Problem set 3 (PS3) Due Monday February 6

PS3-1 Two air streams are mixed in a well insula6ed duct system at 14.7 psia atmospheric pressure. The warm stream is at is at 70 F db, 50 F wb . The cold stream is at 40 F and 80 % relative humidity. The volumetric flow of the warm stream is three times the volumetric flow of the cold stream. Determine the relative humidity, and dry bulb temperature of the resulting mixture. Sketch the process on a sketch of a psychrometric chart.

PS3-2 Air at 35 C, 60 % relative humidity is cooled and dehumidified in a coil at an atmospheric pressure of 90 kPa. Air and the condensed water leave the coil at 15 C. Sketch the process on a sketch of a psychrometric chart and calculate,

a) the rate of heat transfer from the air
b) the amount of water condensed in kg water/ kg dry air
c) the sensible heat transfer in kJ/kg dry air
d) the latent heat transfer in kJ/ kg dry air
e) the sensible heat factor
f) check the total heat transfer value using EES

PS3-3 2000 ft^3/min of outside air at 60 F, 30% relative humidity and 14.7 psia is heated in a coil and then humidified with 5 psig steam to 110 F and 30 % relative humidity. Calculate the coil heat load and the amount of steam required. What is the temperature between the coil and the humidification process? Sketch a psychrometric chart of the process.

PS3-1

$$\gamma_g = \frac{18}{29}\frac{p_v @ T_{wb}}{p_{atm} - p_v @ T_{wb}} = \frac{18}{29}\frac{.17812}{(14.7 - .17812)} = .0076$$

$$\gamma_1 = \frac{c_p(T_{wb} - T_{db}) + (\gamma_g \times h_{fg})_{wb}}{h_{v\,db} - h_{l\,wb}}$$

$$\gamma_1 = \frac{.24(50-70) + (.0076 \times 1065)}{1091.8 - 18.07} = .00308 \text{ lb water/lb dry air}$$

$$h_1 = c_p T_{db} + \gamma \times h_v @ T_{db}$$

$$h_1 = .24 \times 70 + .00308 \times 1091.8 = 20.16 \text{Btu/lb dry air}$$

$$\gamma_2 = \frac{18}{29}\frac{.12173 \times .8}{(14.7 - .12173 \times .8)} = .00414$$

$$h_2 = .24 \times 40 + .00414 \times 1078.7 = 14.065$$

$$V_w = 3V_c$$

$$\frac{1}{3} = \frac{V_{cold}}{V_{warm}} = \frac{V_2}{V_1} = \frac{m_2 R T_2}{p_2}\frac{p_1}{m_1 R T_1}$$

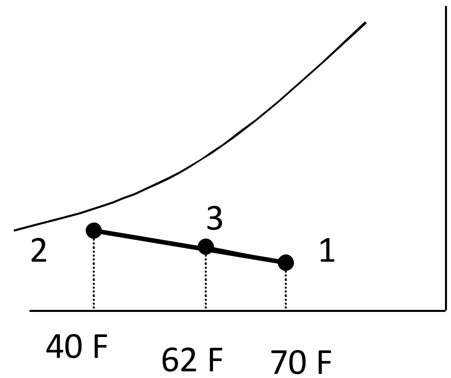
$$\frac{m_2}{m_1} = \frac{1}{3} \times \frac{14.603}{14.6274} \times \frac{(460+70)}{(460+40)} = .3527$$

$$m_2 = .3527 m_1$$

$$m_1 + m_2 = m_1 + .3527 m_1$$

$$\frac{m_1}{m_1 + m_2} = \frac{m_1}{1.3527 m_1} = .7392$$

$$\frac{m_2}{m_1 + m_2} = \frac{.3527 m_1}{1.3527 m_1} = .2607$$



Mixing Process

$$h_3 = \frac{m_1}{m_1 + m_2} h_1 + \frac{m_2}{m_1 + m_2} h_2$$

$$h_3 = .7392 \times 20.16 + .2607 \times 14.065 = 18.576 \text{ Btu/lb dry air}$$

$$\gamma_3 = \frac{m_1}{m_1 + m_2}\gamma_1 + \frac{m_2}{m_1 + m_2}\gamma_2$$

$$\gamma_3 = .7392 \times .00308 + .2607 \times .00416 = .00336 \text{ lb water/ lb dry air}$$

$$h_3 = c_p T_3 + \gamma_3 (1061.8 + .44 \times T_3)$$

$$18.576 = .24 T_3 + .00336(1061.8 + .44 T_3)$$

$$T_3 = 62 \text{ F}$$

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"PS3-1  2012  EES"

"INPUT"
T1=70
T1wb=50
T2=40
R2=.8
Vrat=3
patm=14.7
m1=1

"SOLUTION"
w1=humrat(AirH2O,T=T1,B=T1wb,p=patm)
h1=enthalpy(AirH2O,T=T1,B=T1wb,p=patm)
v1=volume(AirH2O,T=T1,B=T1wb,p=patm)


w2=humrat(AirH2O,T=T2,R=R2,p=patm)
h2=enthalpy(AirH2O,T=T2,R=R2,p=patm)
v2=volume(AirH2O,T=T2,R=R2,p=patm)

m1*v1=3*m2*v2

hm=m1/(m1+m2)*h1+m2/(m1+m2)*h2
wm=m1/(m1+m2)*w1+m2/(m1+m2)*w2

Tm=temperature(AirH2O,h=hm,W=wm,p=patm
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```
RESULTS
h1=20.2
h2=14.08
hm=18.6
m1=1
m2=0.3527
patm=14.7
R2=0.8
T1=70
T1wb=50
T2=40
Tm=62.17
v1=13.42
v2=12.68
Vrat=3
w1=0.003088
w2=0.004148
wm=0.003365
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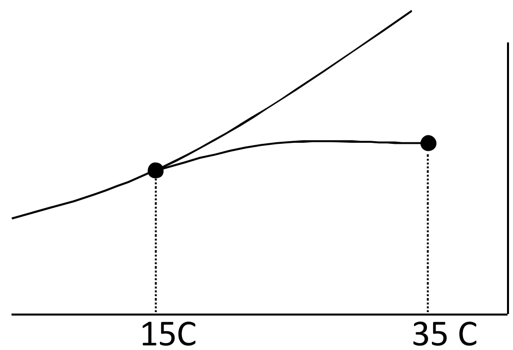
PS3-2

Point 1

$$p_1 = \phi_1 \times P_g \ @\ 35\,C = .6 \times 5.6291 = 3.377\ kPa$$

$$\omega_1 = \frac{18}{29} \times \frac{3.377}{(90 - 3.377)} = .0242\ \text{kg water/kg dry air}$$

$$h_1 = 1.005 \times 35 + .0242 \times 2564.6 = 97.238\ \text{kJ/kg dry air}$$



Point 2 is saturated, $\phi = 100\,\%$

$$\omega_2 = \frac{18}{29} \times \frac{1.7057}{(90 - 1.7057)} = .012$$

$$h_2 = 1.005 \times 15 + .012 \times 2528.3 = 45.391$$

a) $q = (h_1 - h_{2)} = 51.758\ \text{kJ/kg dry air}$

b) $\text{condensate} = (\omega_2 - \omega_1) \times h_{fg}\ @\ T_1$

$\text{condensate} = (.0242 - .012) = .0122\ \text{kg water/kg dry air}$

c) $q_{sensible} = q - q_{latent} = 51.758 - 29.52 = 22.238$

d) $q_{latent} = (\omega_2 - \omega_1) \times h_{fg} @ T_1$

$q_{latent} = (.01227 \times 2417.9 = 29.52\text{kJ/kgdryair}$

e) $SHR = \dfrac{q_{sensible}}{q} = \dfrac{22.238}{51.758} = .44$

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"PS3-2 2012  EES"

"INPUT"
T1=35
R1=.6
T2=15
R2=1.
patm=90

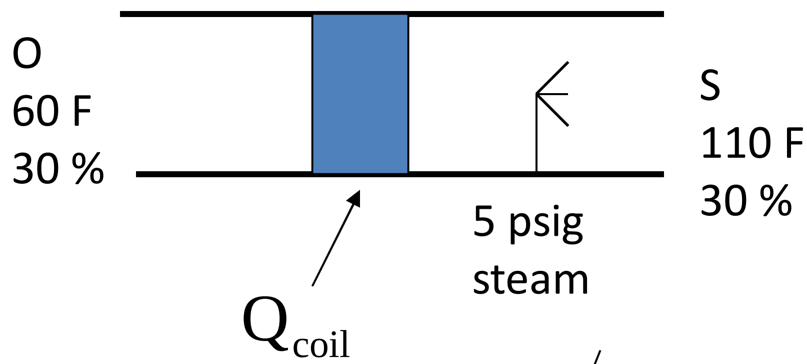
"SOLUTION"
h1=enthalpy(AirH2O,T=T1,R=R1,p=patm)
w1=humrat(AirH2O,T=T1,R=R1,p=patm)
hl1=enthalpy(Steam,T=T1,x=0)
hv1=enthalpy(Steam,T=T1,x=1)


h2=enthalpy(AirH2O,T=T2,R=R2,p=patm)
w2=humrat(AirH2O,T=T2,R=R2,p=patm)

Qtotal=h1-h2
Qlatent=(w1-w2)*(hv1-hl1)
Qsensible=Qtotal-Qlatent
SHF=Qsensible/Qtotal
```

```
RERSULTS
h1=97.45
h2=45.48
hl1=146.6
hv1=2564
patm=90
Qlatent=29.6
Qsensible=22.37
Qtotal=51.97
R1=0.6
R2=1
SHF=0.4304
T1=35
T2=15
w1=0.02425
w2=0.012
```

PS3-3



$$p_{vO} = \phi \times p_g = .3 \times .2563 = .07689 \text{ psia}$$

$$\omega_O = \frac{18}{29}\frac{.07689}{(14.7 - .07689)} = .003264 \text{ lb water/ lb dry air}$$

$$p_{vS} = \phi \times p_g = .3 \times 1.2748 = .38244 \text{ psia}$$

$$\omega_S = \frac{18}{29}\frac{.38244}{(14.7 - .07689)} = .01656 \text{ lb water/ lb dry air}$$

$$m_a = \frac{pV}{RT} = \frac{(14.7 - .07689) \times 144 \text{ in}^2/\text{ft}^2 \times 2000 \text{ ft}^3}{53.35 \text{ ft lb}_f/\text{lb}_m \text{ R} \times (460 + 60)}$$

$$m_a = 151.8 \text{ lb dry air/ min}, \quad 9108 \text{ lb dry air/hr}$$

$$h_O = c_p T + \omega_S h_{vS}$$

$$h_O = .24 \times 60 + .003264 \times 1088 = 17.95 \text{ Btu/ lb dry air}$$

$$h_S = .24 \times 100 + .01656 \times 1109.4 = 44.7 \text{ Btu/ lb dry air}$$

Energy Balance on the Duct

$$m_a h_O + Q_{coil} + m_a \phi\omega h_v = m_a h_S$$

$$Q_{coil} = m_a (h_S - h_O) - m_a \phi\omega h_v$$

$$Q_{coil} = 9108 \times (44.7 - 17.95) - 9108 \times (.01656 - .003264) \times 1156.$$

$$Q_{coil} = 243{,}639. - 140{,}007. = 103{,}632 \text{ Btu/ hr}$$

$$Q_{coil} = m_a (h_{int} - h_O)$$

$$h_{int} = (Q_{coil}/ma) + h_O = (103{,}632/9108) + 17.95 = 11.378 + 17.95 = 29.33$$

$$h_{int} = c_p \times T_{int} + \omega_3 \times (106.8 + .45 \times T_{int})$$

$$29.33 = .24 \times T_3 + .003264 \times (1061.8 + .45 \times T_3)$$

$$T_{int} = 107.1 \text{F}$$

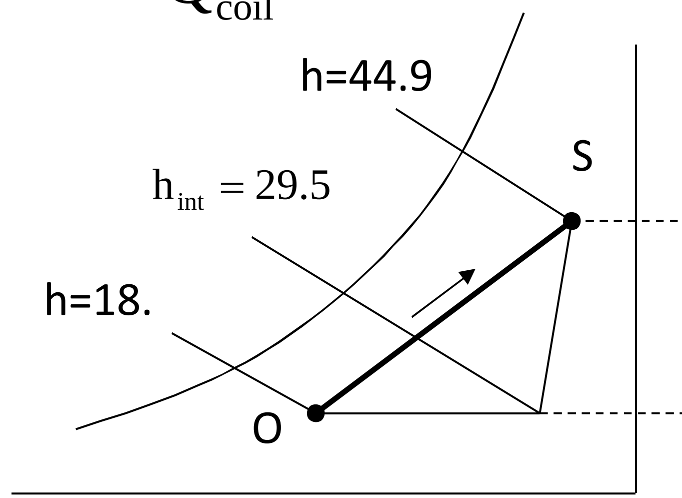


Chart Solution :

$$Q_{coil} = \frac{CFM}{v_O} \times 60 \times (h_{int} - h_O)$$

$$Q_{coil} = \frac{2000}{13.2} \times 60 \times (29.5 - 18)$$

$$Q_{coil} = 104{,}545. \text{ BTU/ hr}$$

```
"PS3-3 2012  EES

"INPUT"
T1=60
R1=.3
T2=110
R2=.30
Vol1=2000
ps=5 +14.7
patm=14.7

"SOLUTION"
h1=enthalpy(AirH2O, T=T1,R=R1,p=patm)
w1=humrat(AirH2O,T=T1,R=R1,p=patm)
v1=volume(AirH2O,T=T1,R=R1,p=patm)
hl1=enthalpy(steam,T=T1,x=0)
hv1=enthalpy(steam,T=T1,x=1)

h2=enthalpy(AirH2O, T=T2,R=R2,p=patm)
w2=humrat(AirH2O,T=T2,R=R2,p=patm)

hsteam=enthalpy(Steam,p=ps,x=1)

ma=60*Vol1/v1
"ENERGY BALANCE"
ma*H1+Qcoil+ma*(w2-w1)*hsteam=ma*h2
mwater=ma*(w2-w1)
Qlatent=(w2-w1)*(hv1-hl1)
Qsensible=Qcoil-Qlatent
Qsensible=ma*(hint-h1)
Tint=temperature(AirH2O,h=hint,w=w1,p=patm
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RRESULTS

```
h1=17.98
h2=44.9
hint=29.45
hl1=28.05
hsteam=1156
hv1=1087
ma=9115
mwater=121.8
patm=14.7
ps=19.7
Qcoil=104632
Qlatent=14.16
Qsensible=104618
R1=0.3
R2=0.3
T1=60
T2=110
Tint=107.4
v1=13.17
Vol1=2000
w1=0.003271
w2=0.01664
```