} \qquad (3)$$

This simply says that the water lost by the wet clothing streams = water gained by air stream

Use clothing component mass balance to determine water loss/gain

$$\dot{m}_{c_3} = \dot{m}_{c_4} \qquad (4)$$

$$C_{c_3}\dot{m}_3 = C_{c_4}\dot{m}_4$$

C_{ji} = mass % j in stream i

$C_{w_i} + C_{c_i} = 1, \quad i = 3, 4 \qquad (5)$

$$(1 - C_{w_3})\dot{m}_3 = (1 - C_{w_4})\dot{m}_4$$

Can solve for $\dot{m}_4$

$$\dot{m}_4 = \frac{(1 - C_{w_3})}{(1 - C_{w_4})}\dot{m}_3$$

$$\dot{m}_{w_3} - \dot{m}_{w_4} = C_{w_3}\dot{m}_3 - C_{w_4}\dot{m}_4$$

= water loss by clothing (3)

$$C_{w_3}\dot{m}_3 - C_{w_4}\frac{(1 - C_{w_3})}{(1 - C_{w_4})}\dot{m}_3 = \text{water loss by clothing}$$

Substituting this into (3)

$$\dot{m}_{w_1} - \dot{m}_{w_2} = \dot{m}_{w_3} - \dot{m}_{w_4}$$

$$= \left[C_3 - C_4\frac{(1 - C_{w_3})}{(1 - C_{w_4})}\right]\dot{m}_3$$

By dividing through by MWT_W

$$\dot{n}_{w_1} - \dot{n}_{w_2} = \left[C_3 - C_4\frac{(1 - C_{w_3})}{(1 - C_{w_4})}\right]\frac{\dot{m}_3}{MWT_W} \qquad (9)$$

now need to solve for $\dot{n}_{w_1}$ + $\dot{n}_{w_2}$

From ideal gas law (8)

$$P_{W_1}\dot{V}_{Total\,1} = \dot{n}_{W_1} R T_1 \Rightarrow \dot{n}_{W_1} = \frac{P_{W_1}\dot{V}_{Total\,1}}{RT_1}$$

$$P_{W_2}\dot{V}_{Total\,2} = \dot{n}_{W_2} R T_2 \Rightarrow \dot{n}_{W_2} = \frac{P_{W_2}\dot{V}_{Total\,2}}{RT_2}$$

Substituting into (9)

$$\frac{P_{W_1}\dot{V}_{Total\,1}}{RT_1} - \frac{P_{W_2}\dot{V}_{Total\,2}}{RT_2} = \left[C_3 - C_4\frac{(1-C_{W3})}{(1-C_{W4})}\right]\frac{\dot{m}_3}{MW_{T_W}}$$

$$P_{W_1} = RH_1 \cdot P^*_{vap}(T_1) \qquad \text{from (7)}$$

$$P_{W_2} = RH_2 \cdot P^*_{vap}(T_2)$$

$$P^*_{vap}(T) \Rightarrow P^*_{vap} = e^{A - \frac{B}{C+T}} \qquad \text{from (8)}$$

$\therefore$ Can Calc. $P^*_{vap}(T_1)$ & $P^*_{vap}(T_2)$

$\therefore$ can calc P_{W_1} and P_{W_2}

$$\frac{P_{W_1}\dot{V}_{Total\,1}}{RT_1} - \frac{P_{W_2}\dot{V}_{Total\,2}}{RT_2} = \left[C_3 - C_4\frac{(1-C_{W3})}{(1-C_{W4})}\right]\frac{\dot{m}_3}{MW_{T_W}}$$

Now need to relate $\dot{V}_{total_1}$ to $\dot{V}_{total_2}$

from air component mass balance

$$\dot{n}_{a_1} - \dot{n}_{a_2} = 0 \quad \text{or} \quad \dot{n}_{a_1} = \dot{n}_{a_2} \qquad (2)$$

$P_a = P - P_W$ ∴ can calc P_a given P_W

$$\frac{P_{a_1} \dot{V}_{total_1}}{R\,T_1} = \frac{P_{a_2} \dot{V}_{total_2}}{R T_2} \qquad \text{using } (8)$$

$$\dot{V}_{total_1} = \frac{P_{a_2}}{P_{a_1}} \frac{T_1}{T_2} \dot{V}_{total_2}$$

Plugging this into previous eqn

$$\frac{P_{W_1} \dot{V}_{total_1}}{R T_1} - \frac{P_{W_2} \dot{V}_{total_2}}{R\,T_2} = \left[C_3 - C_4 \frac{(1-C_{W3})}{(1-C_{W4})}\right] \frac{\dot{m}_3}{MW T_W}$$

$$\frac{P_{W_1}}{RT_1} \frac{P_{a_2}}{P_{a_1}} \frac{T_1}{T_2} \dot{V}_{total_2} - \frac{P_{W_2} \dot{V}_{total_2}}{R\,T_2} = \left[C_3 - C_4 \frac{(1-C_{W3})}{(1-C_{W4})}\right] \frac{\dot{m}_3}{MW T_W}$$

solving for $\dot{V}_{total_2}$

$$\dot{V}_{total_2} = \frac{\left[C_3 - C_4 \frac{(1-C_{W3})}{(1-C_{W4})}\right] \frac{\dot{m}_3}{MW T_W}}{\frac{P_{W_1}}{RT_1} \frac{P_{a_2}}{P_{a_1}} \frac{T_1}{T_2} - \frac{P_{W_2}}{RT_2}}$$

∴ can calc $\dot{V}_{total_2}$ + $\dot{V}_{total_1}$

$$\dot{V}_{total_1} = \frac{P_{a_2}}{P_{a_1}} \frac{T_1}{T_2} \dot{V}_{total_2}$$

So now can calc all m_{j_i} m_{j} +

$$\dot{m}_{w_1} = \frac{P_{w_1} \dot{V}_{total_1}}{R T_1} MWT_w \qquad \dot{m}_{w_2} = \frac{P_{w_2} \dot{V}_{total_2}}{R T_2} MWT_w$$

$$\dot{m}_{a_1} = \frac{P_{a_1} \dot{V}_{total_1}}{R T_1} MWT_a \qquad \dot{m}_{a_2} = \dot{m}_{a_1}$$

$$\dot{m}_1 = \dot{m}_{w_1} + \dot{m}_{a_1} \qquad \dot{m}_2 = \dot{m}_{w_2} + \dot{m}_{a_2}$$

$$\dot{m}_{w_3} = C_{w_3} \dot{m}_3$$

$$\dot{m}_{c_3} = (1 - C_{w_3}) \dot{m}_3 \qquad \dot{m}_{c_4} = \dot{m}_{c_3}$$

$$\dot{m}_4 = \frac{(1 - C_{w_3})}{(1 - C_{w_4})} \dot{m}_3$$

$$\dot{m}_{w_3} = C_{w_4} \dot{m}_4$$

Energy balance

$$\dot{E}_1 + \dot{E}_3 + Q - E_2 - E_4 = \frac{dE_{sys}}{dt} = 0$$

Need relationships / laws to quantify terms

$$\dot{E}_i = \sum_i \dot{m}_{j_i} H_{j_i} = \sum_i \dot{m}_{j_i} Cp_j (T_i - T_{ref})$$

where $i \Rightarrow$ stream # (1 – 4)

$j \Rightarrow$ component (a, w, c)

Must also include $\Delta H_{vap} \rightarrow \Delta H_{vap} \left[C_3 - C_4 \frac{(1-C_{w3})}{(1-C_{w4})} \right] \frac{\dot{m}_3}{MW_{w}}$

So can solve for all $\dot{E}_i$ (can select any T_{ref})

$\therefore$ can calc Q

$$Q = \dot{E}_2 + \dot{E}_4 - \dot{E}_1 - \dot{E}_3 + \Delta H_{vap} \left[C_3 - C_4 \frac{(1-C_{w3})}{(1-C_{w4})} \right] \frac{\dot{m}_3}{MW_{w}}$$