HW2

PROBLEM 7.2 $W, h, v = ?$

$p_{TOT} = 14.696\, psiA$ → ATMOSPHERIC p AT SEA-LEVEL

$RH = 100\%$ → FROM " SATURATED AIR "

a) $t = 70°F$

DIRECTLY FROM TABLE A1E: $p_{w_s} = 0.36324\ lbf/in^2$ (psi), $v_g = 867.61\ ft^3/lbm$, $h_{fg} = 1054.2$

$$W = W_s = 0.622 \frac{p_{ws}}{p_{TOT} - p_{ws}} = 0.622 \cdot \frac{0.363}{14.696 - 0.363} = 0.0157 \frac{lb_w}{lb_{DA}}$$

$$h = h_{DA} + w\, h_{fg} = c_{p_{DA}} \cdot t + w_s\, h_{fg} = 0.24 \cdot 70 + 0.0157 \cdot 1054 = 16.8 + 17.1 = 33.3\ Btu/lbm$$

$T = 70 + 459.7 = 529.7°R$

$$v = \frac{R_a T}{p_{TOT} - p_{ws}} = \frac{0.37 \cdot 529.7}{14.696 - 0.363} = 13.67\ ft^3/lbm$$

b) $t = -20°F$

$p_{ws} = 618 \cdot 10^{-5}\ psi$, $h_{fg} = 1220.4\ Btu/lbm$

$$W_s = 0.622 \frac{p_{ws}}{p_{TOT} - p_{ws}} = 0.622 \frac{618 \cdot 10^{-5}}{14.696} = 0.26 \cdot 10^{-3} \frac{lb_w}{lb_{DA}}$$

($p_{TOT} - p_{ws} \approx p_{TOT}$)

$$h = h_{DA} + W\, h_{fg} = 0.24 \cdot 20 + 0.26 \cdot 10^{-3} \cdot 1220.4 = 16.8 + 0.3 = 17.1 \frac{Btu}{lbm} \approx h_{DA}$$

($16.8 = h_{DA}$)

$$v \approx v_{DA} = \frac{R_a T}{p_{TOT}} = \frac{0.37 \cdot 509.7}{14.696} = 12.83\ ft^3/lbm$$

PROBLEM 7.4

$t = 70\,°F \quad \Rightarrow \quad p_{ws} = 0.363\ psi$

$RH = 50\%$

$p = 14.696\ psi$

$V = 30 \times 15 \times 8\ ft^3 = 3600\ ft^3$

$m_w = ?$

$$m_w = W \cdot m_{DA} = W \cdot V \cdot \rho_{DA} = W \cdot V \cdot \frac{1}{v_{DA}}$$

$$v_{DA} = \frac{R_a T}{p_{TOT}} = \frac{0.37 \cdot 529.7}{14.696} = 13.34\ ft^3/lb$$

$$W = 0.622 \frac{RH \cdot p_{ws}}{p_{TOT} - RH \cdot p_{ws}} = 0.622 \frac{0.5 \cdot 0.363}{14.696 - 0.5 \cdot 0.363} = 0.0078\ \frac{lb_w}{lb_{DA}}$$

$$m_w = 0.0078 \cdot 3600 \cdot \frac{1}{13.34} = 2.1\ lb_w$$

PROBLEM 7.10

$t_{WIND} = 5\,°C$

$t = 20\,°C$

$p_{TOT} = 101.325\ kPa$

$t_{DP} = t_{WIND}$

$RH_{max} = ?$

$$RH_{max} = RH\,[W = W_s(t_{WIND}),\ t = 20\,°C]$$

$W_s(t = 5\,°C) = ?$ FOR $t = 5\,°C$ FROM TABLES: $p_{ws} = 0.00087\ 10^6\ Pa$

$$W_s(t=5) = 0.622 \frac{870}{101325 - 870} = 0.0054\ \frac{kg_w}{kg_{DA}}$$

$W_s(t = 20\,°C) = ?$

$\hookrightarrow p_{ws} = 0.002339 \qquad W_s(t = 20\,°C) = 0.0147\ \frac{kg_w}{kg_{DA}}$

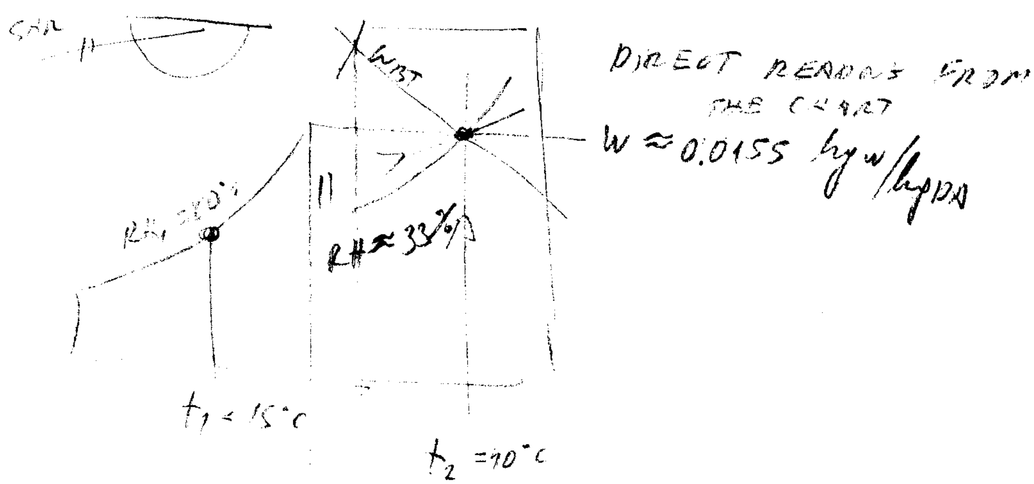
EQUATION 7.6 $\quad RH = \frac{W}{W_s} \cdot \frac{0.622 + W_s}{0.622 + W}$ (HERE $W = W_s(t = 5\,°C)$)

$$RH_{max} = \frac{0.0054}{0.0147} \cdot \frac{0.622 + 0.0147}{0.622 + 0.0054} = 0.37 \qquad RH_{max} = 37\%$$

PROBLEM 7.28

$t_1 = 15°C$
$RH_1 = 100\%$
$p_{ATM} = 101\,325\ Pa$
$SHR = 0.7$
$t_2 = 40°C$

a) $W = ?$
b) $t_{DP} = ?$
c) $RH = ?$
d) $WBT = ?$



$t_{DP} \approx 21°C$

$WB \approx 26°C$

DIRECT READING

$W = 0.0155\ kg_w/kg_{DA}$
$t_{DP} = 21°C$
$RH = \varphi = 33\%$
$WBT = 26°C$

PROBLEM 8.2

$q_{SEN} = 80000$ Btu/h

$q_{LAT} = 34000$ Btu/h

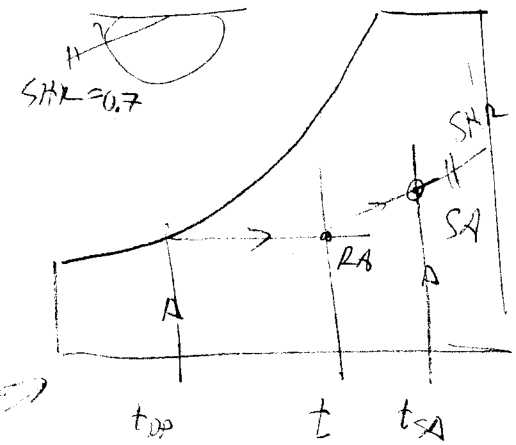
$t = 70°F$

$t_{DP} = 44°F$

$t_{SA} = 95°F$

$p = p_{ATM} = 29.921$ in Hg ≈ 14.7 psi

$$SHR = \frac{80}{80+34} = 0.7$$



a) RH = ?

DIRECT READING FROM THE CHART RH ≈ 34%

b) m_{SA} = ?

$$q_{SEN} = \rho \dot{V} \cdot c_p \cdot (t_{SA} - t_{RA}) \Rightarrow$$

$$\Rightarrow \dot{V} = \frac{q_{SEN}}{\rho c_p \Delta T} = \frac{80000 \text{ Btu/h}}{0.075 \text{ lb/ft}^3 \cdot 0.24 \text{ Btu/lb°F} \cdot 25 \text{ F}} = 177\,778 \text{ ft}^3/\text{h} = 2963 \text{ CFM}$$

PROBLEM 8.7

$t_{IN} = 89°F$

$t_{WB,IN} = 65°F$

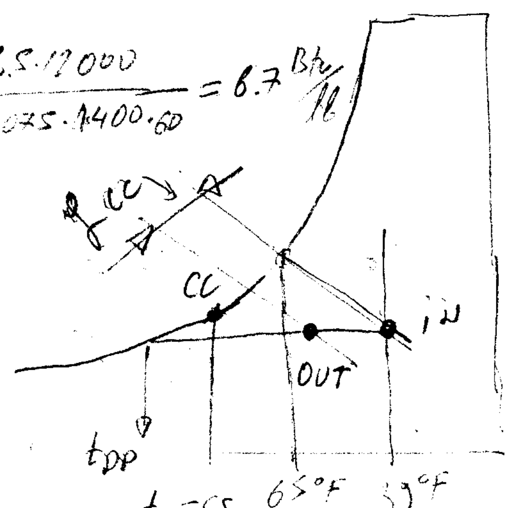
$\dot{V} = 1400$ ft³/min

$t_{CC} = 55°F$

$q_{CC} = 3.5$ ton $= 3.5 \times 12000$ Btu

p_{ATM}

$$q_{CC} = \frac{Q_{CC}}{\rho \cdot \dot{V}} = \frac{3.5 \cdot 12000}{0.075 \cdot 1400 \cdot 60} = 6.7 \text{ Btu/lb}$$



FROM THE GRAPH:

t_{OUT} = ? (BASED ON t_{CC} & t_{DP}

$t_{WB\,OUT}$ = ? (THERE IS NO CONDENSATION ⇒ $W_{IN} = W_{OUT}$

$$t_{OUT} = t_{IN} - \frac{q_{CC}}{c_p} = 89 - \frac{6.7}{0.24} = 61°F$$

$t_{WBT\,OUT} = 55°F$ → FROM CHART

PROBLEM 8.20

WINTER

$q_{SEN} = 260$ kW

$q_{LATEN} = 29$ kW

{ SHR = 0,9

$t_{ROOM} = 20°C$

RH = 40%

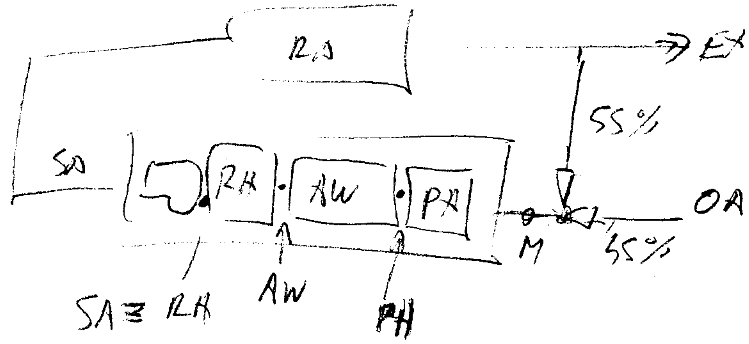
$t_{OA} = 3°C$

$RH_{OA} = 30\%$

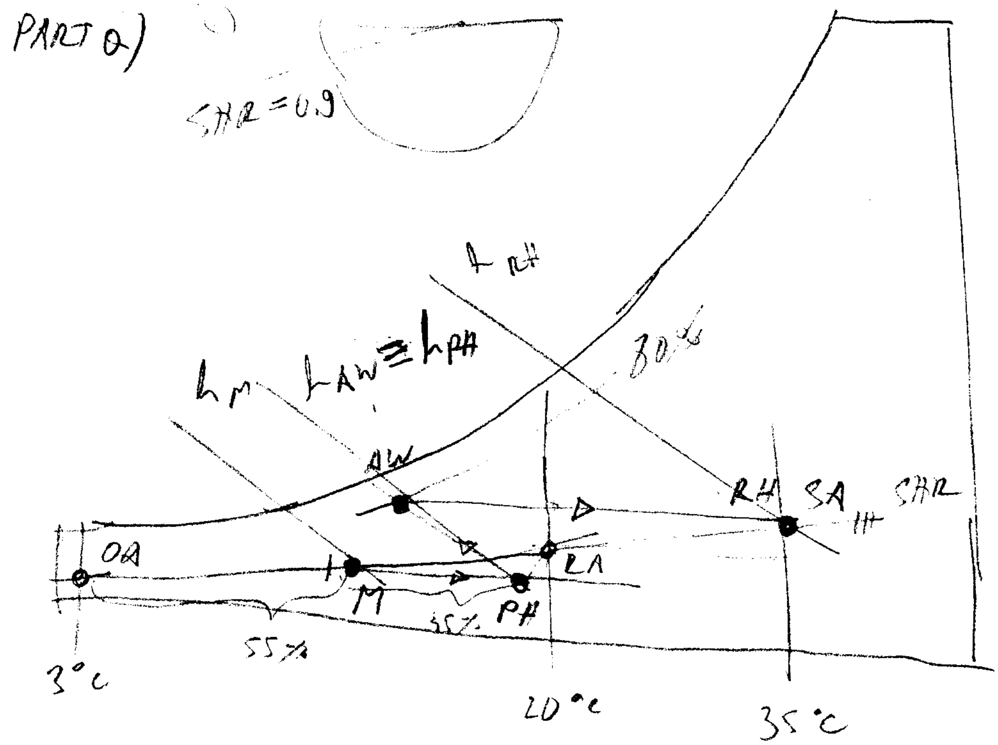
RECIRCULAT: 55%

$t_{SA} = 35°C$

$RH_{AW} = 80\%$



PART a)



PART b) $q_{PH} = ?$

FROM CHART: $h_M = 21$ kJ/kg

$h_{PH} = 28$ kJ/kg

$$Q_{PH} = m_{SA}(h_{PH} - h_M)$$

$m_{SA} = ?$ FROM $q_{SEN} = m_{SA} c_p (t_{SA} - t_R) \Rightarrow m_{SA} = \frac{Q_{SEN}}{c_p \Delta T}$

$$\dot{m}_{SA} = \frac{260 \cdot 10^3}{1005 \cdot 15} = 17.2 \text{ kg/s}$$

$$Q_{PH} = 17.2 \cdot (28 - 21) = 120.4 \text{ kW}$$

PART c)

$$\dot{m}_W = \frac{Q_{LAT}}{h_{fg}} = \frac{29\,000}{2750 \cdot 10^{-3}} = 105 \cdot 10^{-3} \text{ kg/s} = 38 \text{ kg/h}$$

PART d)

$$Q_{RH} = \dot{m}_{DA}(h_{RH} - h_{PH}) = 17.2(52 - 28) = 413 \text{ kW}$$

$h_{RH} = 52$ kJ/kg $\Rightarrow$ FROM CHART

PROBLEM 8.18

$t = 75°F$

$RH = 50\%$

$Q_S = 82000 \ Btu/h$

$h_{fg} = 1200 \ Btu/lb_w$

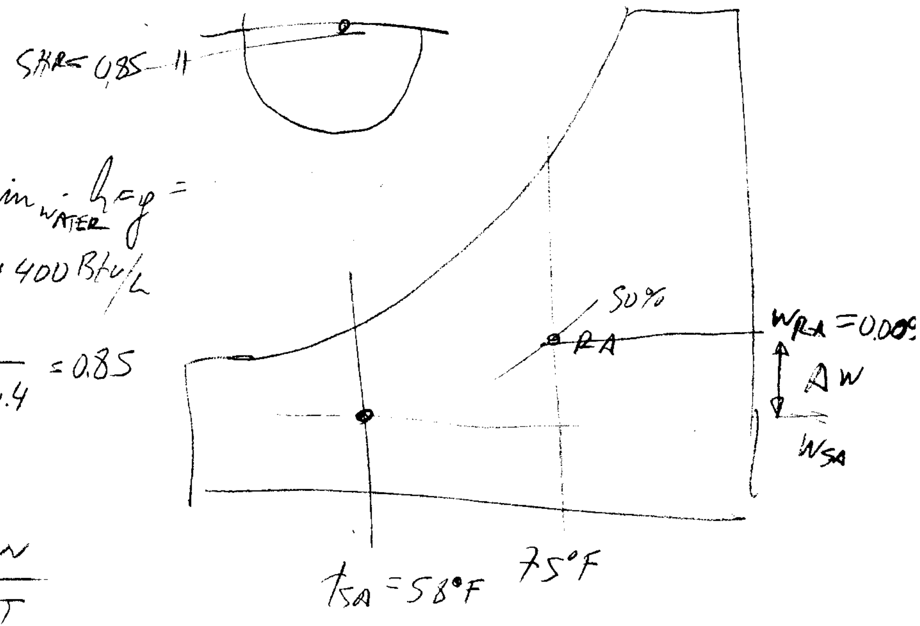
$\dot{m}_{WATER} = 12 \ lb_w/h$

$p_{ATM} = 14.696 \ psi$

$t_{SA} = 58°F$

$Q_{LAT} = \dot{m}_{WATER} \, h_{fg} = 14\,400 \ Btu/h$

$SHR = \frac{82}{82+14.4} = 0.85$



a) $t_{DP_{SA}} = ?$

$t_{WB_{SA}} = ?$

$$\dot{m}_{DA} = \frac{Q_{SEN}}{c_p \cdot \Delta T}$$

$$\dot{m}_{DA} = \frac{82000}{0.24 \cdot (75-58)} = 20,100 \ lb/h$$

$$\Delta W \cdot \dot{m}_{DA} = \dot{m}_{WATER} \Rightarrow W_{SA} = W_{RA} - \frac{\dot{m}_{WATER}}{\dot{m}_{DA}}$$

$$W_{SA} = 0.0098 - \frac{12}{20100} = 0.0092$$

$W_{SA} = 0.0092$, $t_{SA} = 58°F$ → $t_{DP} \simeq 50°F$, $t_{WBT} \approx 55°F$

b) $$\dot{V} = \dot{m}_{DA} / \rho_{DA} = \frac{20100 \ lb/h}{0.075 \ lb/ft^3} = 268 \cdot 10^3 \ ft^3/h = 4467 \ ft^3/min$$

Design Problem # 1

a) Winter, RH control to 50%

$T_{RA} = 24°C$ $Q_{SEN} = -20 kW$ $Q_{LAT} = -10 kW$ SHR = 0.667

$\dot{V}_{OA} = 2 m^3/s$ $T_{HC} =$ $T_{SA} = 32°C$ $T_{OA} = 0$ $RH_o = 80\%$

Assume: load from ventilation is in addition to Q_{SEN} & Q_{LAT}
Water vapor added at same h as saturated steam

Find: $\dot{m}$, $\dot{V}$ of air; heating energy.

Solution:

Plot T_{RA} on chart. $T_{RA} \rightarrow T_{SA}$ using SHR = 0.667

$T_{RA} = 24°C$ 50% RH
$T_{SA} = 32°C$ 37% RH

Find h_{RA}, h_{SA} from chart. calc. Δh

$h_{RA} = 48.2 \frac{kJ}{kg}$ $h_{SA} = 61.0 \frac{kJ}{kg}$ $\Delta h = 12.8$

Calculate $\dot{m}_{SA}$

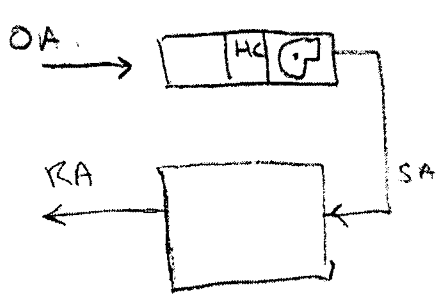
$$\dot{m}_{SA} = \frac{|Q|}{\Delta h} = \frac{30 \frac{kJ}{s}}{12.8 \frac{kJ}{kg}} = 2.344 \frac{kg}{s}$$

Locate T_{OA} on chart, $T_{OA} = 0°C$ RH = 80%

Assume OA volume taken @ $T_{set\,point} = 24°C$
(after heating to room conditions).
Thus, $v_{OA} = v_{T=24°C} = 0.854$

$$\dot{m}_{OA} = \frac{2 m^3/s}{0.854 \frac{m^3}{kg}} = 2.34 \frac{kg}{s} \cong \dot{m}_{SA} = 2.344 \frac{kg}{s}$$

Since $\dot{m}_{OA} = \dot{m}_{RA}$, only outdoor air is used.
& $\boxed{\dot{m} = 2.34 \frac{kg}{s}}$



Next page

Design Problem #1 (continued)

a) Winter, RH control to 50% (continued)

$h_{OA} = 7.1 \frac{kJ}{kg}$ $h_{SA} =$

NOTE: Assume added steam is saturated – Does not change T of air.

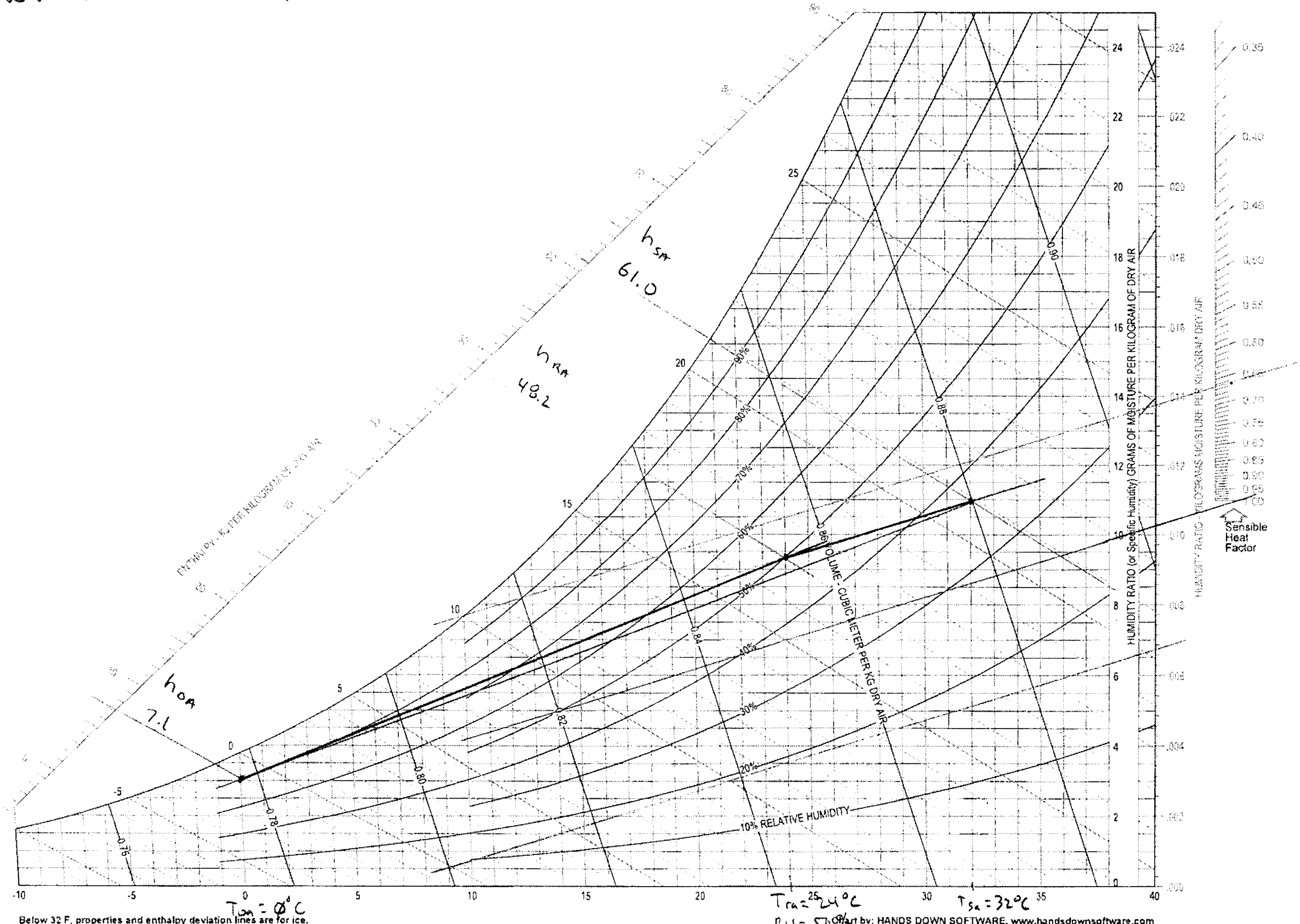
$Q_{total} = \dot{m}(h_{SA} - h_{OA})$

$= 2.34 \frac{kg}{s} \cdot (61.0 - 7.1)\left[\frac{kJ}{kg}\right] \cdot \frac{kW}{kJ/s}$

$= 126\ kW$

Design prob #1

Winter Conditions, $T_{RA} = 24°C$ RH = 50%



Design Problem #1

b) Summer, no humidity Control

$T_{sp} = 24°C$ $Q_{SEN} = 40 kW$ $Q_{LAT} = 30 kW$ $SHR = 0.57$

$\dot{V}_{OA} = 2 m^3/s$ $T_{cc} = 8°C$ $T_{oa} = 40°C$ $T_{sa} = 13°C$ $RH_{OA} = 33\%$

Assume: Load from Ventilation air Conditioning is in addition to Q_{sen} & Q_{lat}.

Find: $\dot{m}, \dot{V}$ of air
Cooling energy

Solution:

Plot T_{cc}. draw $T_{cc} \rightarrow T_{RA}$ using SHR = 0.57
Locate $T_{SA} = 13°$ on line $T_{cc} \rightarrow T_{RA}$.
Find h_{sa}, h_{RA} from graph

$h_{sa} = 34.2 \frac{kJ}{kg}$ $h_{RA} = 54.4 \frac{kJ}{kg}$ $\Delta h = 20.2 \frac{kJ}{kg}$

Calculate $\dot{m}_{sa}$: $Q_{sen} + Q_{lat} = \dot{m}_{sa} \cdot \Delta h_{RA\text{-}SA} \rightarrow \dot{m}_{sa} = \frac{Q_{TOTAL}}{\Delta h}$

$$\dot{m}_{RA} = \dot{m}_{sa} = \frac{70 \frac{kJ}{s}}{20.2 \frac{kJ}{kg}} = 3.465 \frac{kg}{s}$$

Calculate Fresh air flow: $\dot{m}_{oa}$

$\dot{m}_{oa} = \dot{V}_{oa} \cdot \rho_{oa} = \dot{V}_{oa} \cdot \frac{1}{v_{oa}}$ from chart, v_{oa} @ 40°C = $0.947 \frac{m^3}{kg}$

$$\dot{m}_{oa} = 2 \frac{m^3}{s} \cdot \frac{1 kg}{0.947 m^3} = 2.112 \frac{kg}{s}$$

Locate T_{in} on graph.

$$T_{in} = \frac{\dot{m}_{oa}}{\dot{m}_{oa} + \dot{m}_{RA}} \cdot (T_{OA} - T_{RA}) + T_{RA}$$

$$= \frac{2.112}{3.465} (16°C) + 24°C$$

$$= 33.75 C$$

From chart:
$h_{in} = 70.3$

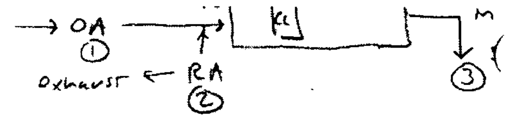
$$Q_{TOTAL} = \dot{m} (h_{in} - h_{SA}) = 3.465 \frac{kg}{s} \cdot \left(70.3 \frac{kJ}{kg} - 34.2 \frac{kJ}{kg}\right) \cdot \frac{1 kW}{kJ/s}$$

$$= 104 kW$$

Design prob #1

b) Summer, $T_{RA} = 24°C$, No humidity

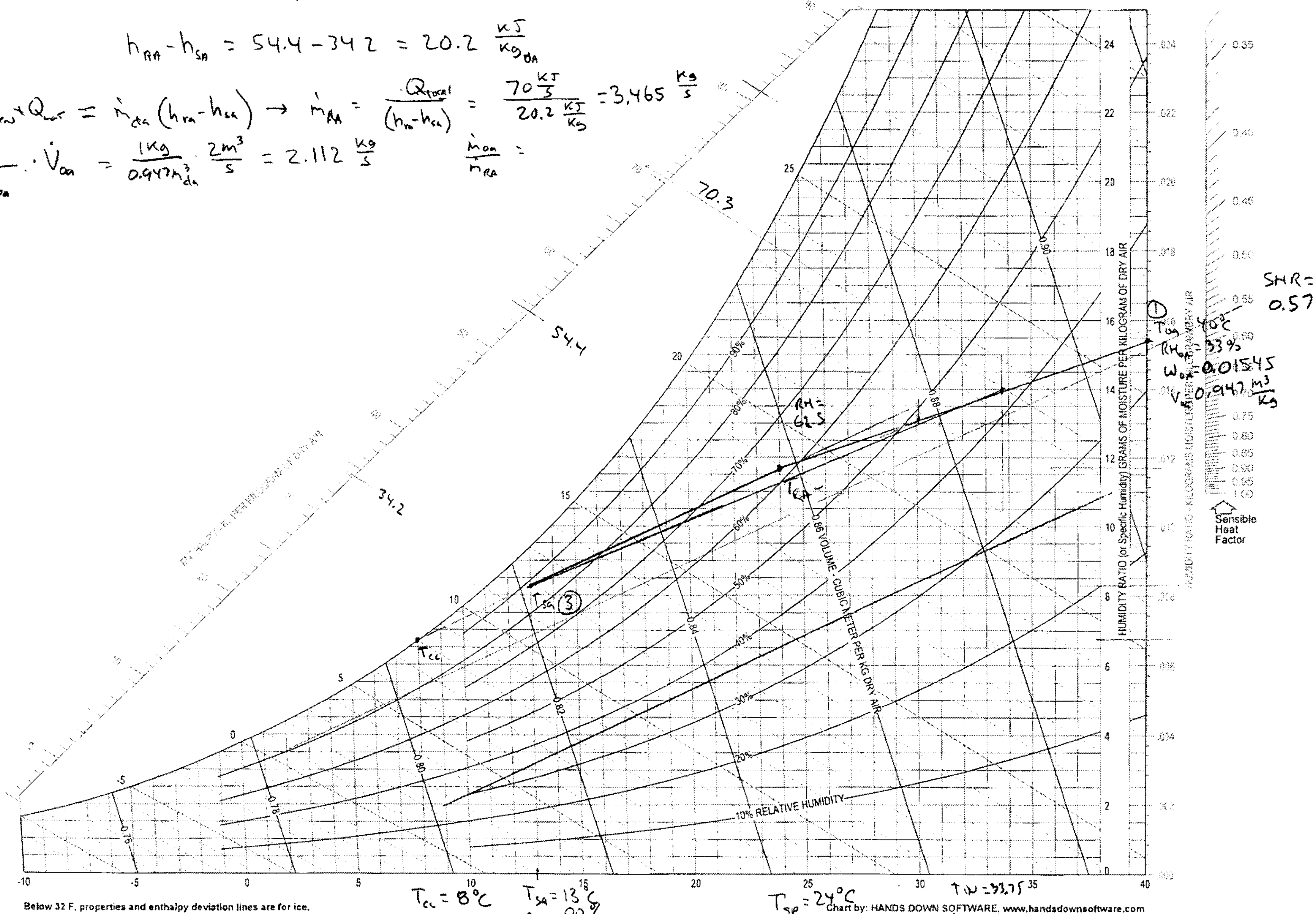
$T_{sa} = 13°C$



$$h_{RA} - h_{SA} = 54.4 - 34.2 = 20.2 \frac{kJ}{kg_{DA}}$$

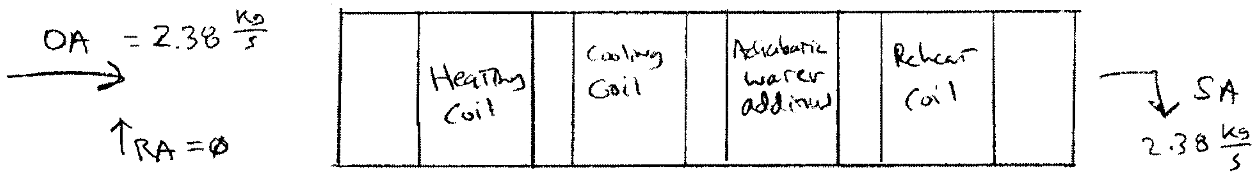
$$Q_{sen} + Q_{lat} = \dot{m}_{da}(h_{ra} - h_{sa}) \rightarrow \dot{m}_{RA} = \frac{Q_{total}}{(h_{ra} - h_{sa})} = \frac{70 \frac{kJ}{s}}{20.2 \frac{kJ}{kg}} = 3.465 \frac{kg}{s}$$

$$\dot{m}_{oa} = \frac{1}{v_{oa}} \cdot \dot{V}_{oa} = \frac{1 kg}{0.947 m^3_{da}} \cdot \frac{2 m^3}{s} = 2.112 \frac{kg}{s} \qquad \frac{\dot{m}_{oa}}{\dot{m}_{RA}} =$$



Design Prob. #2

a) Winter Condition, Conditions as below:



$T_{RA} = 24°C$, $T_{SA} = 32°C$ $RH_{RA} = 50\%$

Solution:

Plot T_{RA}, T_{SA} using SHR 0.667. Plot T_{OA}

Find $\dot{m}_{SA}$

$$\dot{m}_{SA} = \frac{|Q_{sen} + Q_{lat}|}{h_{sa} - h_{RA}} = \frac{30 \frac{KJ}{s}}{(61 - 48.4)\frac{KJ}{kg}} = 2.38$$

Assume Ventilation air evaluated at $T_{set\ point}$ for Volume.

$$\dot{m}_{OA} = \frac{\dot{V}}{v} = \frac{2 m^3/s}{0.854} = 2.34$$

Since $\dot{m}_{OA} \cong \dot{m}_{SA} = \dot{m}_{RA}$, use only outside air

$$\boxed{\dot{m}_{OA} = \dot{m}_{SA} = 2.38 \frac{kg}{s}}$$

Energy use:

$$Q = \dot{m}(h_{SA} - h_{OA}) = 2.38 \frac{kg}{s} \cdot (61.0 - 7.0)\left[\frac{KJ}{kg}\right] \cdot \frac{1 KW}{KJ/s}$$

$$\boxed{= 128 \text{ KW}}$$

Water use:

$$\dot{m} \cdot (W_{SA} - W_{OA}) = 2.38 \frac{kg}{s} \cdot (0.0110 - 0.0031)$$

$$\boxed{= 0.0188 \frac{kg}{s} \text{ water}}$$

Design Prob # 2