PSYCHROMETRICS

- study of physical and thermal properties of air-water vapor mixtures

Objective:

Student should become familiar with psychrometric properties and principles; understand and be able to use the psychrometric chart.

Psychrometric Terms

- humidity ratio
- relative humidity
- degree of saturation
- specific volume
- dry-bulb temperature
- wet-bulb temperature
- dewpoint temperature
- vapor pressure

Humidity Ratio, W

$W = m_{mv}/m_{da}$

where:

m_{mv} = mass water vapor

m_{da} = mass dry air

units: lb/lb

Relative humidity, RH

$RH = p/p_s$

where:

p = actual water vapor pressure

p_s = vapor pressure of saturated air

units: %

Degree of saturation, u

$u = W_a/W_s$

where:

W = actual humidity ratio

W = humidity ratio at saturation

Specific volume, V

- inverse of density
- determined from PV = mRT

units: cuft/lb

Dry-bulb temperature, t_{db}

- temperature as read from a common thermometer

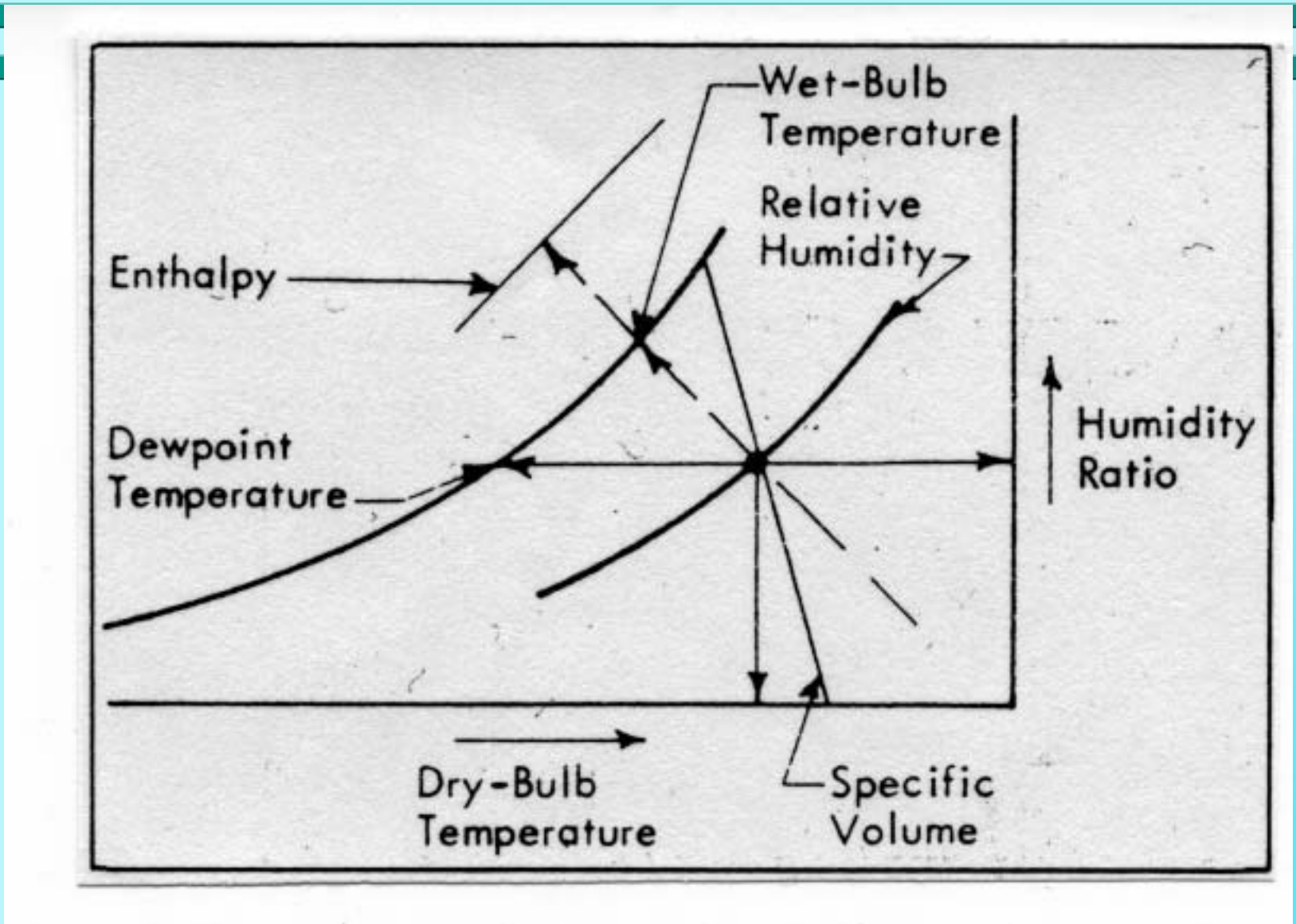
Wet-bulb temperature, t_{wb}

- temperature depressed by cooling of wet wick on bulb

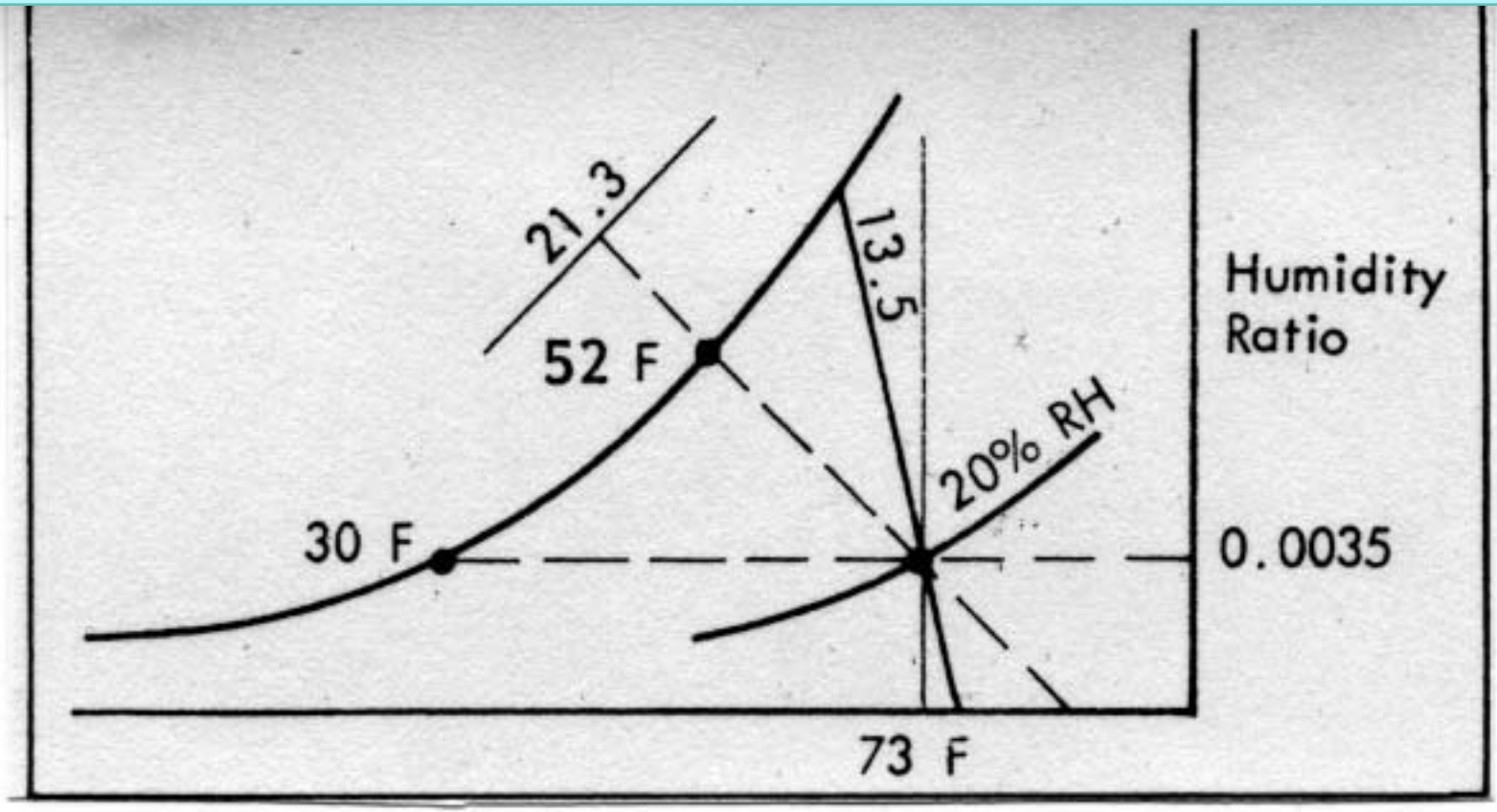
Dewpoint temperature, t_{dpt}

- temperature at which condensation occurs

Psychrometric Properties on the Chart



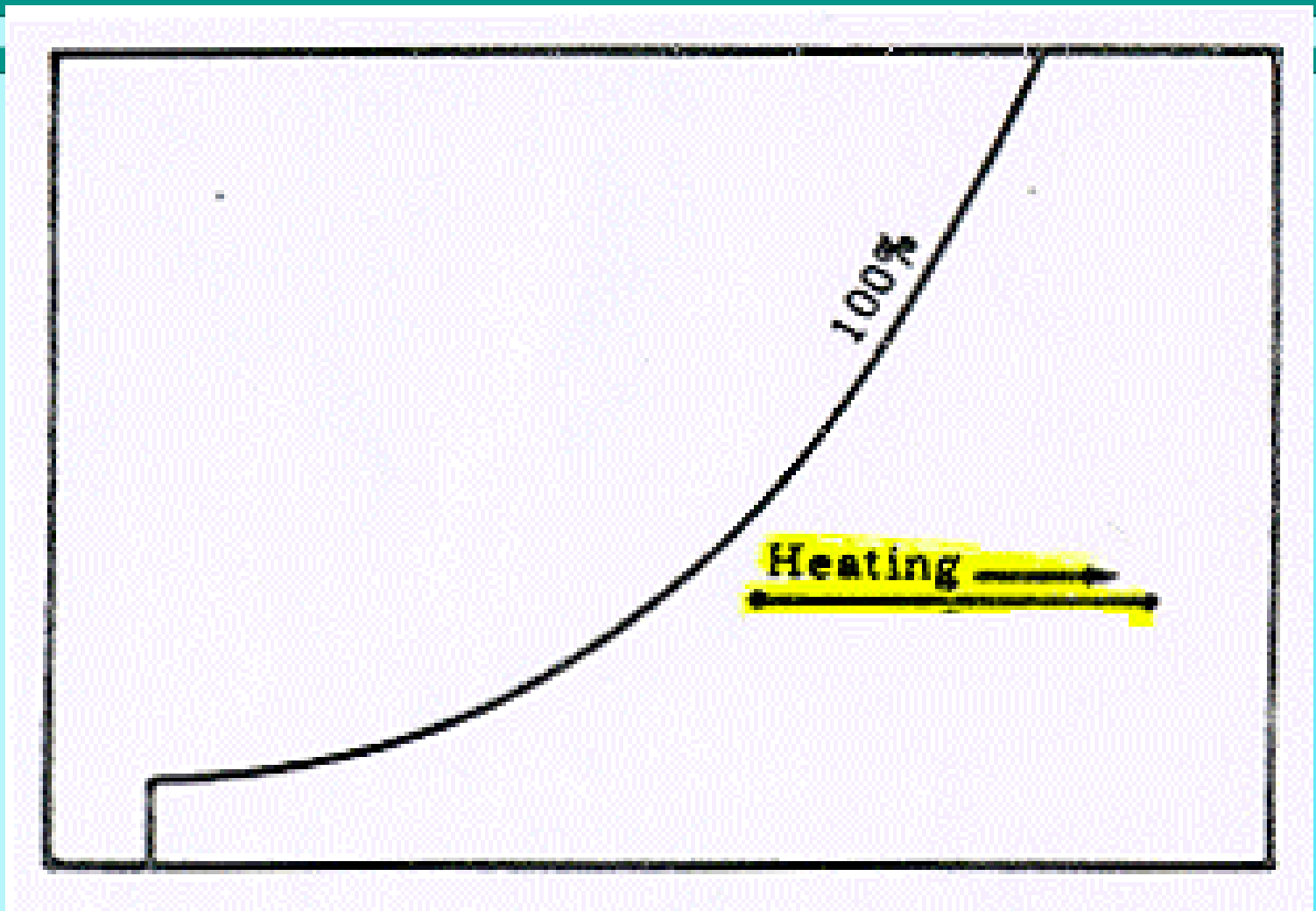
Psychrometric State (Air Conditions)



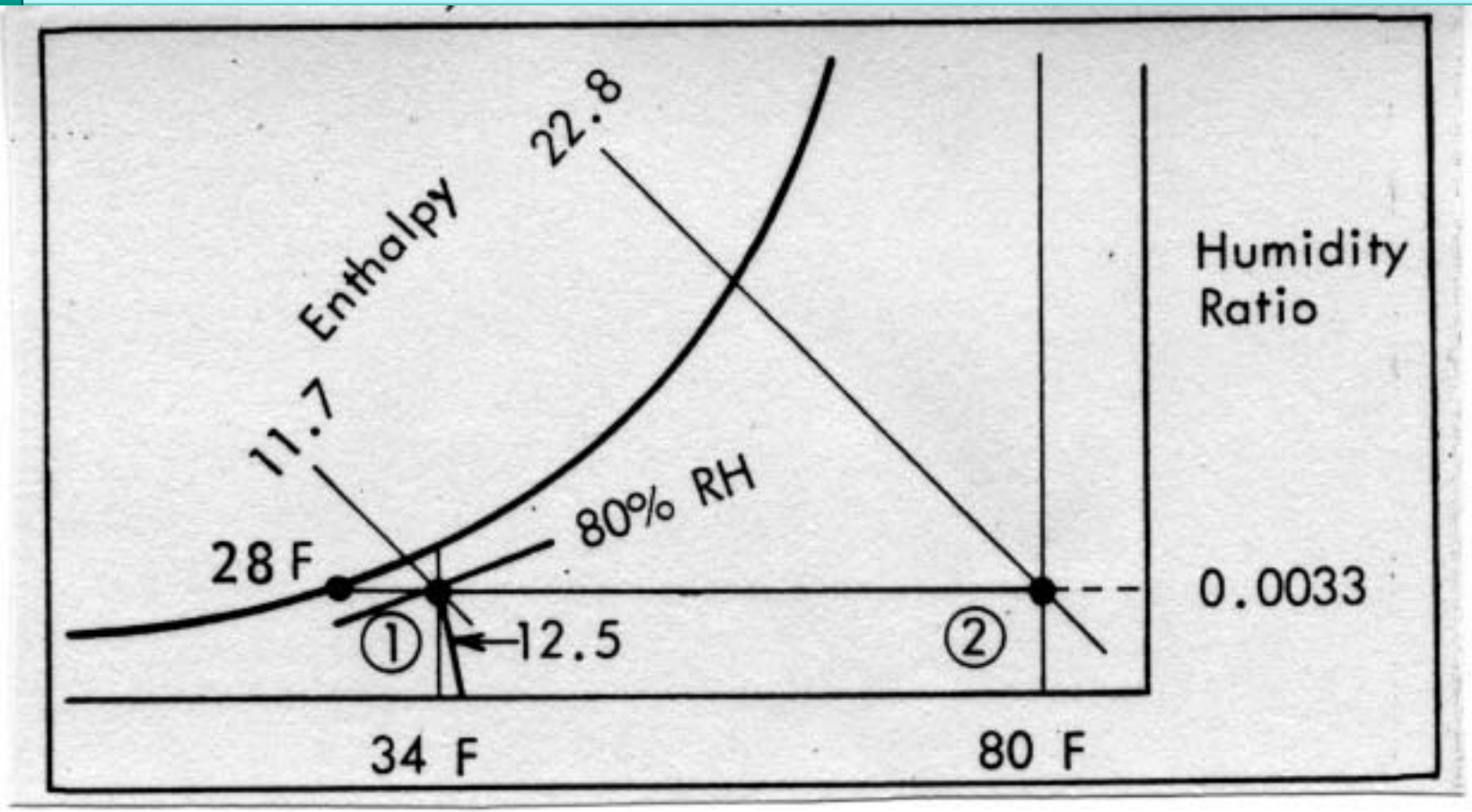
Psychrometric Processes

- sensible heating
- sensible cooling
- evaporative cooling
- heating and humidifying
- cooling and dehumidifying
- adiabatic mixing

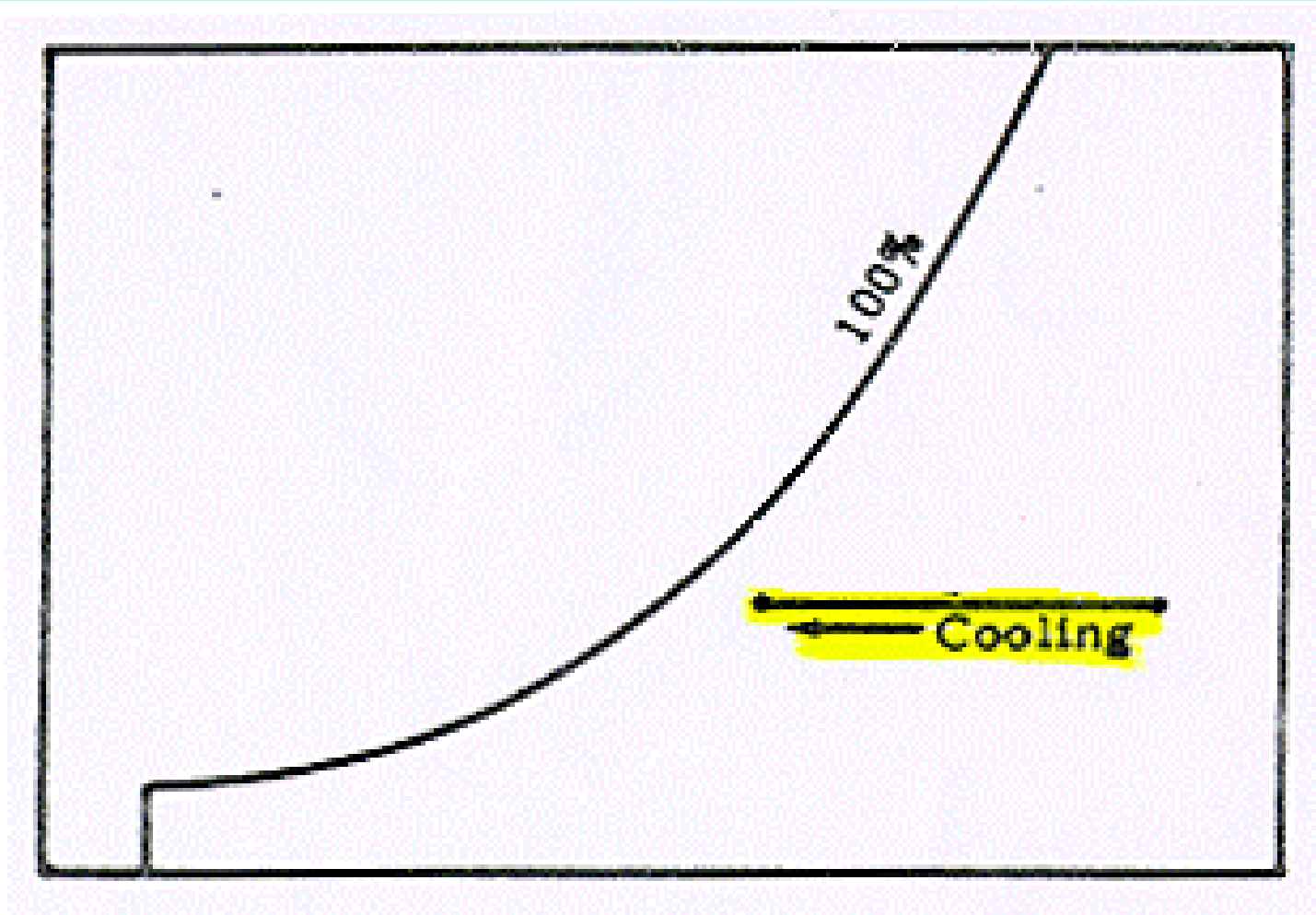
Sensible heating



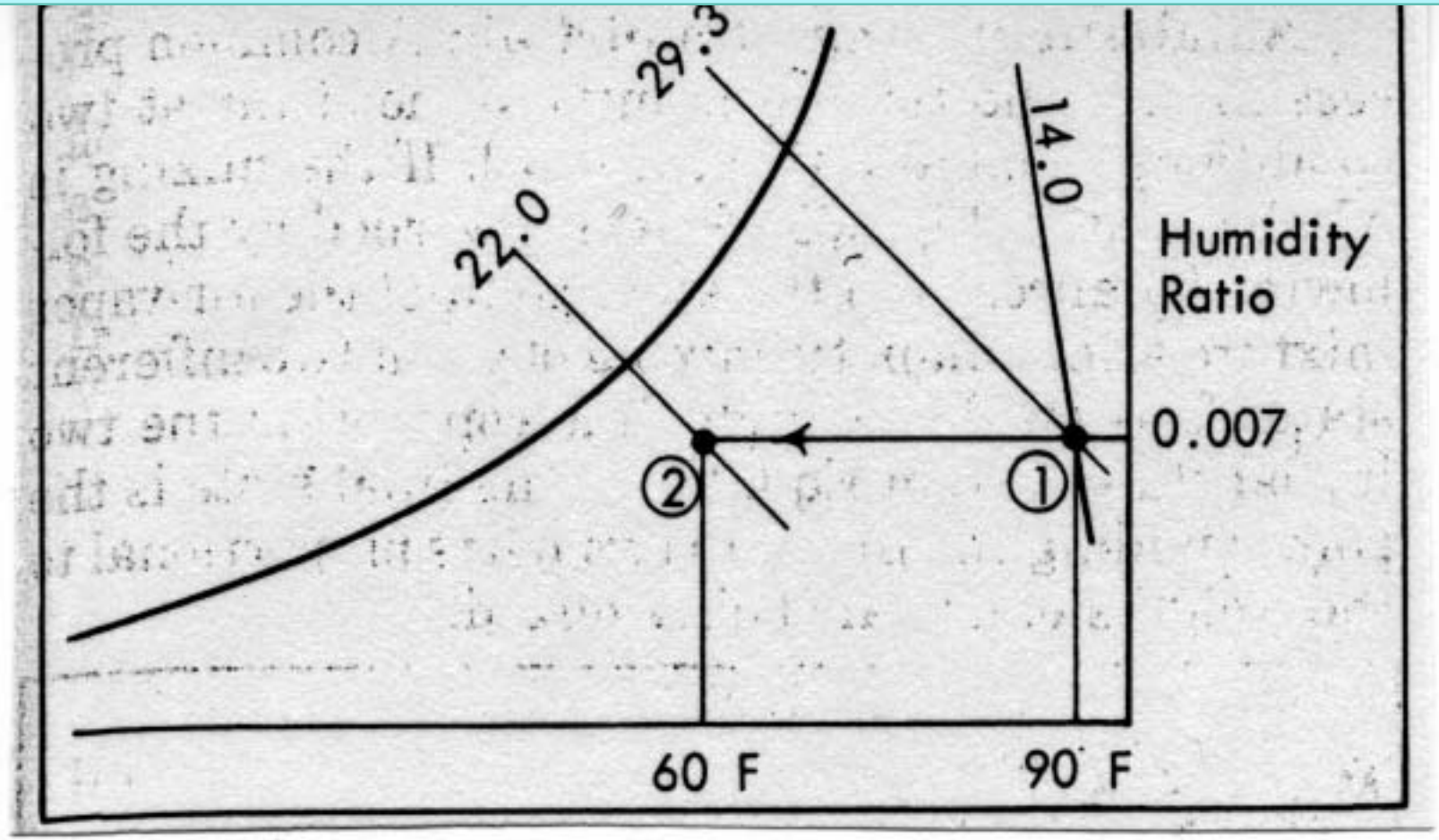
Sensible Heating Example



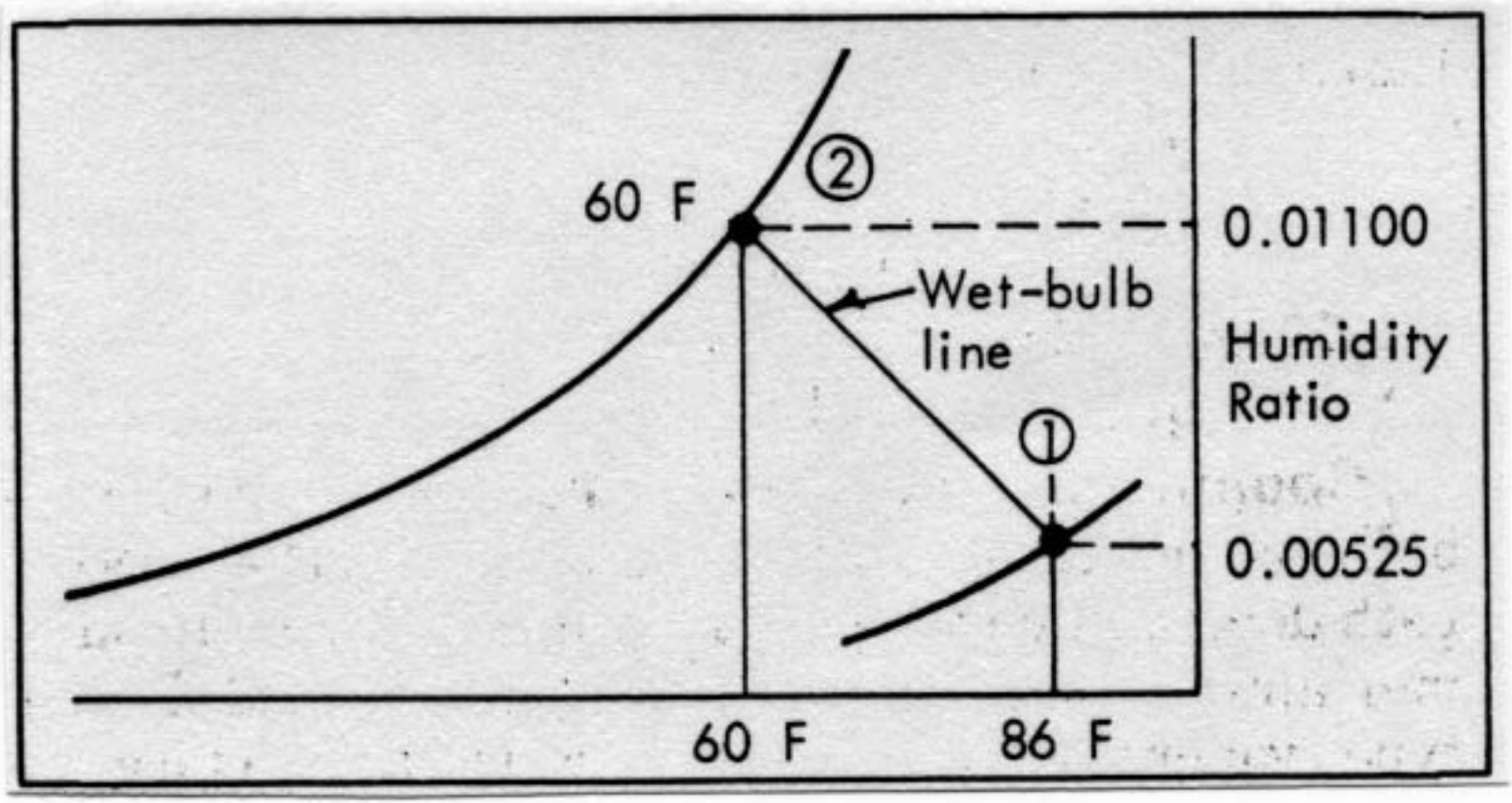
Sensible cooling



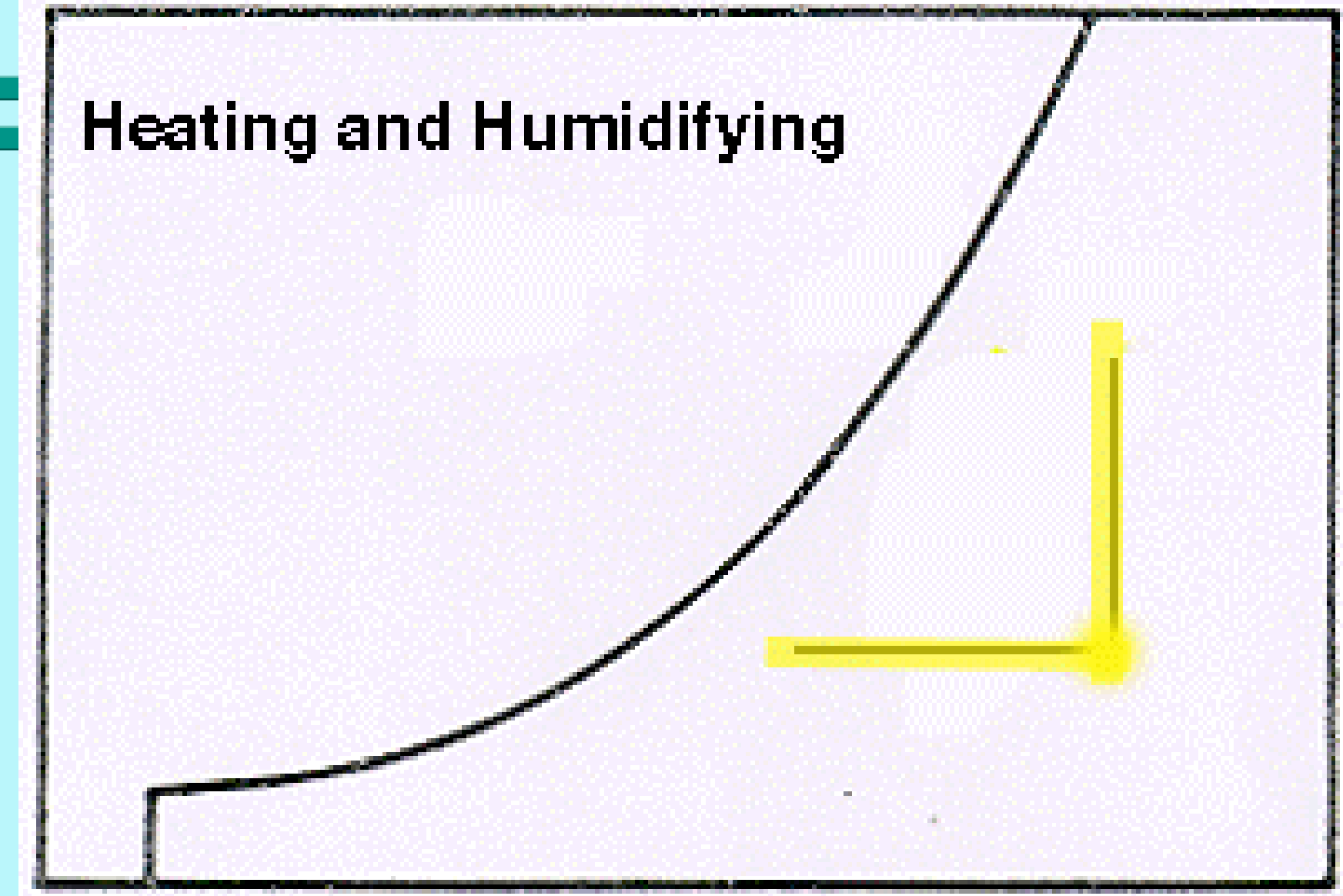
Sensible Cooling Example



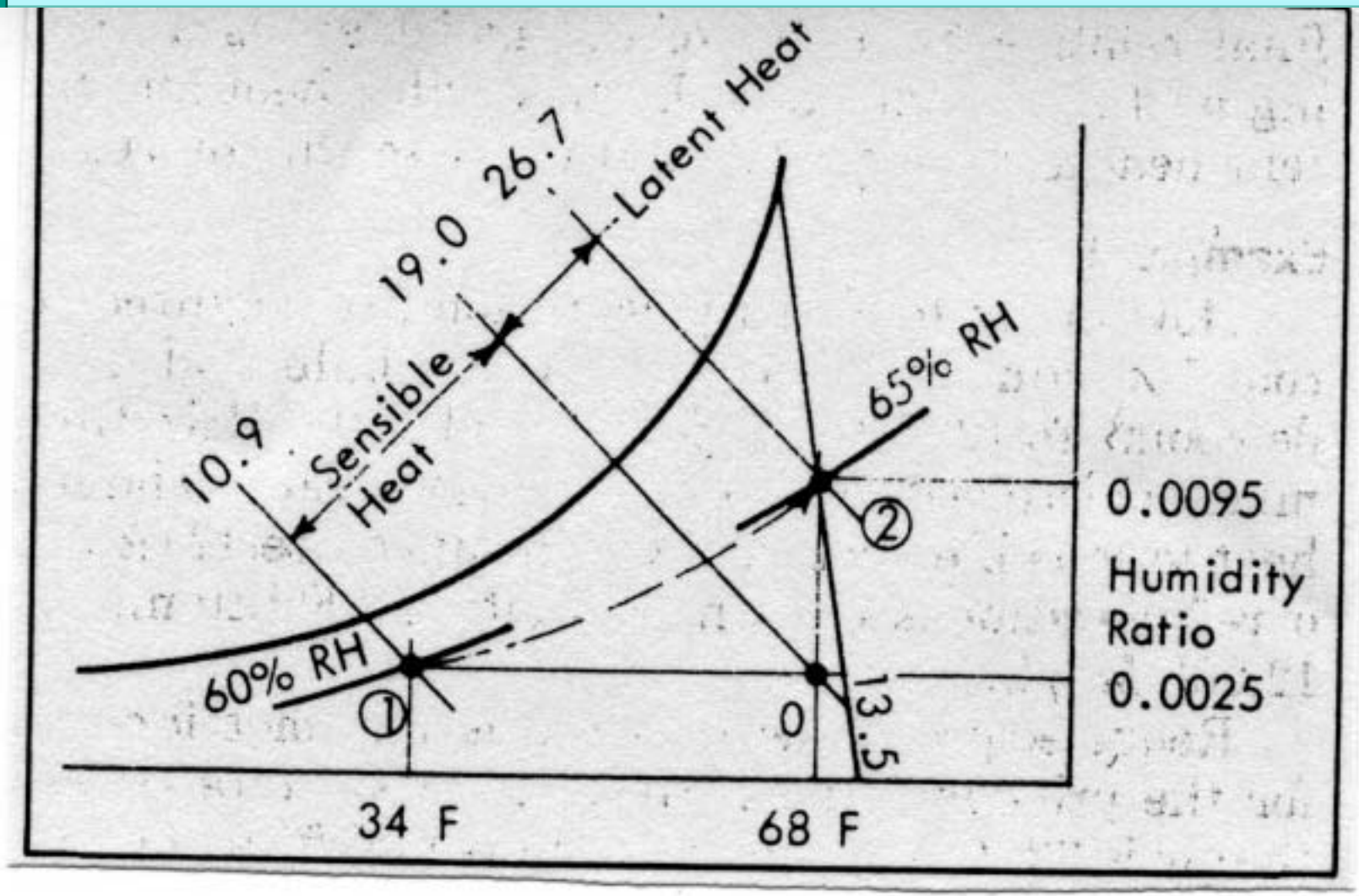
Evaporative Cooling Example



Heating and Humidifying



Heating & Humidifying



Psychrometric Exercise:

- Consider air at t_{db} = 100 F & t_{wb} = 80 F
- Find %RH, HR, t_{dpt}, enthalpy, sp. vol.

Solution:

RH = 42%

HR = 0.0175 lb_m/lb_{da}

t_{dpt} = 73 F

enthalpy = 43.3 Btu/lb

sp. vol. = 14.5 cuft/lb

Psychro. Exercise 2:

Determine the amount of sensible heat needed to increase the temperature of air from 50 F & 50% RH to 90 F.

Solution:

enthalpy (50 F, 50% RH) = 16 Btu/lb

(HR = 0.0038 lb/lb)

enthalpy (90 F, same HR) = 26 Btu/lb

heat added = 26 - 16 = 10 Btu/lb

Psychro Exercise 3:

How much moisture is added to 20 lb of air going from 50 F, 50% RH to 80 F, 60% RH?

Solution:

HR (50 F, 50% RH) = 0.0038 lb_m/lb_{da}

HR (80 F, 60% RH) = 0.0132 lb_m/lb_{da}

Water added = 20 lb * (0.0132 - 0.0038) lb/lb = 0.188 lb_m

QUIZ TIME: Please take a clean paper and put your name on it.

1. Define relative humidity
2. Define wet-bulb temperature
3. What is the relative humidity for air if the dry-bulb temperature is 99 F and the humidity ratio is 0.016 lb/lb?
4. What is the specific volume of air if the dry-bulb temperature is 70 F and the relative humidity is 45%?

ANSWERS

1. Define relative humidity

- Relative humidity is the ratio of the actual water vapor pressure to the vapor pressure of saturated air at the same temperature

2. Define wet-bulb temperature

- Wet-bulb temperature is the temperature measured with the bulb of the thermometer or the junction of a thermocouple covered with water-moistened wick and in a moving ambient air stream. Evaporation cools the bulb resulting in a depressed temperature.

3. What is the relative humidity for air if the dry-bulb temperature is 99 F and the humidity ratio is 0.016 lb/lb?

- Using the psychrometric chart, the relative humidity at the above conditions is found to be 40%.

4. What is the specific volume of air if the dry-bulb temperature is 70 F and the relative humidity is 45%?

- Using the psychrometric chart, the specific volume at the above conditions is found to be 13.5 cuft/lb.

Problems

1. If air is initially at 40 F and 80% RH, how much heat must be added to bring the temperature to 80 F? What would be the final RH?
2. How much moisture is removed from air which is initially at 90 F, 60% RH and ends up at 90 F, 20% RH?.
3. What is the evaporative cooling potential (final dry bulb temperature) for air at 100 F, 20% RH? How much moisture would be added?
4. If a fan is exhausting 1400 cfm of 82 F, 70% RH air, how many pounds is this?
5. If air is brought in at 57 F, 50% RH and exhausted at 90 F, 40% RH, how many pounds must be exhausted to remove 8.0 lb of moisture?

1. If air is initially at 40 F and 80% RH, how much heat must be added to bring the temperature to 80 F? What would be the final RH?

Solution:

From psychrometric chart:

@40 F, 80% RH: W= 0.0042 lb/lb; h = 14.2 Btu/lb

@80 F, 0.0042 lb/lb: h = 24.0 Btu/lb

dh = 24.0 - 14.2 = 9.8 Btu/lb

or $h = m_a c_a (dt) + m_w c_w (dt)$

$= (1*0.24 + 0.0042*1.0)(80-40) = 9.77$ Btu/lb

RH = 20%

2. How much moisture is removed from air which is initially at 90 F, 60% RH and ends up at 90 F, 20% RH?

Solution

From chart, using $dW = W_1 - W_2$

$= 0.0185 - 0.006 = 0.0125$ lb/lb

3. What is the evaporative cooling potential (final dry bulb temperature) for air at 100 F, 20% RH? How much moisture would be added?

Solution

From chart: $t_{dbf} = 69$ F

$dW = 0.0152 - 0.0082 = 0.007$ lb/lb

4. If a fan is exhausting 1400 cfm of 82 F, 70% RH air, how many pounds is this?

Solution

From chart: v = 14.0 cuft/lb

1400 cfm/14.0 cuft/lb = 100 lb

5. If air is brought in at 57 F, 50% RH and exhausted at 90 F, 40% RH, how many pounds must be exhausted to remove 8.0 lb of moisture?

Solution:

From chart: $W_1 = 0.012$ lb/lb; $W_2 = 0.006$ lb/lb

$dW = 0.012 - 0.006 = 0.006$ lb/lb

Air req'd = 8.0 lb water/(0.006 lb/lb) = 1333 lb