

CAE 331/513

Building Science

Fall 2019



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Psychrometric processes (part 3)

Built
Environment
Research

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sustainability research within the built environment*

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Last time

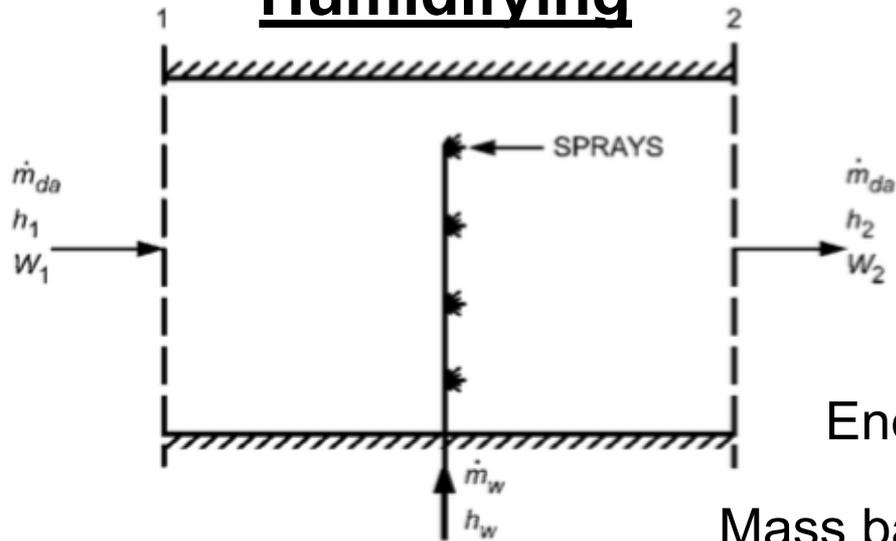
- Energy and mass balances on psychrometric processes
 - Heating
 - Cooling and dehumidification
 - Mixing

PSYCHROMETRIC PROCESSES

Using energy and mass balance equations

Energy/mass balances for psychrometric processes

Humidifying



Energy balance:

$$\dot{m}_{da,1} h_1 + \dot{m}_w h_w = \dot{m}_{da,2} h_2$$

Mass balance on air:

$$\dot{m}_{da,1} = \dot{m}_{da,2} = \dot{m}_{da}$$

Mass balance on water vapor:

$$\dot{m}_{da,1} W_1 + \dot{m}_w = \dot{m}_{da,2} W_2$$

Therefore:

$$\dot{m}_w = \dot{m}_{da} (W_2 - W_1)$$

And:

$$\dot{m}_w h_w = \dot{m}_{da} (h_2 - h_1)$$

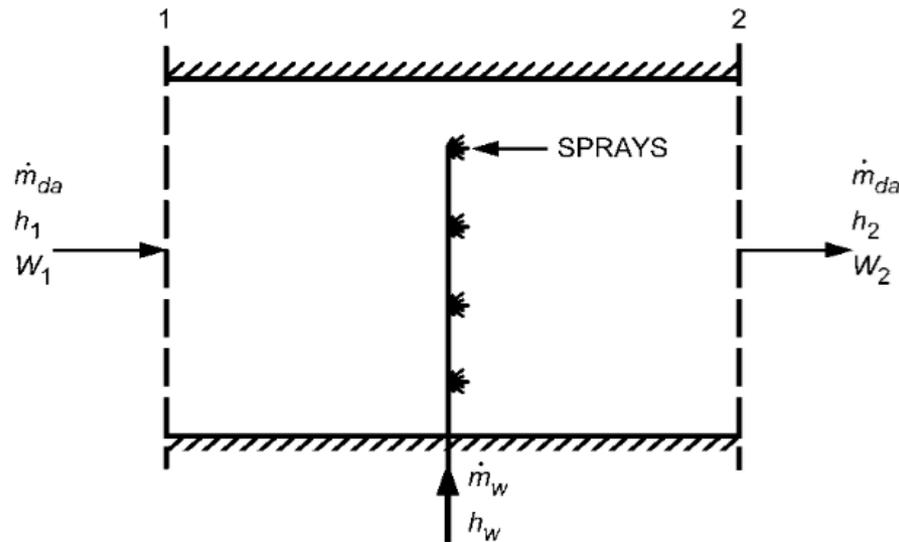
And:

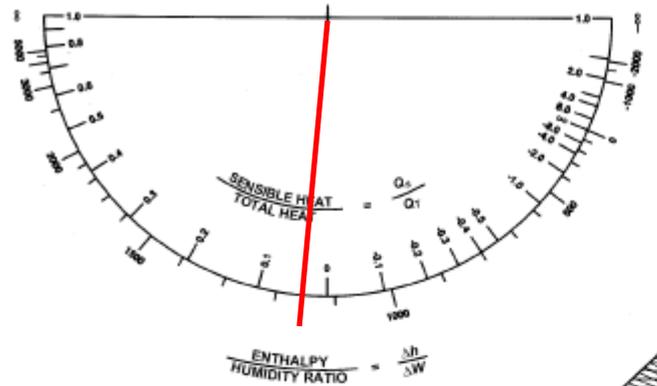
$$\frac{h_2 - h_1}{W_2 - W_1} = \frac{\Delta h}{\Delta W} = h_w$$

*Note that $h_w = h_g$ for steam/vapor and $h_w = h_f$ for water

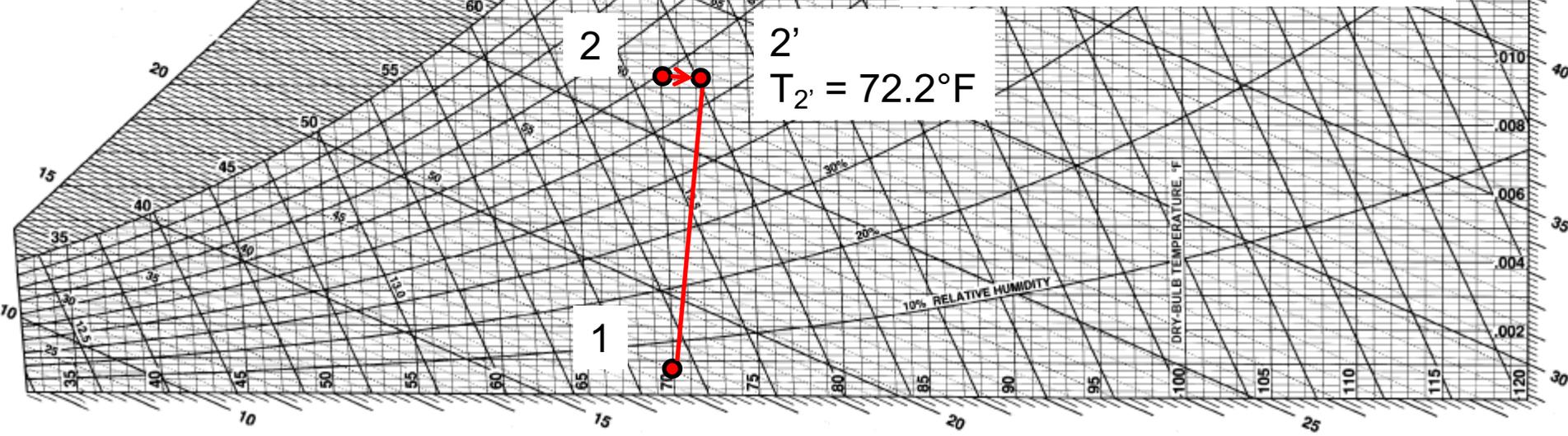
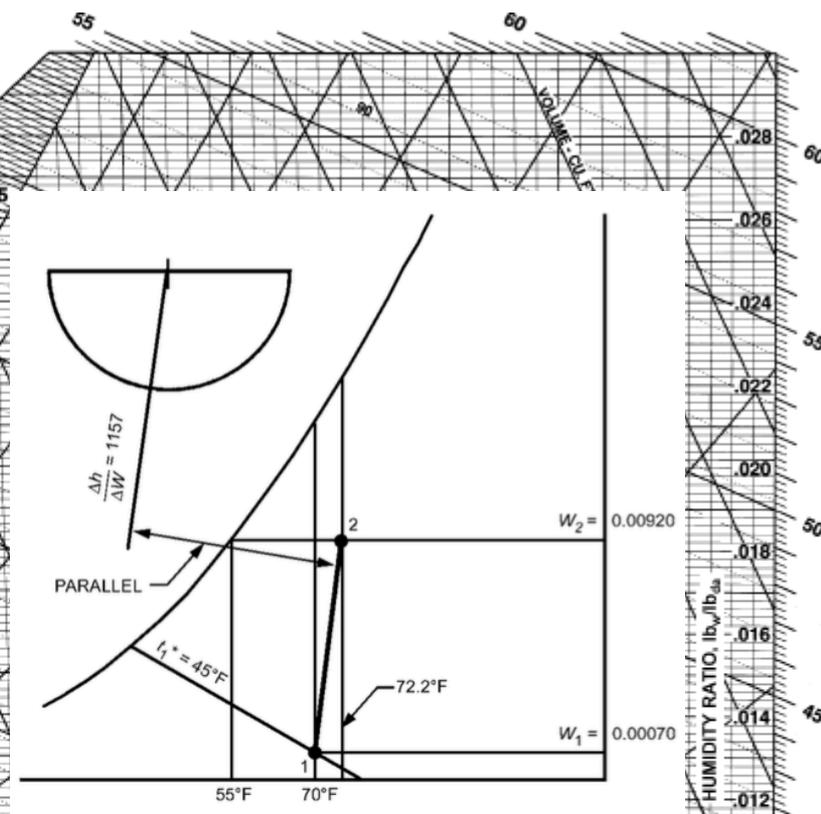
Example 5: Humidification (IP)

- Moist air at 70°F dry bulb temperature and 45°F wet bulb temperature is to be processed to a final dew point of 55°F by adiabatic injection of saturated steam at 230°F
- The air flow rate is 10,000 CFM
 - Find the rate of steam flow required



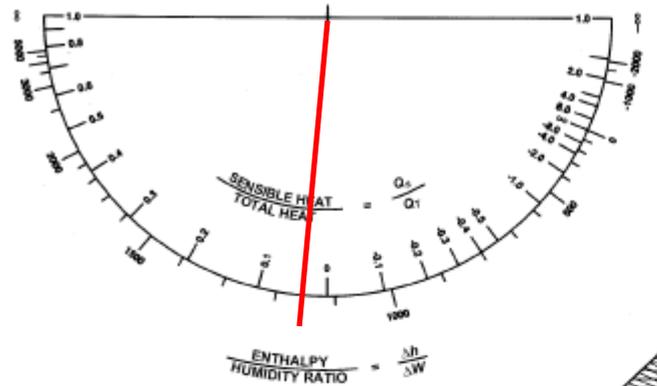


$$\frac{\Delta h}{\Delta W} = 1157 \frac{\text{BTU}}{\text{lb}_w}$$

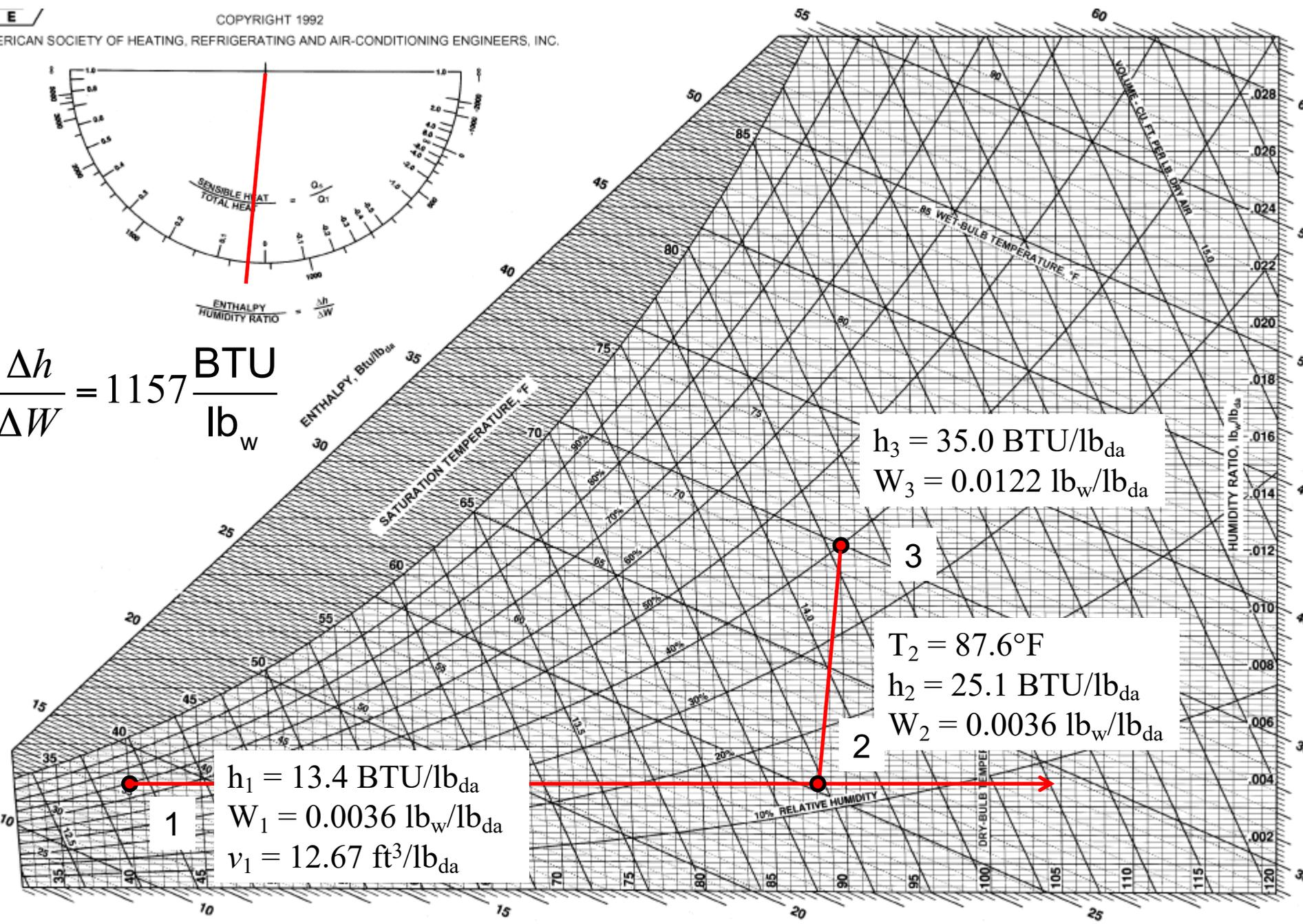


Example 6: Heating and humidification (IP)

- Moist air is heated and humidified by passing it first over a heating coil and then adding moisture. The moist air enters the system at 40°F dry bulb temperature and 36°F wet bulb temperature at a mass flow rate of 235 lb_{da}/min. The humidifier injects saturated steam at 230°F. The moist air exists the system at 90°F dry bulb temperature and 40% RH.
- Locate state 2 on a psychrometric chart and determine the rate of heat addition by the heating coil and the rate of mass addition by the humidifier.



$$\frac{\Delta h}{\Delta W} = 1157 \frac{\text{BTU}}{\text{lb}_w}$$



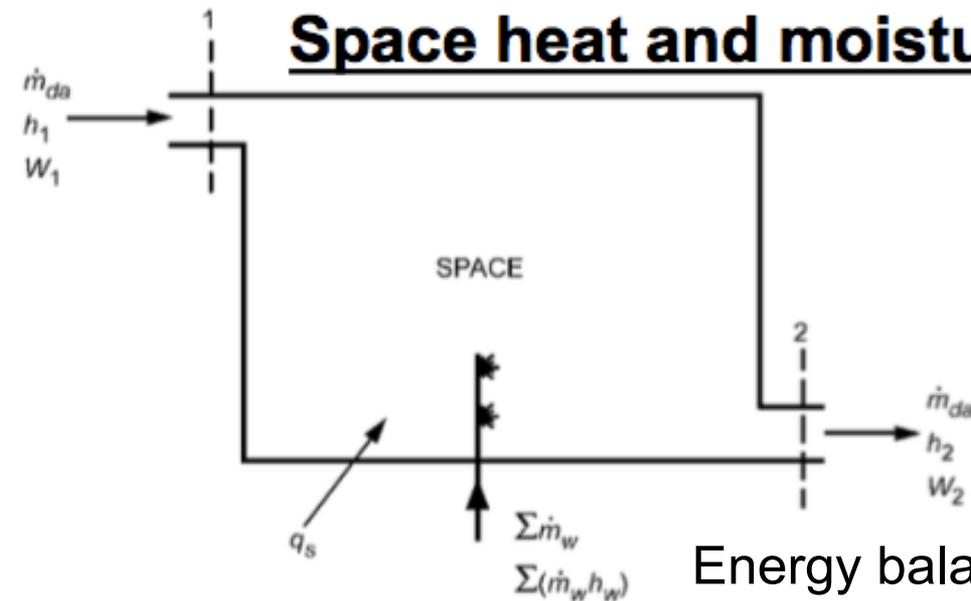
1
 $h_1 = 13.4 \text{ BTU/lb}_{da}$
 $W_1 = 0.0036 \text{ lb}_w/\text{lb}_{da}$
 $v_1 = 12.67 \text{ ft}^3/\text{lb}_{da}$

2
 $T_2 = 87.6^\circ\text{F}$
 $h_2 = 25.1 \text{ BTU/lb}_{da}$
 $W_2 = 0.0036 \text{ lb}_w/\text{lb}_{da}$

3
 $h_3 = 35.0 \text{ BTU/lb}_{da}$
 $W_3 = 0.0122 \text{ lb}_w/\text{lb}_{da}$

Energy/mass balances for psychrometric processes

Space heat and moisture gains



Energy balance: $\dot{m}_{da} h_1 + Q_{gains} + \sum \dot{m}_w h_w = \dot{m}_{da} h_2$

Mass balance on water vapor: $\dot{m}_{da} W_1 + \sum \dot{m}_w = \dot{m}_{da} W_2$

Therefore: $\sum \dot{m}_w = \dot{m}_{da} (W_2 - W_1)$

Therefore: $\sum \dot{m}_w h_w + Q_{gains} = \dot{m}_{da} (h_2 - h_1)$

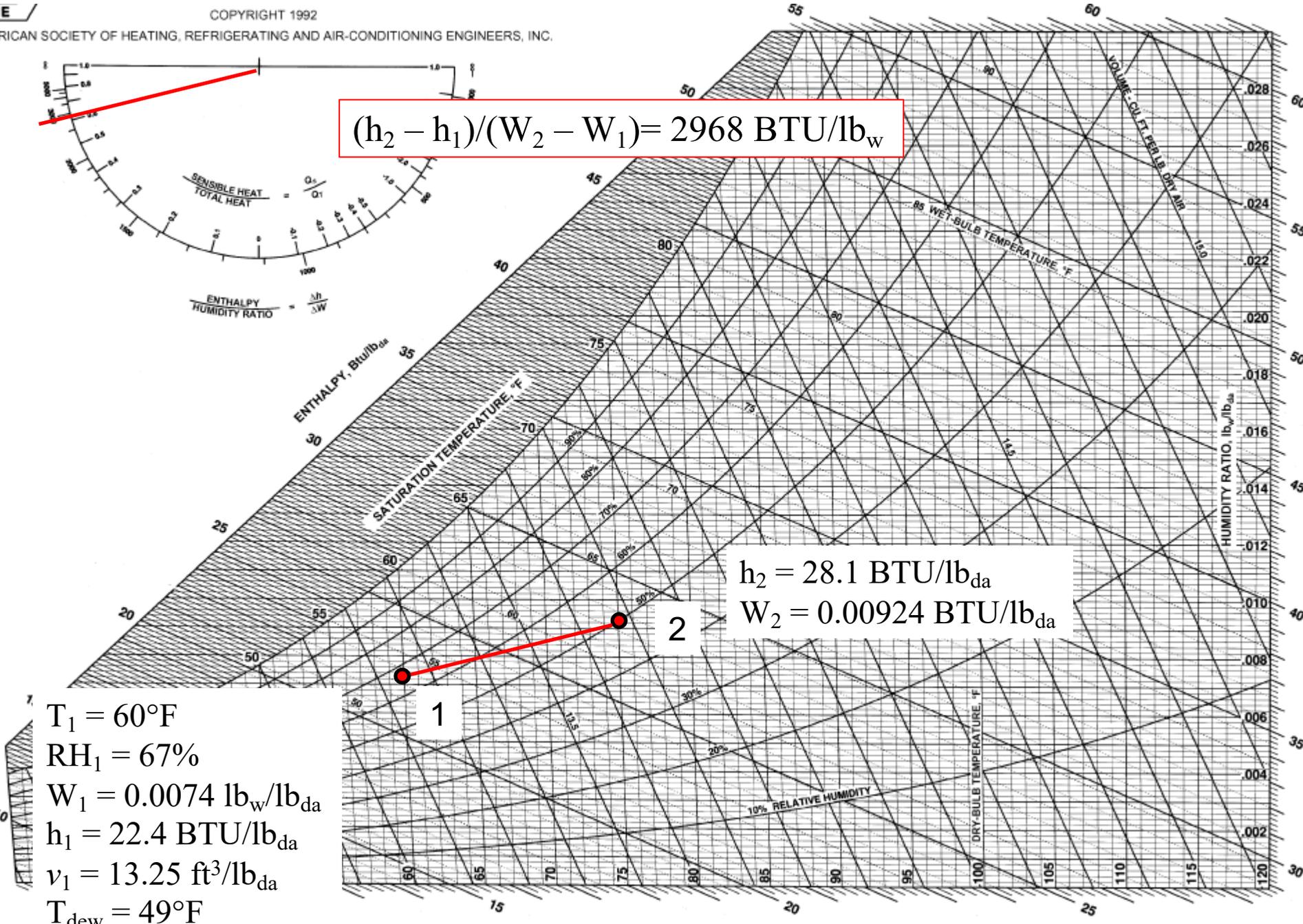
*Note that $h_w = h_g$ for steam/vapor and $h_w = h_f$ for water

And:
$$\frac{\Delta h}{\Delta W} = \frac{\sum \dot{m}_w h_w + Q_{gains}}{\sum \dot{m}_w}$$

Example 7: Space conditioning – cooling (IP)

- The air in a restaurant is to be maintained at 75°F dry-bulb temperature and 50% RH. The load calculations for the restaurant estimate the rate of sensible heat gain to be 178,000 BTU/h. The rate of moisture gain is estimated to be 95 lb_w/h with an average enthalpy of moisture (h_w) of 1095 BTU/lb_w. The supply air temperature is to be 60°F. Assume standard atmospheric pressure.
- Determine the following:
 - a) The required dew-point temperature of the supply air
 - b) The required volumetric flow rate of supply air (in CFM)

$$(h_2 - h_1)/(W_2 - W_1) = 2968 \text{ BTU/lb}_w$$



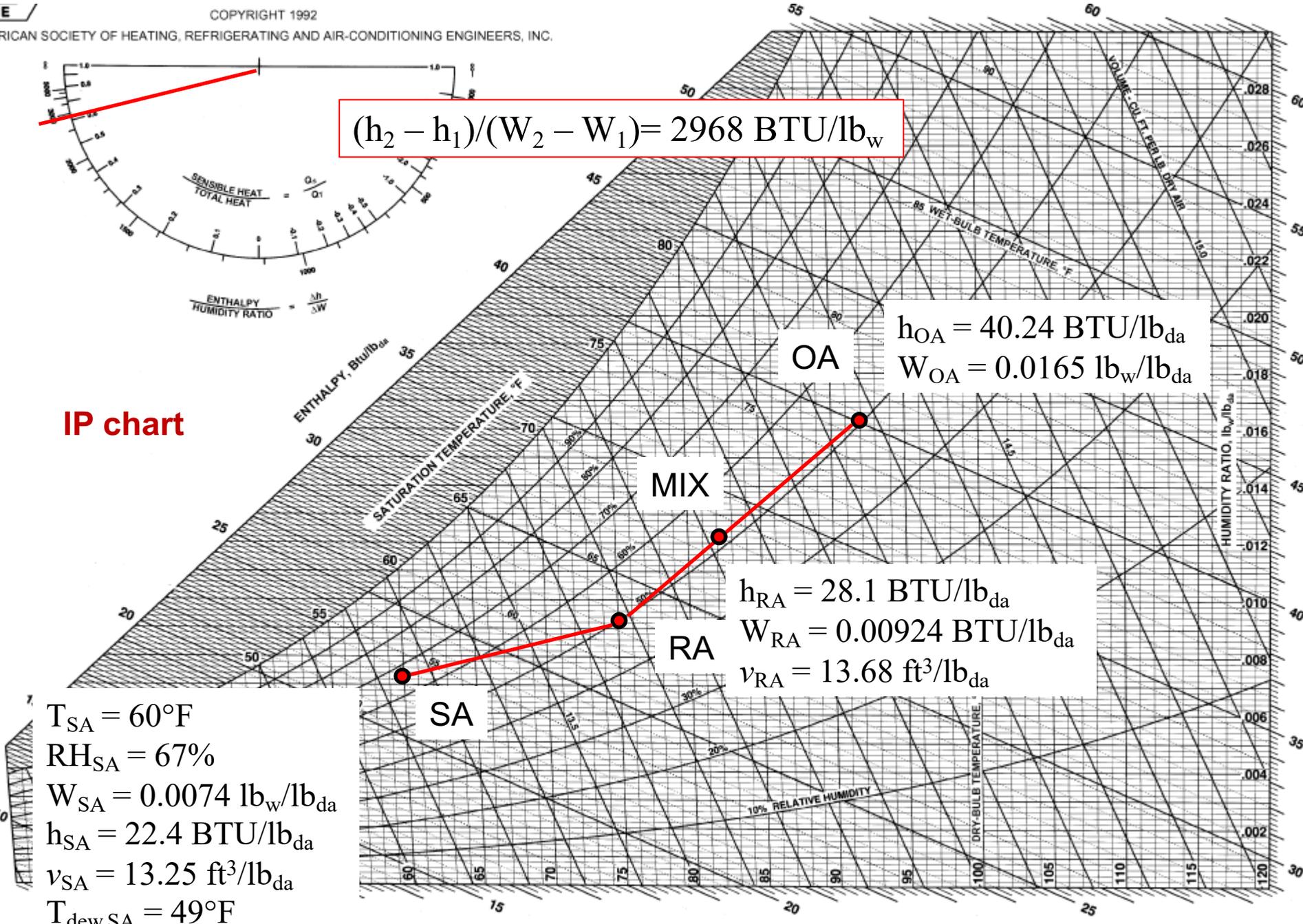
$T_1 = 60^\circ\text{F}$
 $RH_1 = 67\%$
 $W_1 = 0.0074 \text{ lb}_w/\text{lb}_{da}$
 $h_1 = 22.4 \text{ BTU/lb}_{da}$
 $v_1 = 13.25 \text{ ft}^3/\text{lb}_{da}$
 $T_{dew} = 49^\circ\text{F}$

Example 8: Single-zone space conditioning (IP)

- Assume the restaurant from the previous example is to be served by an air handling unit that mixes outdoor air with recirculated air, then passes the air over a cooling coil to the space. Outside air conditions are 92°F dry bulb and 77°F wet bulb temperatures. The rate of exhaust from the restaurant is 4500 CFM.
- Determine the following:
 - a) The mass flow rate of recirculated air
 - b) The thermodynamic state of the moist air entering the cooling coil
 - c) The refrigeration capacity required

$$(h_2 - h_1)/(W_2 - W_1) = 2968 \text{ BTU/lb}_w$$

IP chart



$T_{SA} = 60^\circ\text{F}$
 $RH_{SA} = 67\%$
 $W_{SA} = 0.0074 \text{ lb}_w/\text{lb}_{da}$
 $h_{SA} = 22.4 \text{ BTU/lb}_{da}$
 $v_{SA} = 13.25 \text{ ft}^3/\text{lb}_{da}$
 $T_{dew,SA} = 49^\circ\text{F}$

$h_{RA} = 28.1 \text{ BTU/lb}_{da}$
 $W_{RA} = 0.00924 \text{ lb}_w/\text{lb}_{da}$
 $v_{RA} = 13.68 \text{ ft}^3/\text{lb}_{da}$

$h_{OA} = 40.24 \text{ BTU/lb}_{da}$
 $W_{OA} = 0.0165 \text{ lb}_w/\text{lb}_{da}$