THE PSYCHROMETRIC CHART: Theory and Application

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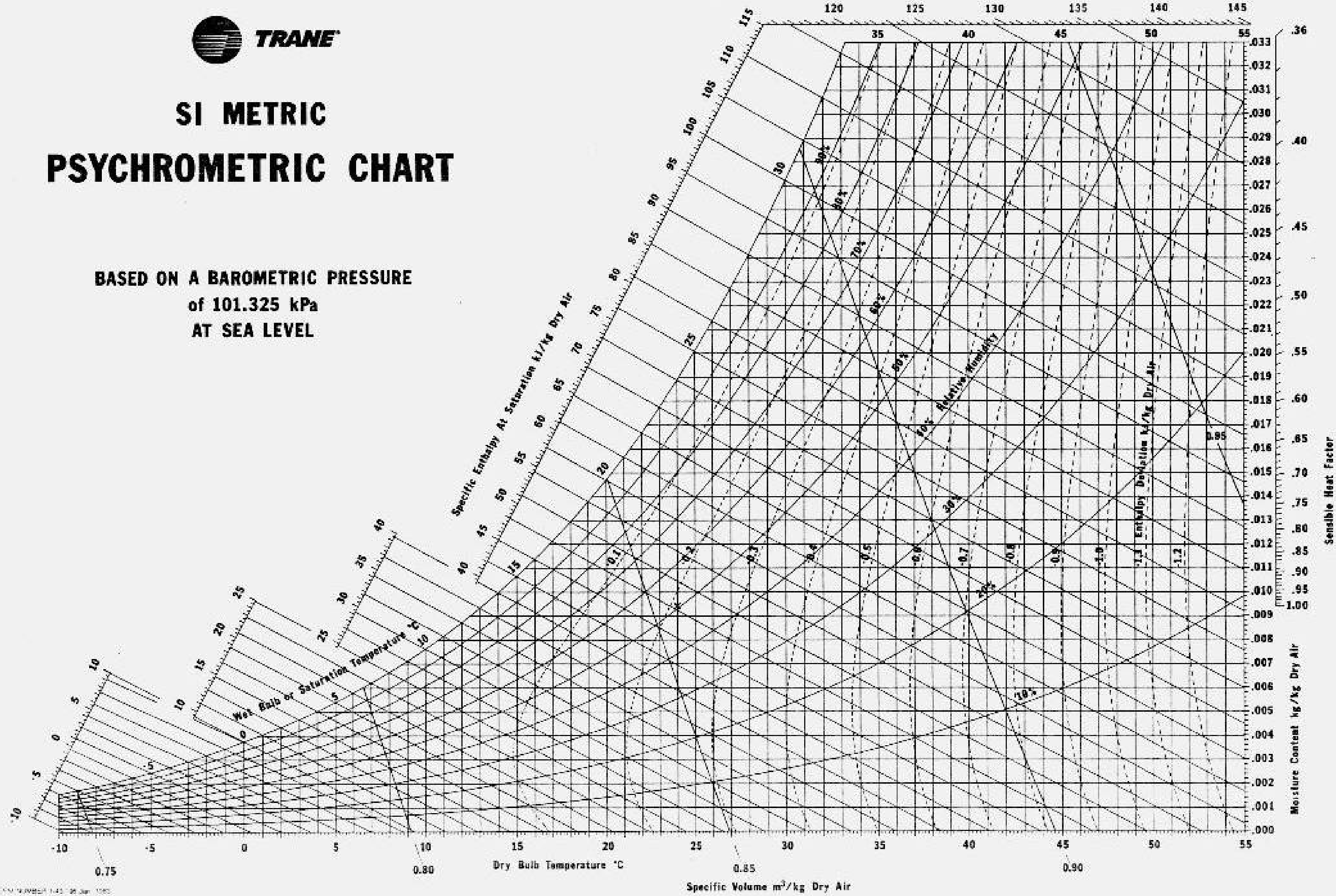
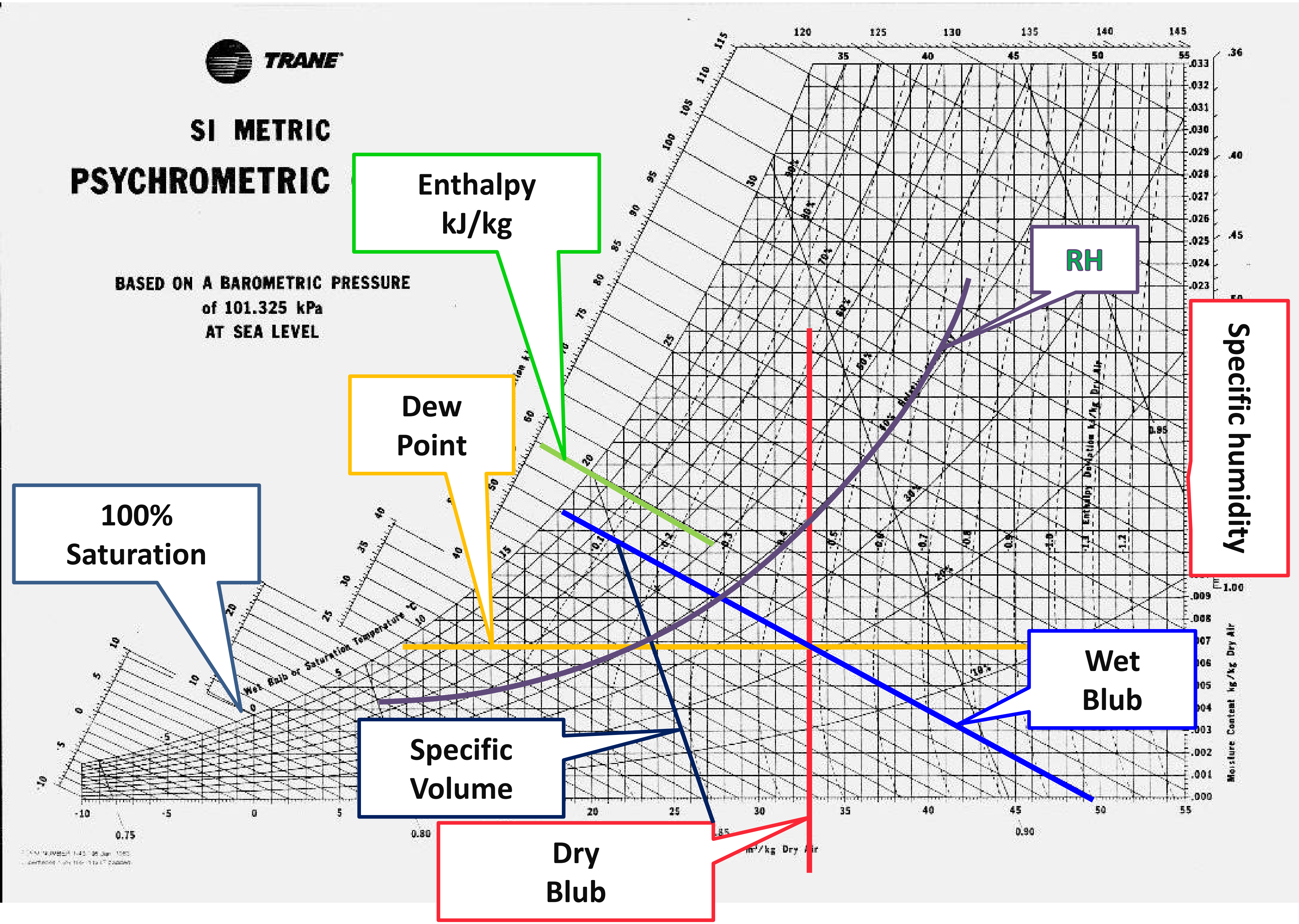
TRANE

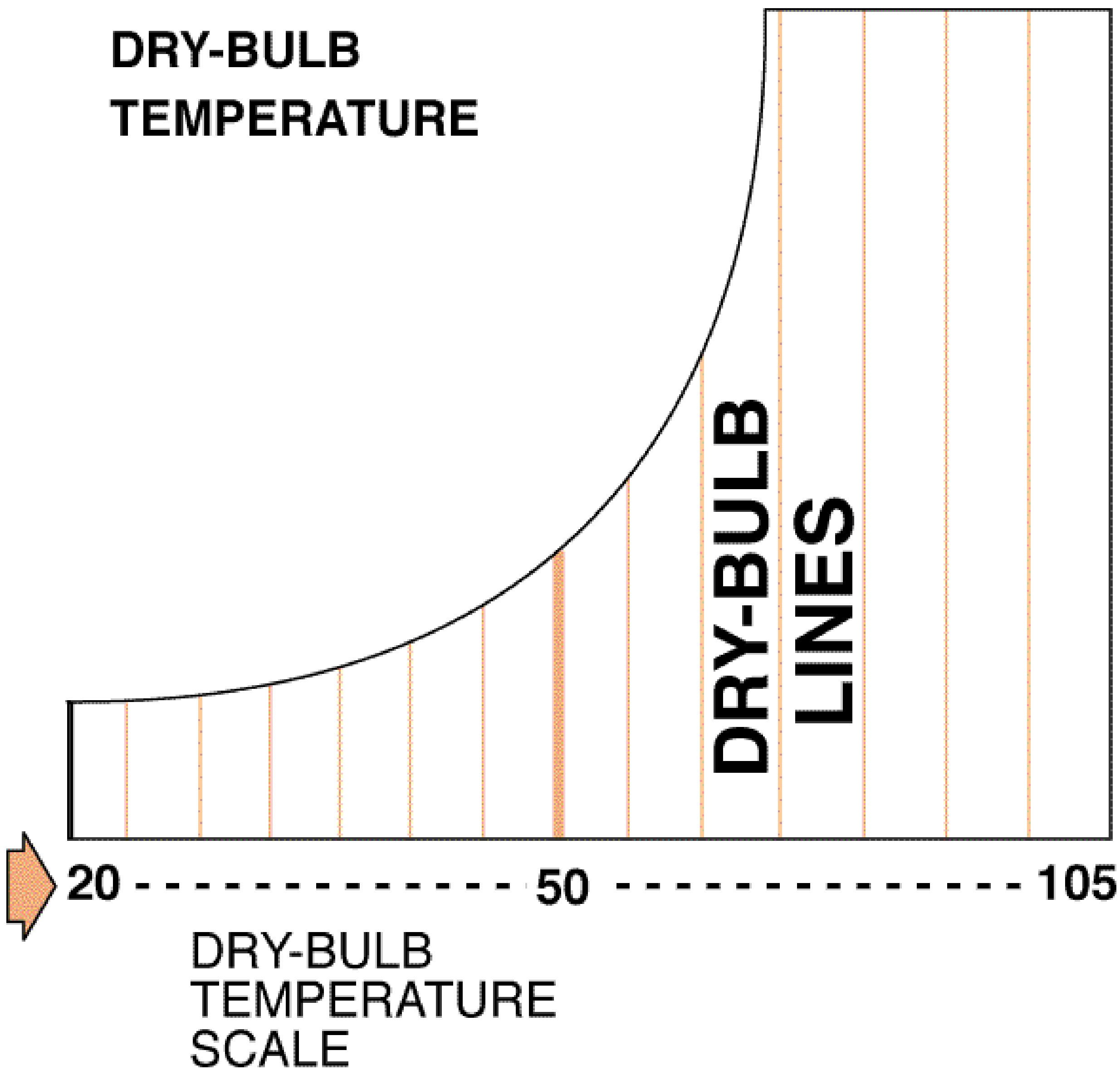
SI METRIC
PSYCHROMETRIC CHART

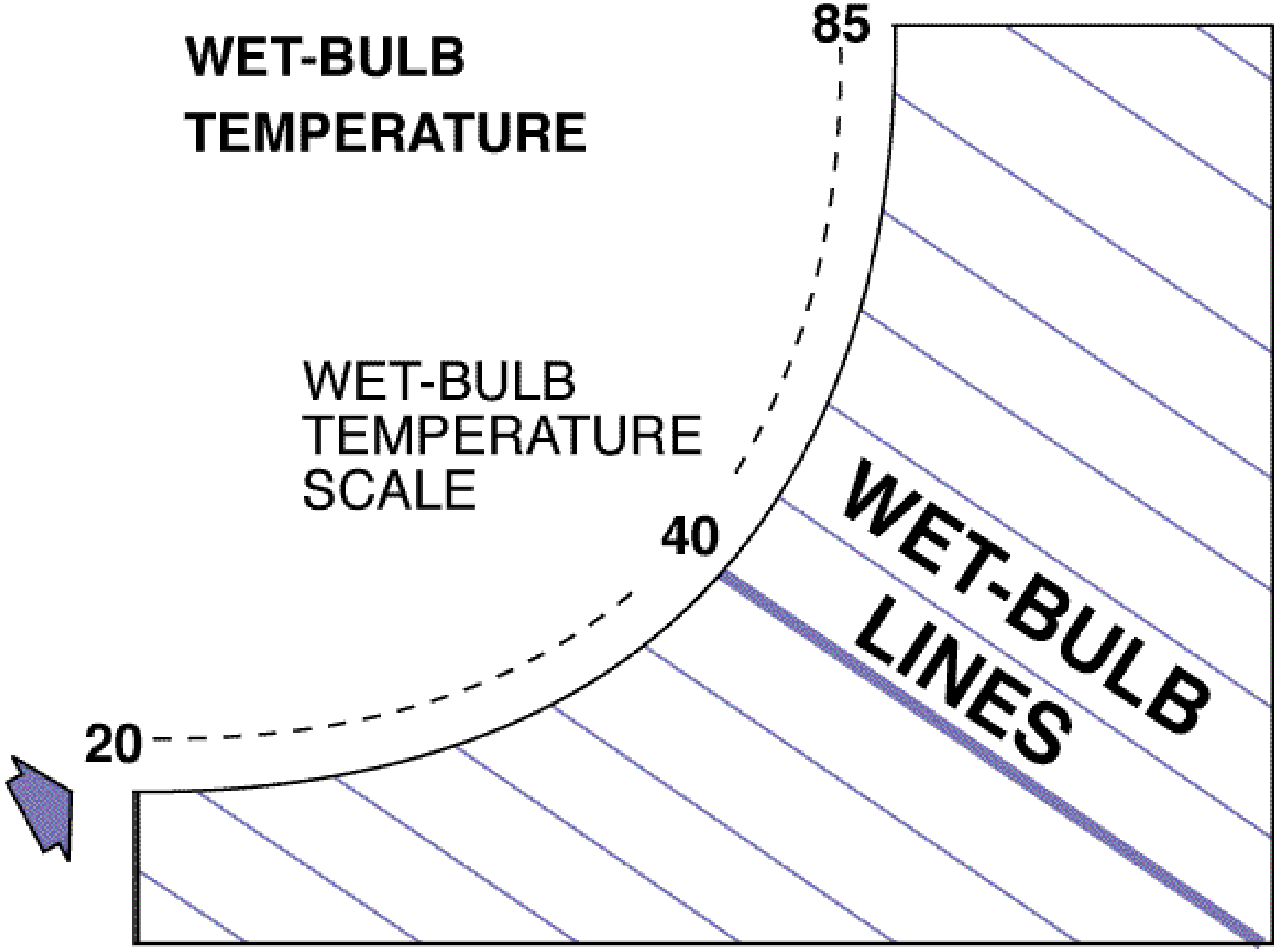
BASED ON A BAROMETRIC PRESSURE
of 101.325 kPa
AT SEA LEVEL

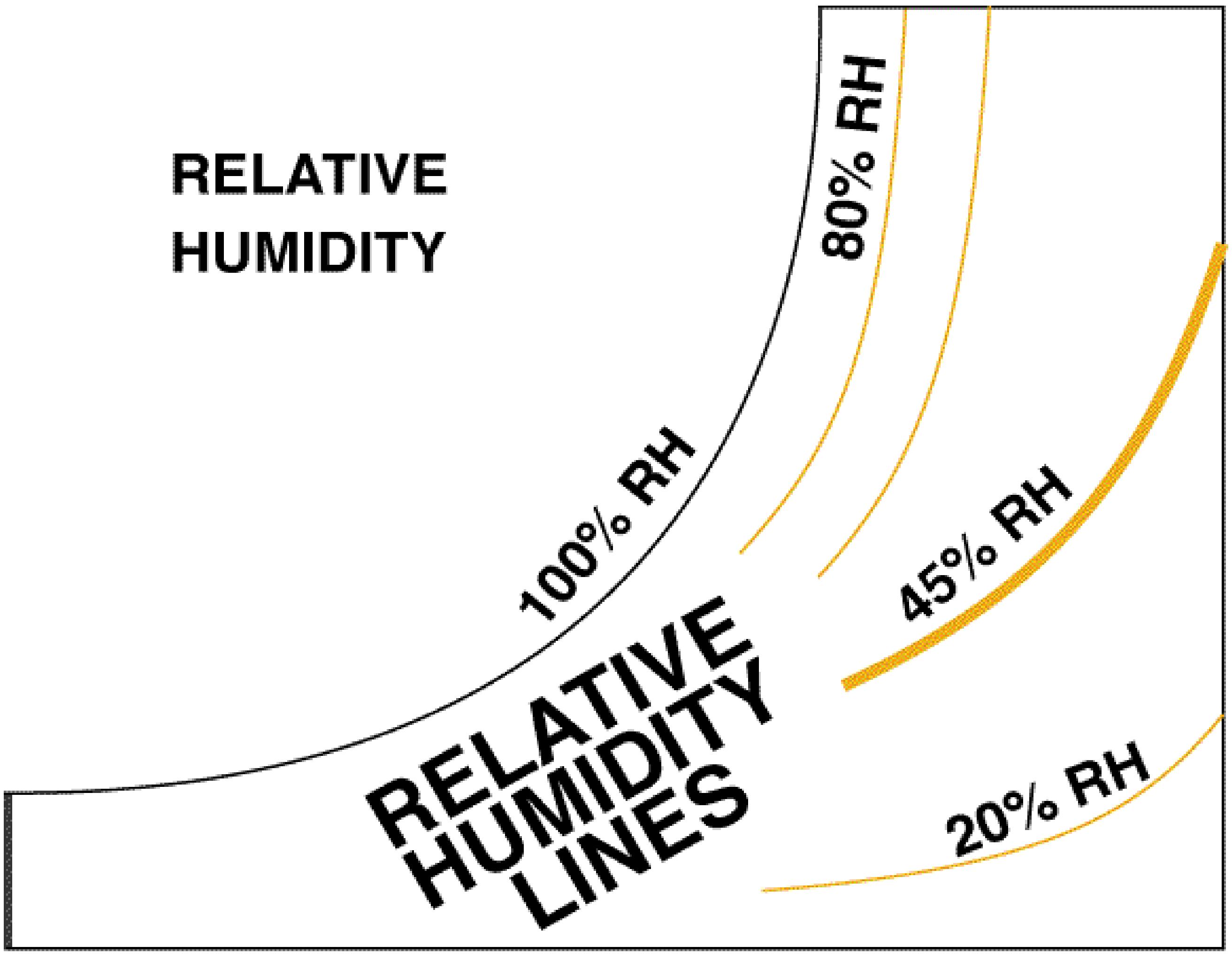


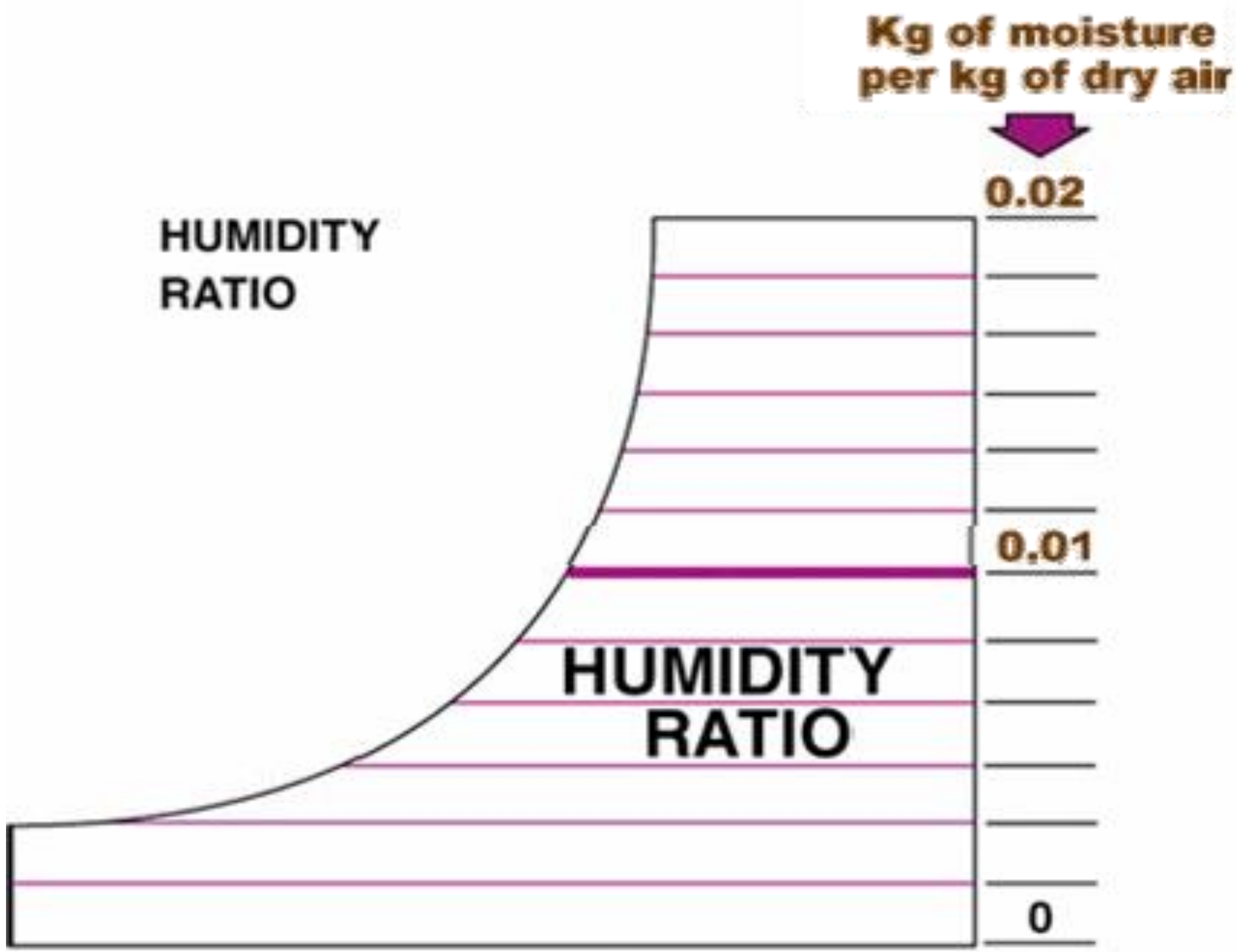


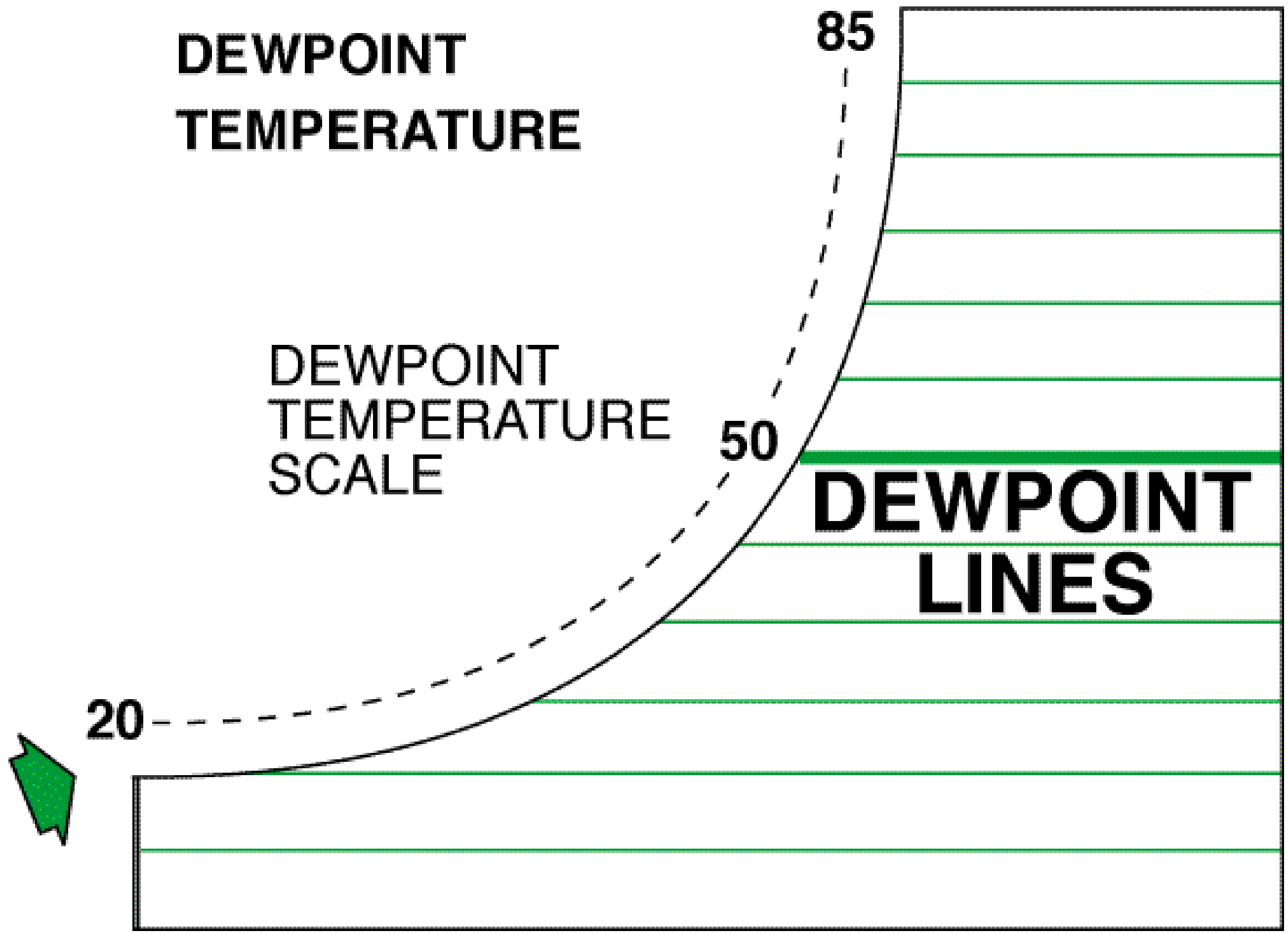
TRANE
SI METRIC
PSYCHROMETRIC
BASED ON A BAROMETRIC PRESSURE
of 101.325 kPa
AT SEA LEVEL
Enthalpy
kJ/kg
Dew
Point
100%
Saturation
RH
Specific humidity
Wet
Blub
Specific
Volume
Dry
Blub
Wet Bulb or Saturation Temperature °C
Moisture Content kg/kg Dry Air


DRY-BULB
TEMPERATURE
DRY-BULB
LINES
20
50
105
DRY-BULB
TEMPERATURE
SCALE

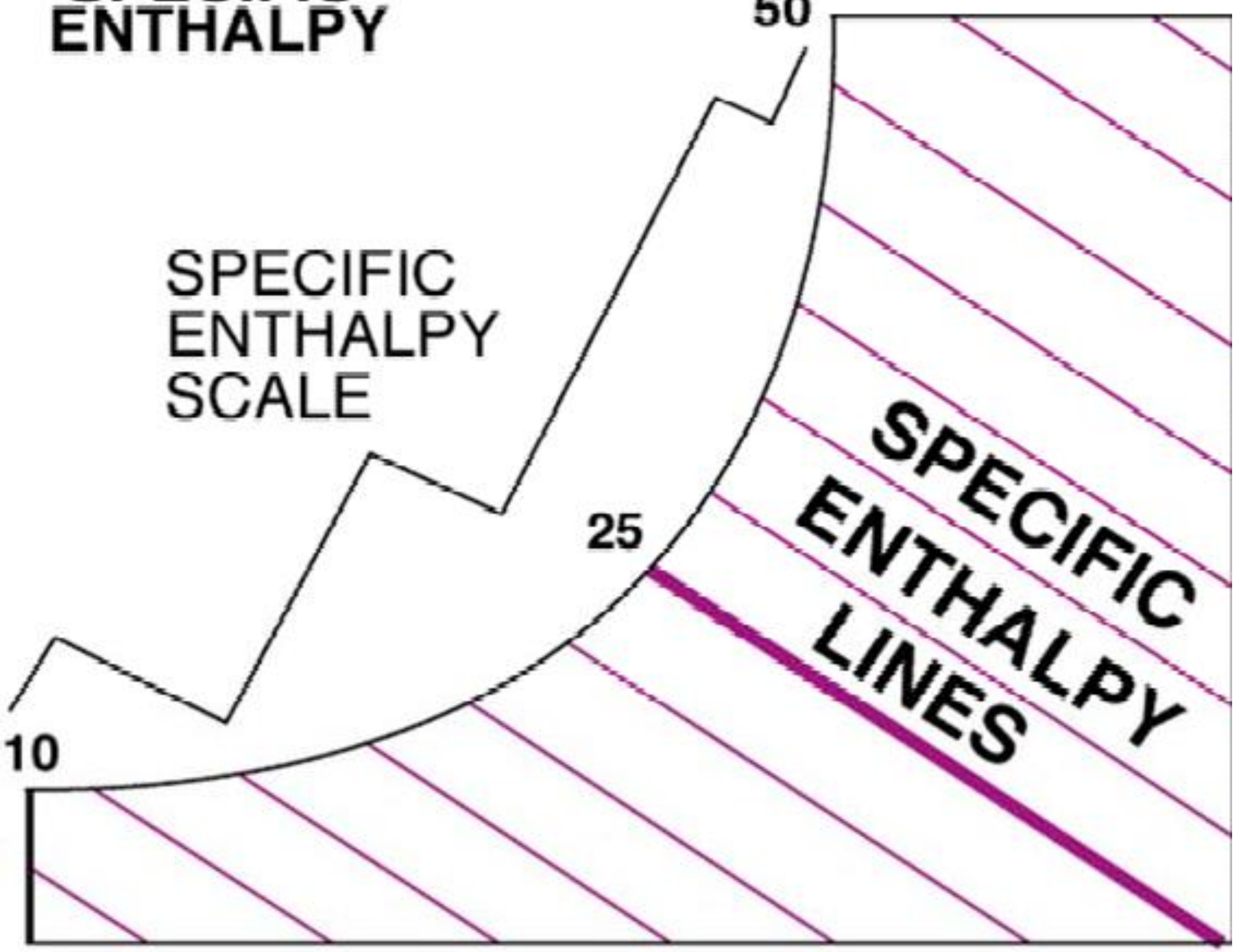

WET-BULB
TEMPERATURE
85
WET-BULB
TEMPERATURE
SCALE
40
20
WET-BULB
LINES


RELATIVE
HUMIDITY
80% RH
100% RH
45% RH
RELATIVE
HUMIDITY
LINES
20% RH

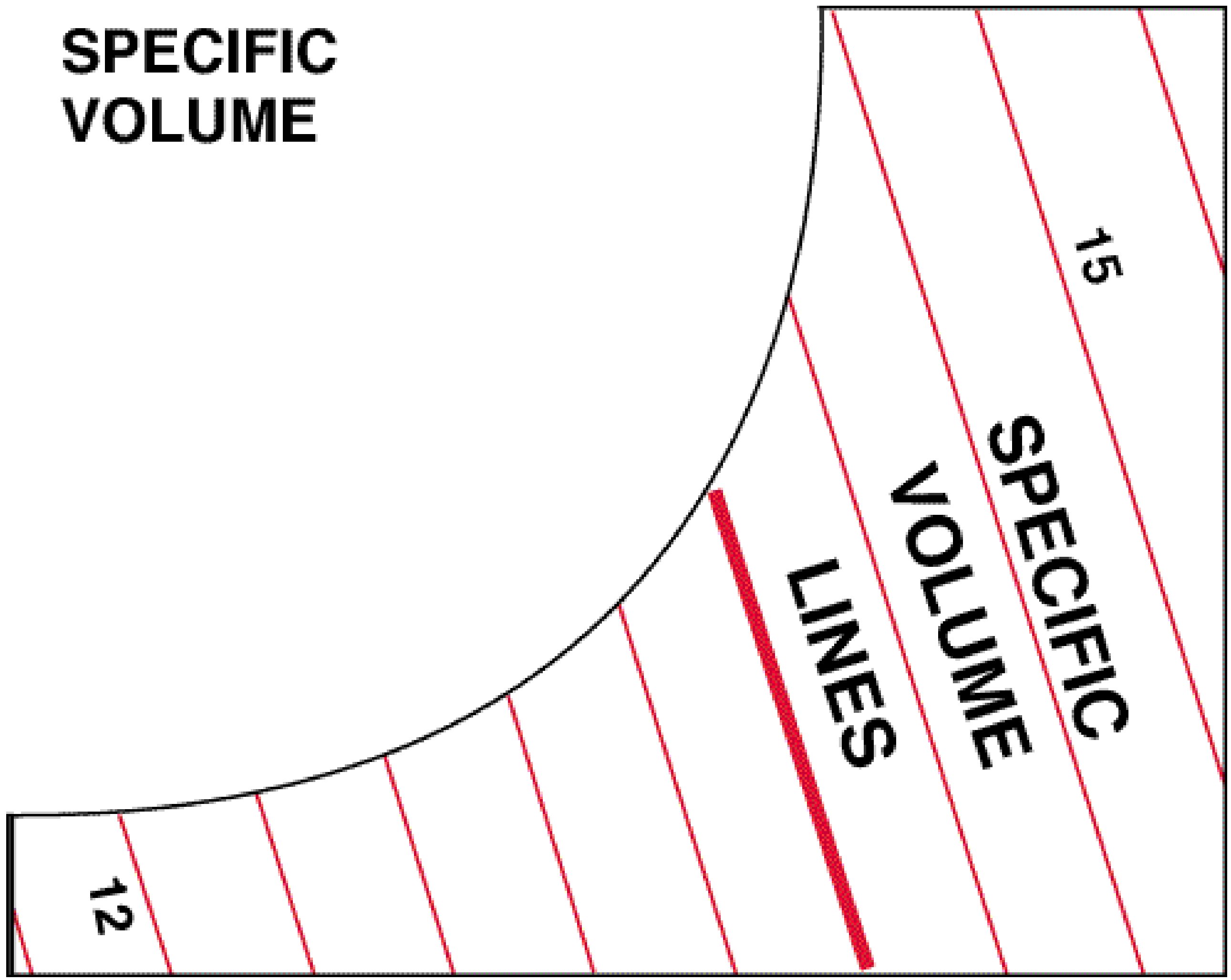

Kg of moisture per kg of dry air
0.02
HUMIDITY RATIO
0.01
HUMIDITY RATIO
0


DEWPOINT
TEMPERATURE
85
DEWPOINT
TEMPERATURE
SCALE
50
DEWPOINT
LINES
20

SPECIFIC ENTHALPY



SPECIFIC VOLUME

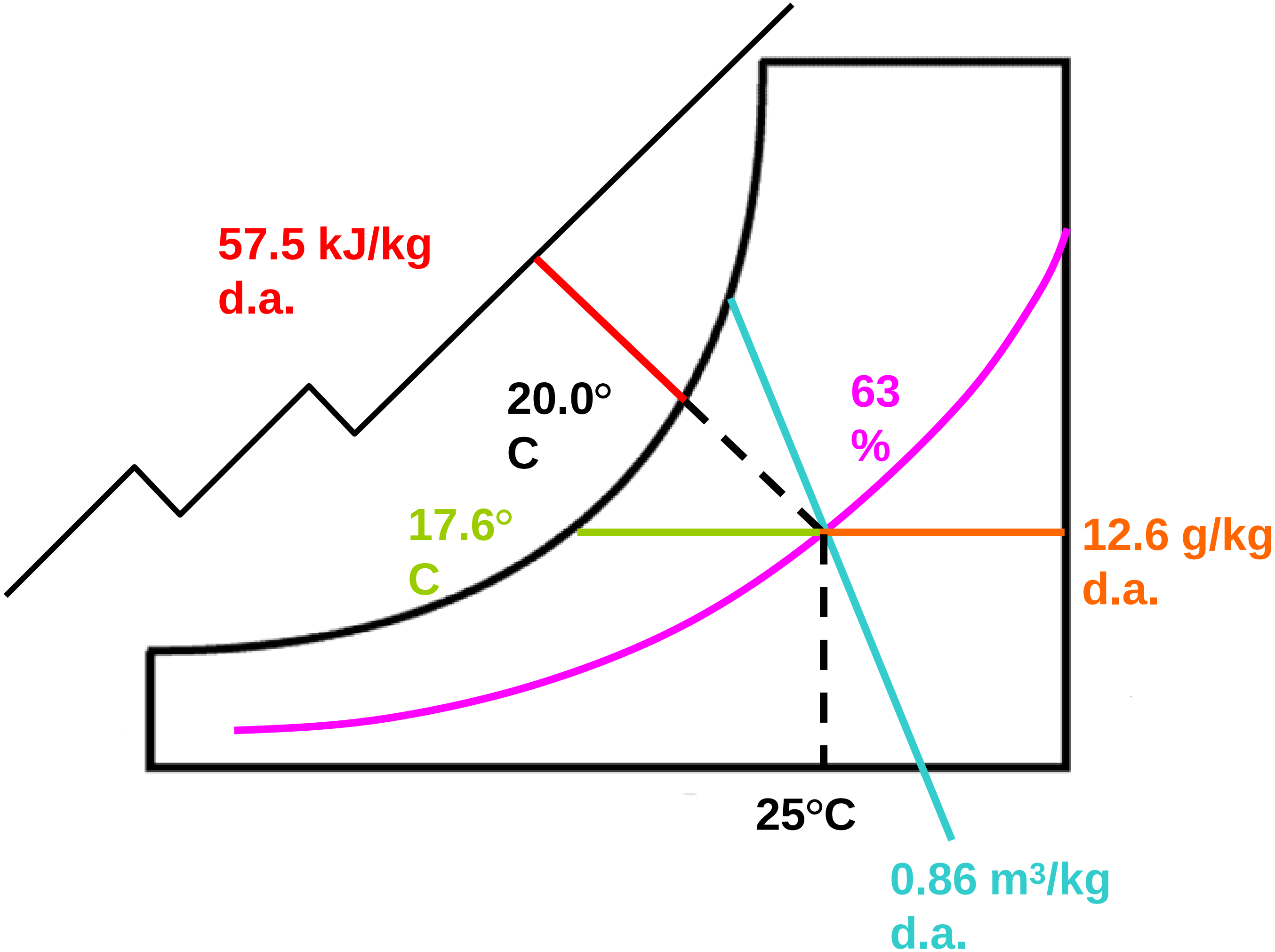


Psychrometric chart: Example 1

Given: $T = 25°C$

$T_w = 20°C$

Required: (a) RH (ϕ), (b) T_{dp}, (c) humidity ratio, (d) v, (e) h

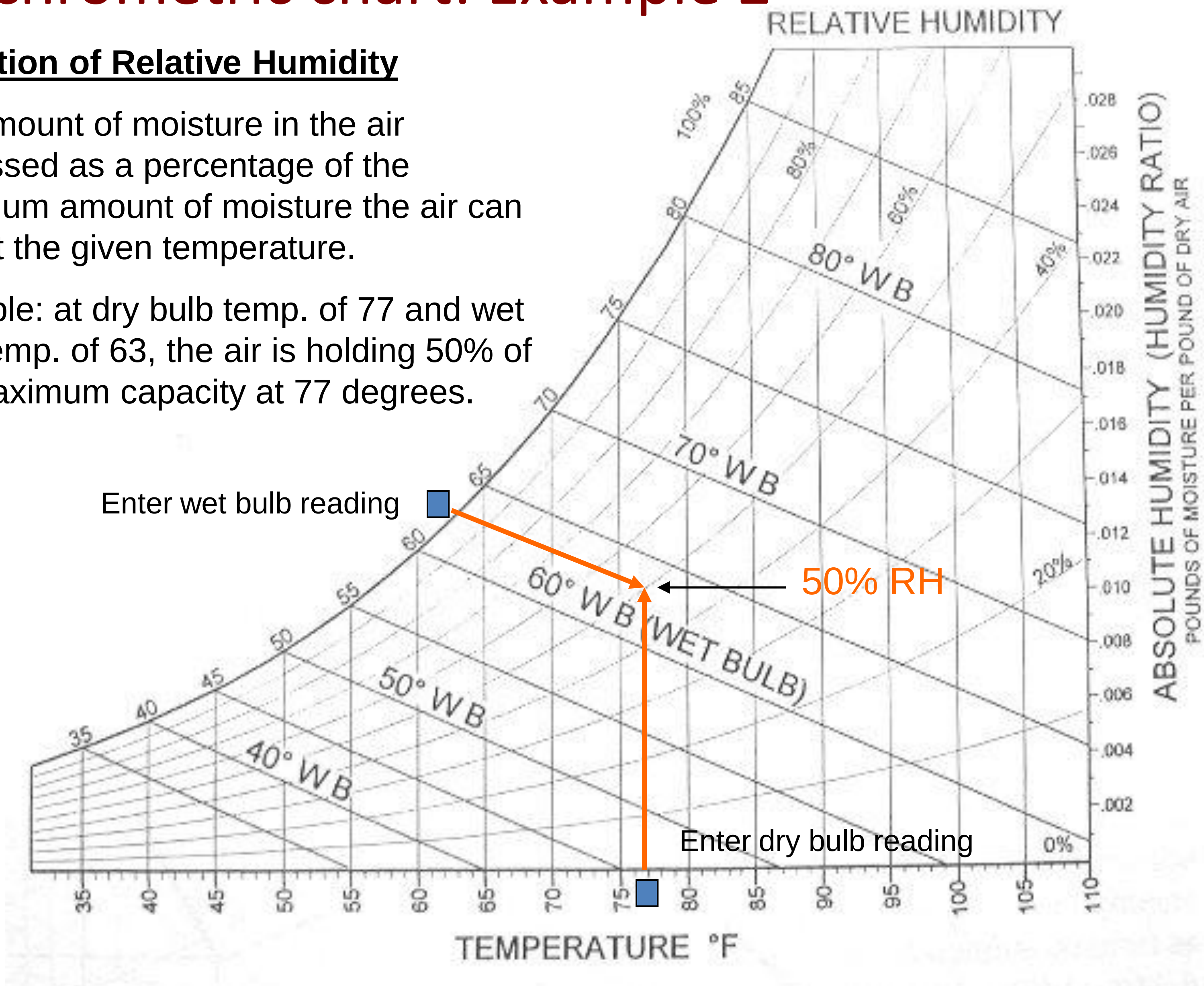


Psychrometric chart: Example 2

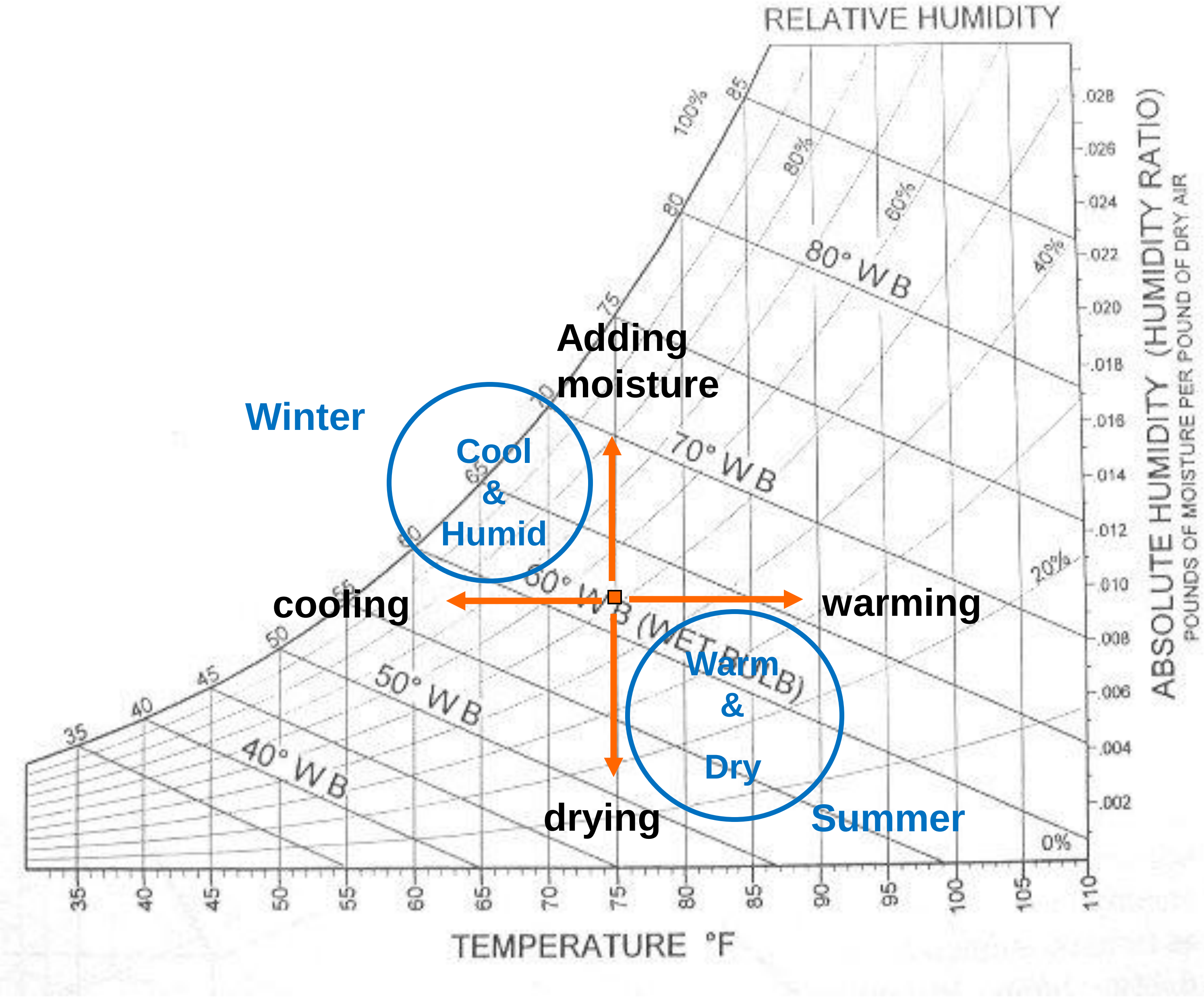
Definition of Relative Humidity

The amount of moisture in the air expressed as a percentage of the maximum amount of moisture the air can hold at the given temperature.

Example: at dry bulb temp. of 77 and wet bulb temp. of 63, the air is holding 50% of it’s maximum capacity at 77 degrees.

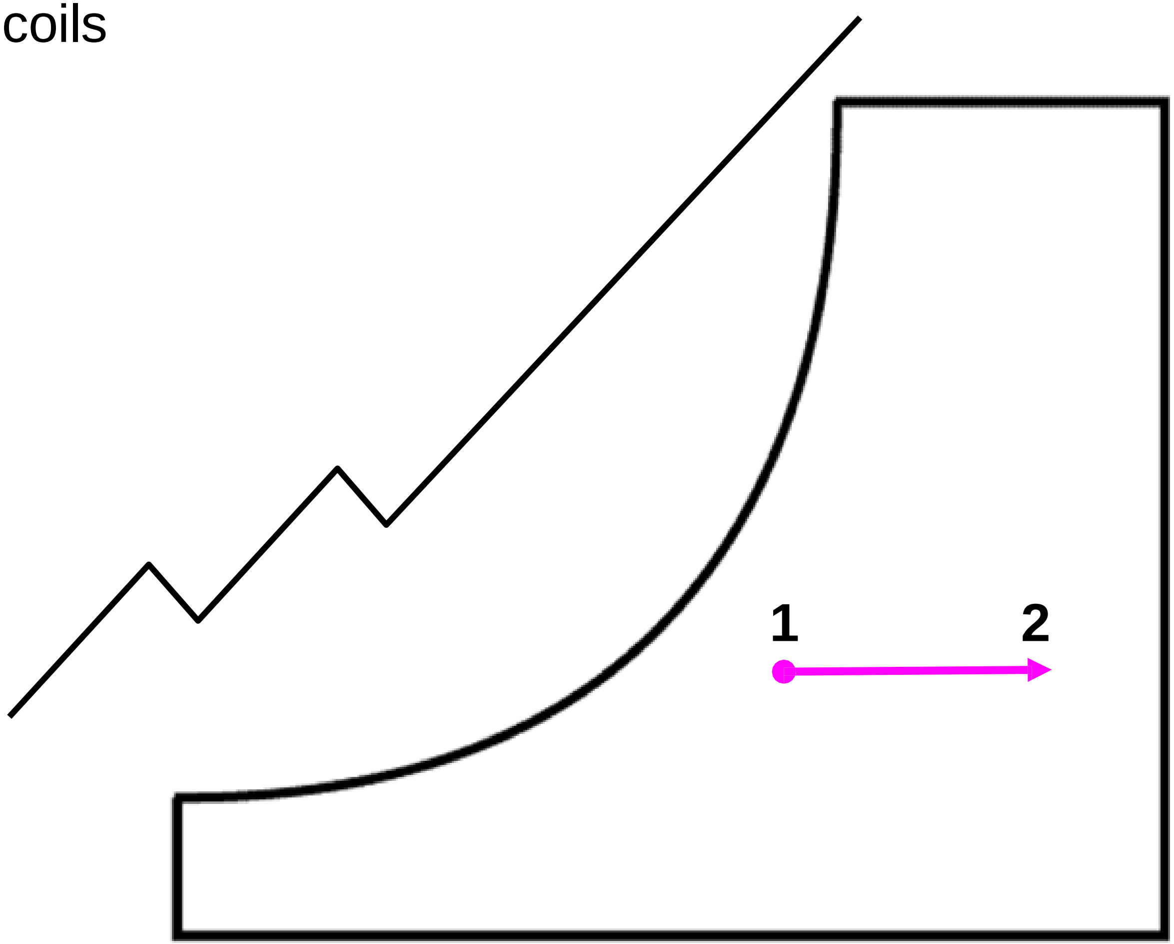


Psychrometric Processes



Sensible Heating or Cooling

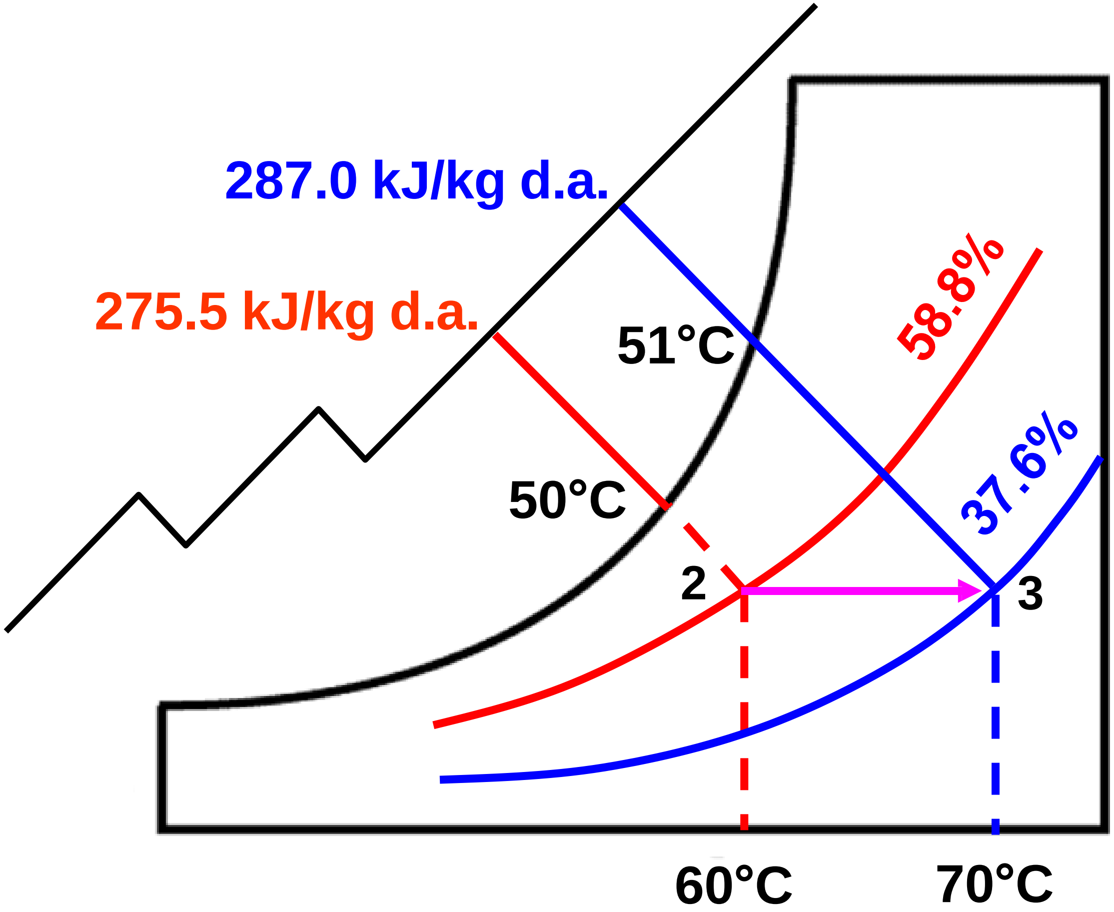
- A psychrometric process that involves the increase or decrease in the temperature of air without changing its humidity ratio
- Example: passing moist air over a room space heater and of kiln air over the heating coils



Example: Sensible Heating

2 → **3**

T_2=60ºC	T_3=70ºC
T_{w2}=50ºC	T_{w3}=?
RH_2=58.8%	RH_3=?

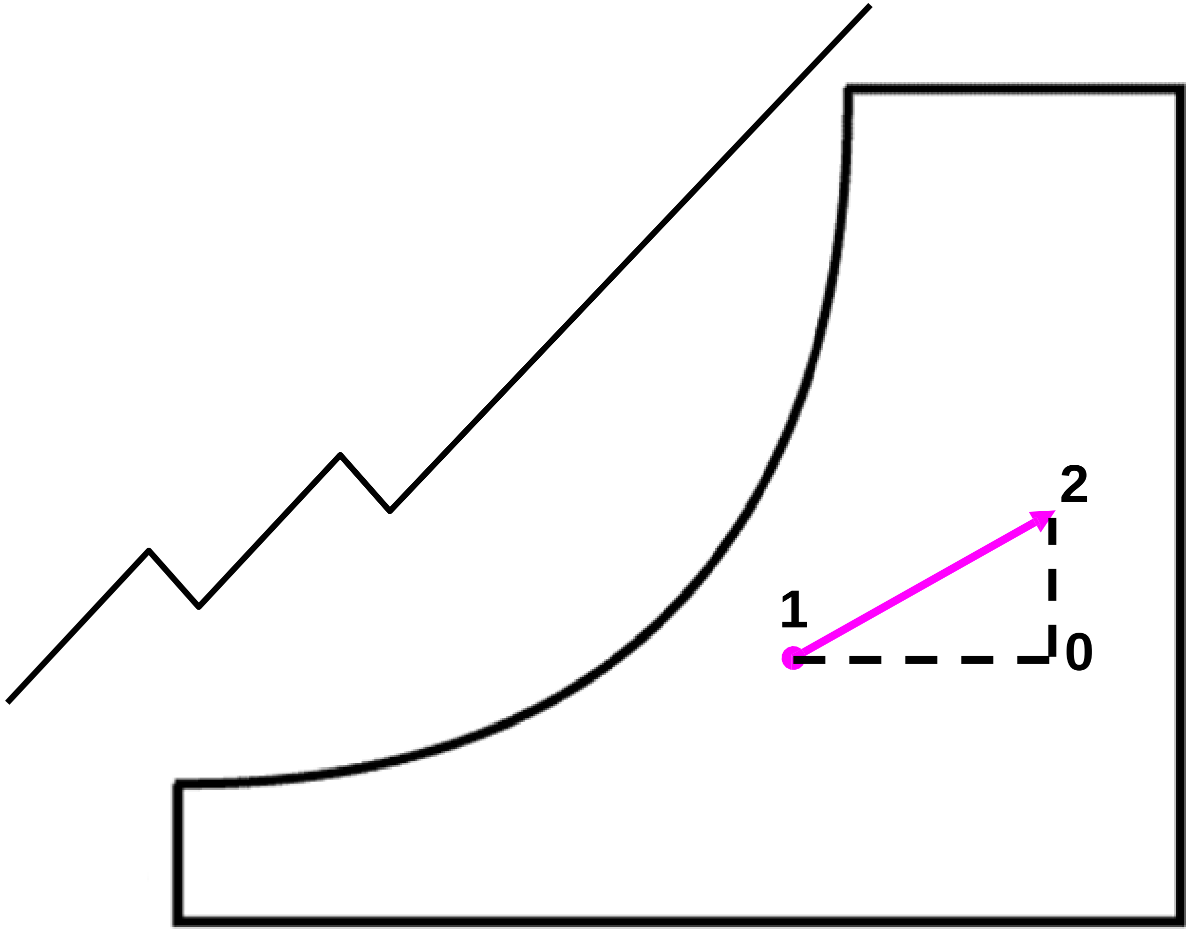


$RH_3 = 37.6\%$

$T_{w3} = 51°C$

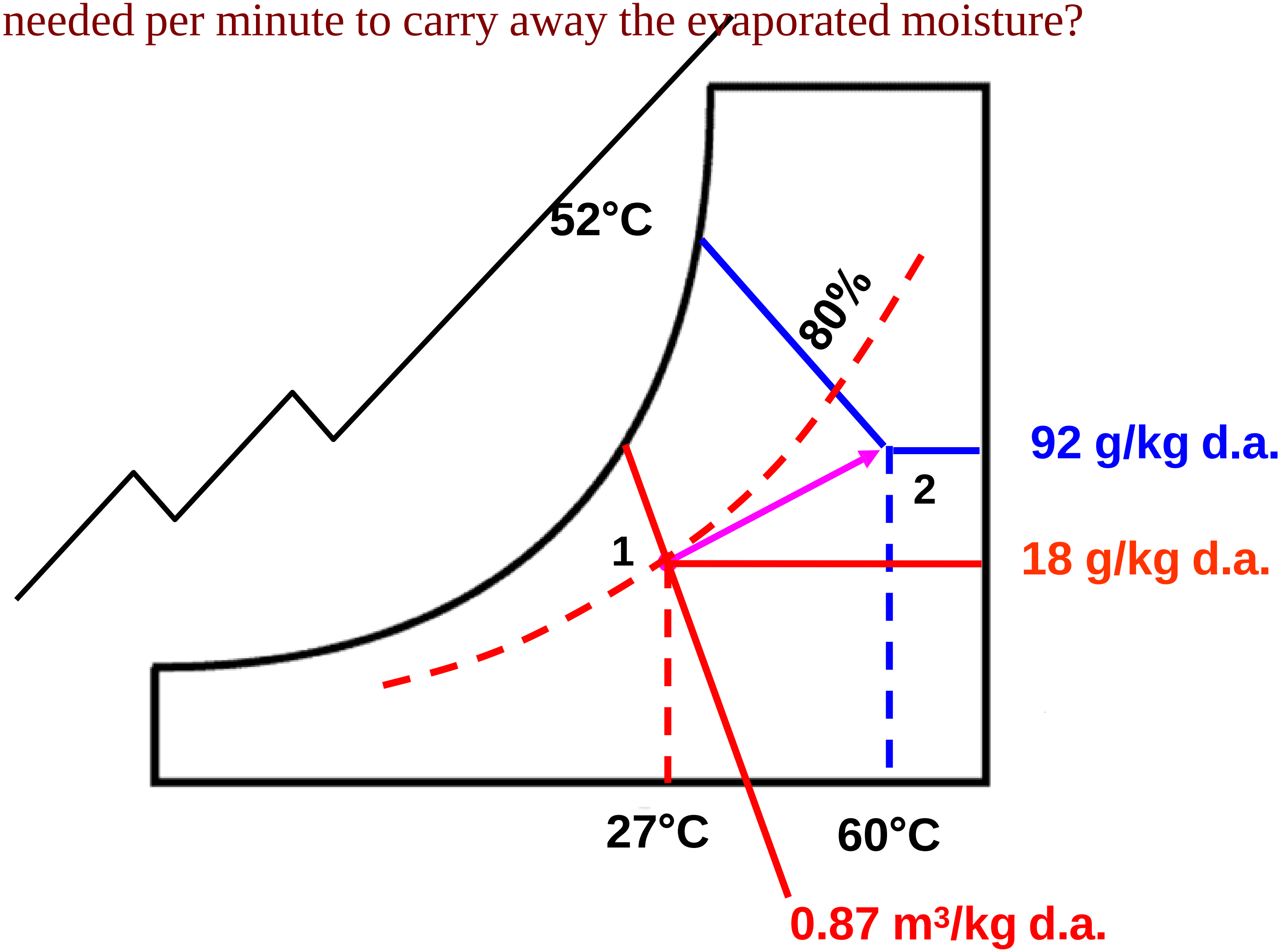
Heating and Humidifying

- A psychrometric process that involves the simultaneous increase in both the dry bulb temperature and humidity ratio of the air



Example: Heating and humidifying

Two and a half cubic meters of lumber is being dried at 60°C dry bulb temperature and 52°C wet bulb temperature. The drying rate of the lumber is 12.5 kg of water per hour. If outside air is at 27°C dry bulb temperature and 80% relative humidity, how much outside air is needed per minute to carry away the evaporated moisture?



Example: Heating and Humidifying (contd.)

$\Delta HR = (92.0 - 18.0)$ g/kg dry air

$= 74.0$ g/kg dry air

w_{a1} = drying rate/ΔHR

= (12.5 kg/hour)/(0.074 kg/kg dry air)

= 168.9 kg drying air/hour

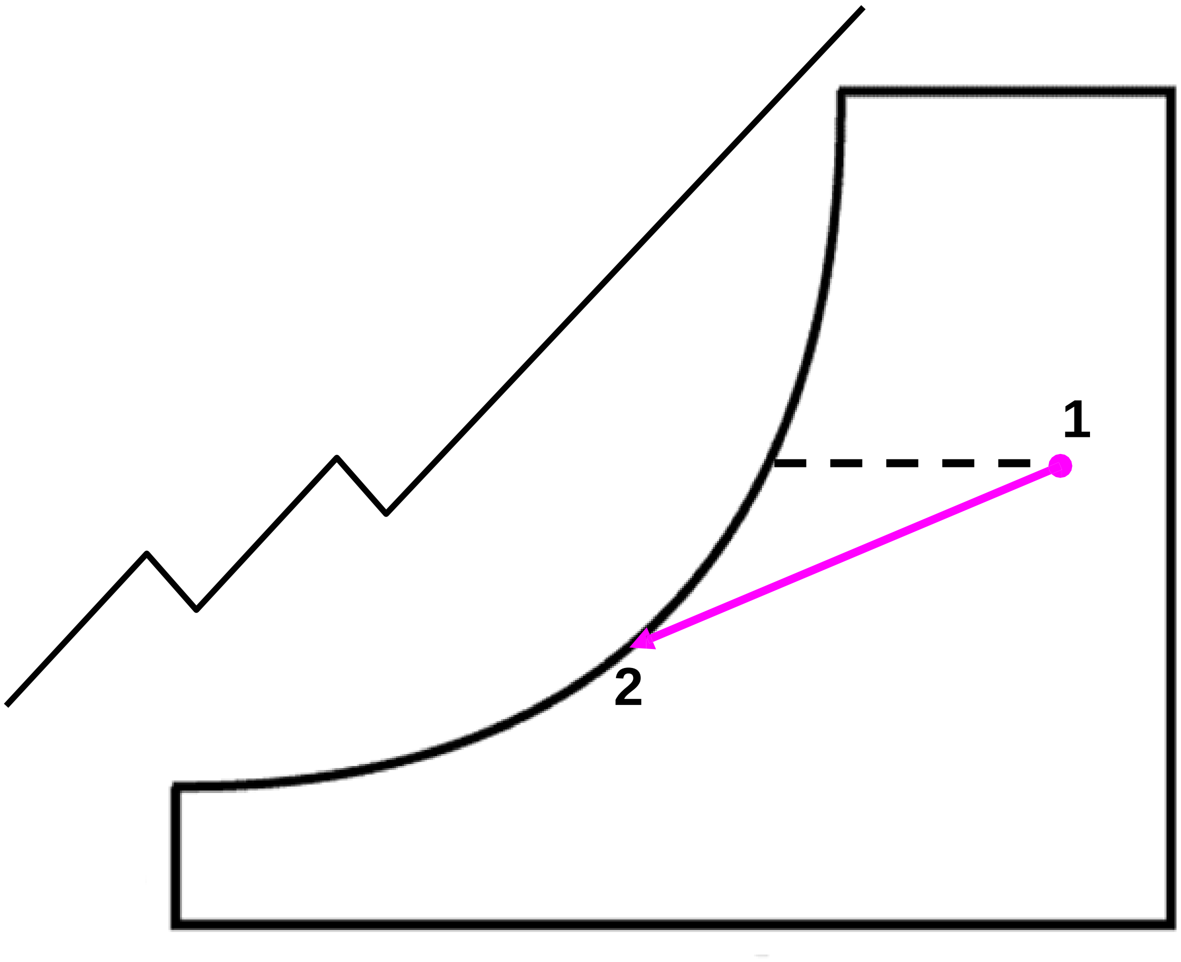
$VF_1 = (w_{a1})(v_1)$

=(168.9 kg dry air/hour)(0.87 m^3/kg dry air)

= 147 m^3/hour = 2.45 m^3/minute

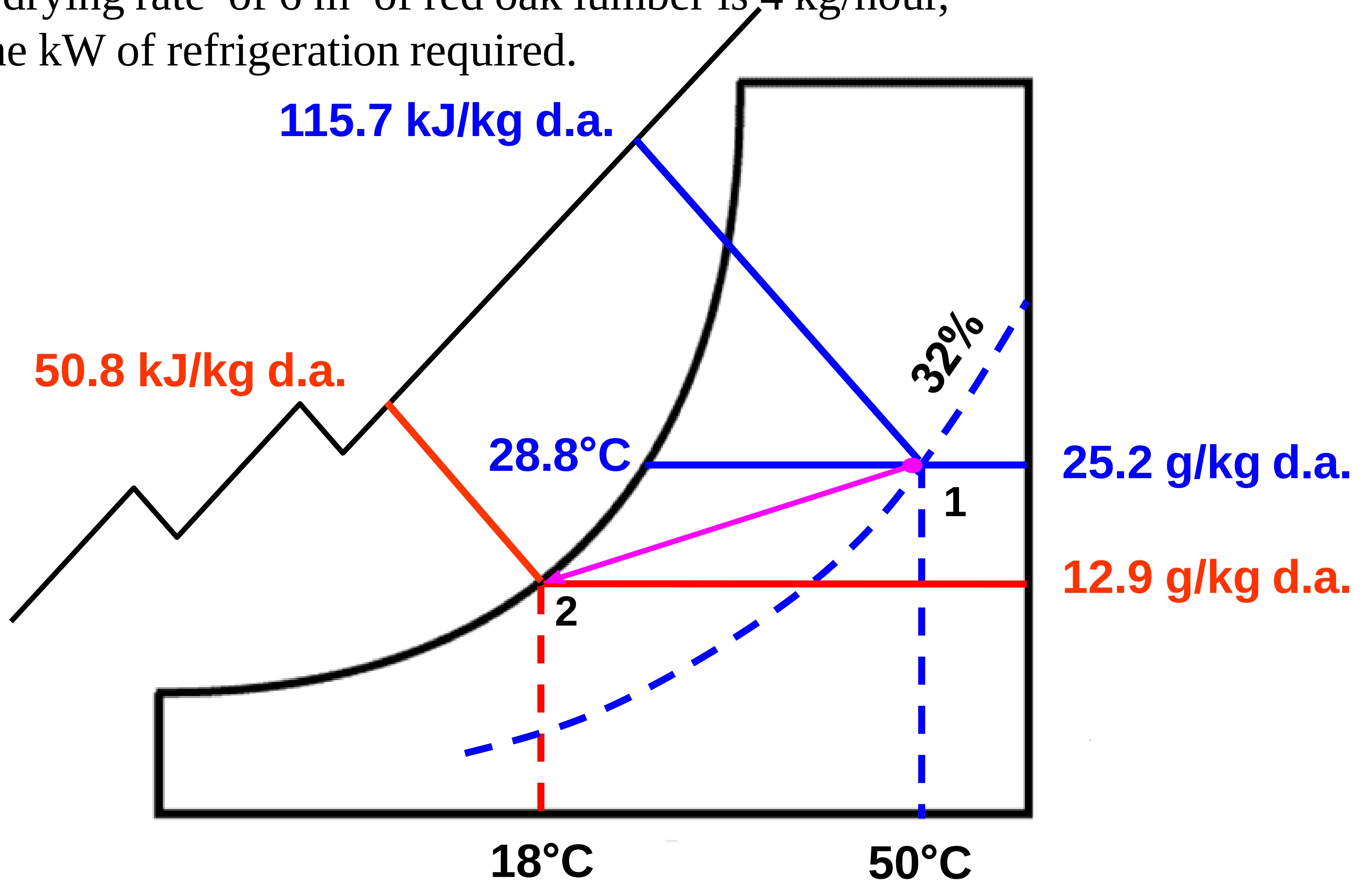
Cooling and Dehumidifying

- A psychrometric process that involves the removal of water from the air as the air temperature falls below the dew- point temperature



Example: Cooling and Dehumidifying

Moist air at 50°C dry bulb temperature and 32% relative humidity enters the cooling coil of a dehumidification kiln heat pump system and is cooled to a temperature of 18°C. If the drying rate of 6 m^3 of red oak lumber is 4 kg/hour, determine the kW of refrigeration required.



Example: Cooling and Dehumidifying (contd.)

$$\Delta HR = (25.2 - 12.9)\text{ g water/kg dry air}$$
$$= 12.3\text{ g water/kg dry air}$$

$$w_a = \frac{\text{drying rate}}{\Delta HR}$$

$$= \frac{4\ \text{kg water}/\text{h}}{0.0123\ \text{kg water}/\text{kg dry air}}$$

$$= 325.2\ \frac{\text{kg dry air}}{\text{h}}$$

Example: Cooling and Dehumidifying (contd.)

$\Delta h = (115.7 - 50.8)$ kJ/kg dry air

$= 64.9$ kJ/kg dry air

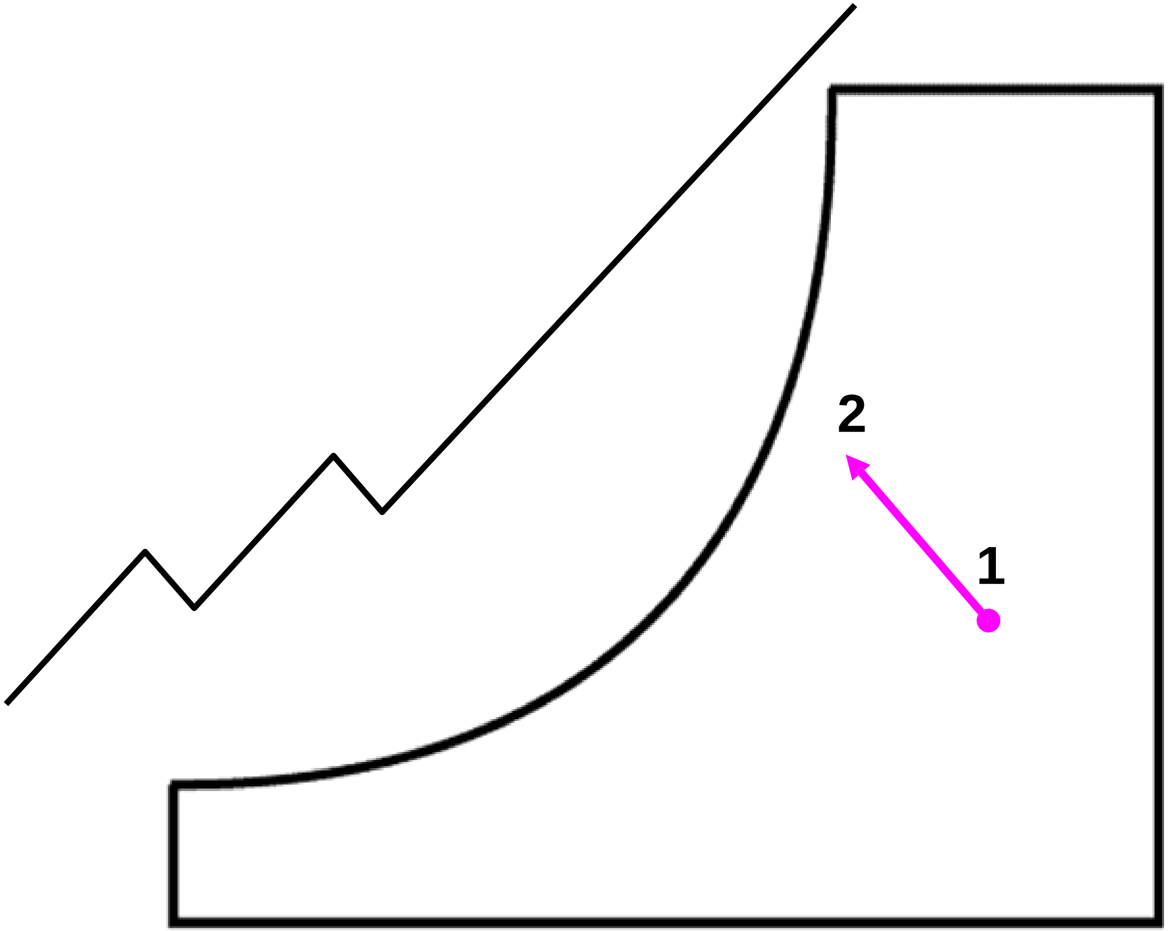
$$q = (\Delta h)(w_a)$$

$$= \left[64.9 \frac{\text{kJ}}{\text{kg dry air}}\right]\left[325.2 \frac{\text{kg dry air}}{\text{h}}\right]$$

$$= 21105.7 \frac{\text{kJ}}{\text{h}} = 5.9\,\text{kW}$$

Adiabatic or Evaporative Cooling

- A psychrometric process that involves the cooling of air without heat loss or gain. Sensible heat lost by the air is converted to latent heat in the added water vapor



Example: Evaporative Cooling

Referring to Figure, air at state point 1 (65°C dry bulb temperature and 57°C wet bulb temperature) experiences a temperature drop of 3°C as it passes through the 1.2-m wide stack of lumber. Determine the properties of the air at state point 2 and compare them with those at state point 1. If the air is flowing at a rate of 2 meters per second, determine the drying rate assuming that the volume of the stack of 2.5-cm-thick lumber is 2.5 m^3. The stack is 1.2 m wide x 3.6 m long, and the boards are separated by stickers 3.8 cm wide x 1.9 cm thick that are spaced 0.6 m apart.

Given:

- T_1 = 65°C; T_{w1} = 57°C
- Adiabatic cooling to T_2 = 62°C Air flow rate = 2 m/s
- Volume of lumber = 2.5 m^3 Board thickness = 2.5 cm
- Stack dimensions: 1.2 m wide x 3.6 m long
- Sticker dimensions: 3.8 cm wide x 1.9 cm thick Sticker spacing = 0.6 m

$$1 \longrightarrow 2$$

T_1=65ºC T_{w1}=57ºC
T_{dp1}, RH_1, HR_1, v_1, h_1 = ?

T=62ºC
T_{w2}, T_{dp2}, RH_2, HR_2, v_2, h_2 = ?

Estimate drying rate.

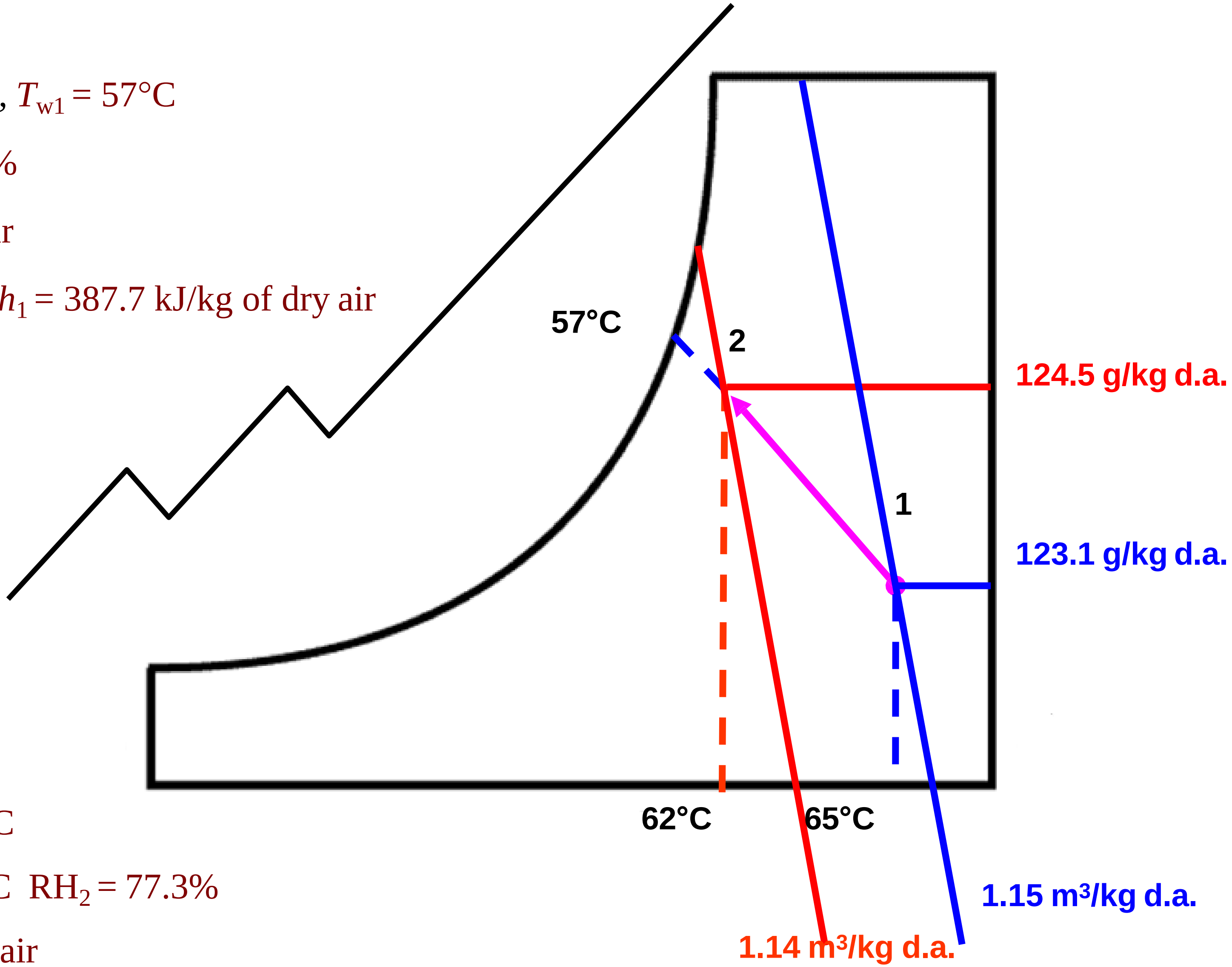
Example: Evaporative Cooling (Contd.)

At state point 1: $T_1 = 65°C$, $T_{w1} = 57°C$

$T_{dp1} = 56.3°C$ $RH_1 = 66.9\%$

$HR_1 = 123.1$ g/kg of dry air

$v_1 = 1.15$ m^3/kg of dry air, $h_1 = 387.7$ kJ/kg of dry air



At state point 2: $T_2 = 62°C$

$T_{w2} = 57°C$ $T_{dp2} = 56.5°C$ $RH_2 = 77.3\%$

$HR_2 = 124.5$ g/kg of dry air

$v_2 = 1.14$ m^3/kg of dry air, $h_2 = 387.7$ kJ/kg of dry air

Example: Evaporative Cooling (Contd.)

(b) $$\text{Drying rate} = (\Delta HR)(w_a)$$

$$w_a = \frac{VF}{v_2}$$

$$VF = (A)(\text{air flowrate})$$

Example: Evaporative Cooling (Contd.)

$$A = \left(\frac{V}{P_l \, P_w \, B_t} \right) \left(P_l \, S_t - \frac{P_l + S_s}{S_s} S_t \, S_w \right)$$

$$A = \left(\frac{2.5}{3.6 * 1.2 * 0.025} \right) \left(3.6 * 0.019 - \frac{3.6 + 0.6}{0.6} 0.019 * 0.038 \right)$$

$$A = 1.47 \, m^2$$

$$VF = (A)(\text{air flowrate})$$

$$VF = \left(1.47 \, m^3\right) \left(2 \, \frac{m}{s} \right) = 2.9 \, \frac{m^3}{s}$$

Example: Evaporative Cooling (Contd.)

$$VF = 2.9\,\frac{m^3}{s}$$

$$w_a = \frac{VF}{v_2} = \frac{2.9\,\dfrac{m^3}{s}}{1.14\,\dfrac{m^3}{\text{kg dry air}}} = 2.6\,\frac{\text{kg dry air}}{s}$$

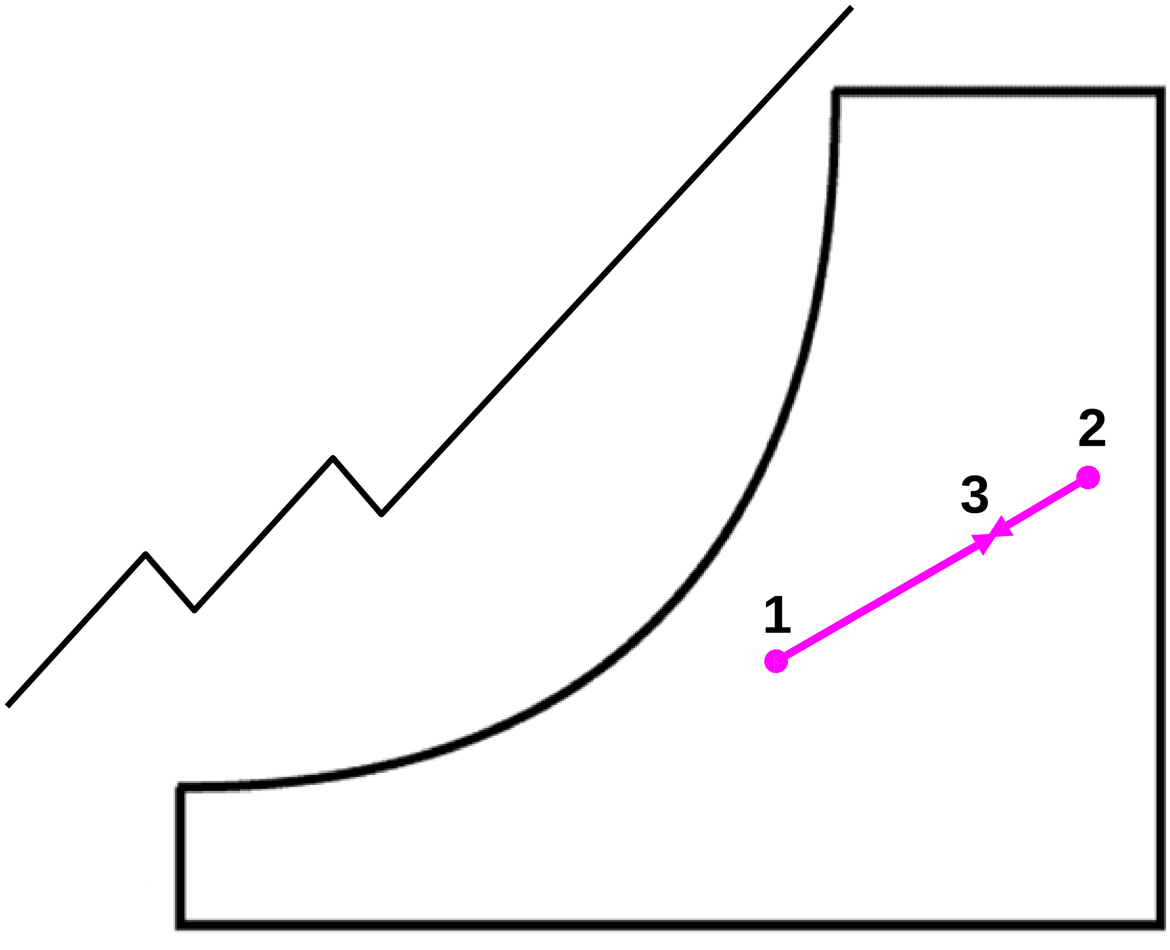
$$\text{Drying rate} = (w_a)(\Delta HR)$$

$$\text{Drying rate} = \left(2.6\,\frac{\text{kg dry air}}{s}\right)\left(1.4\,\frac{g}{\text{kg dry air}}\right)$$

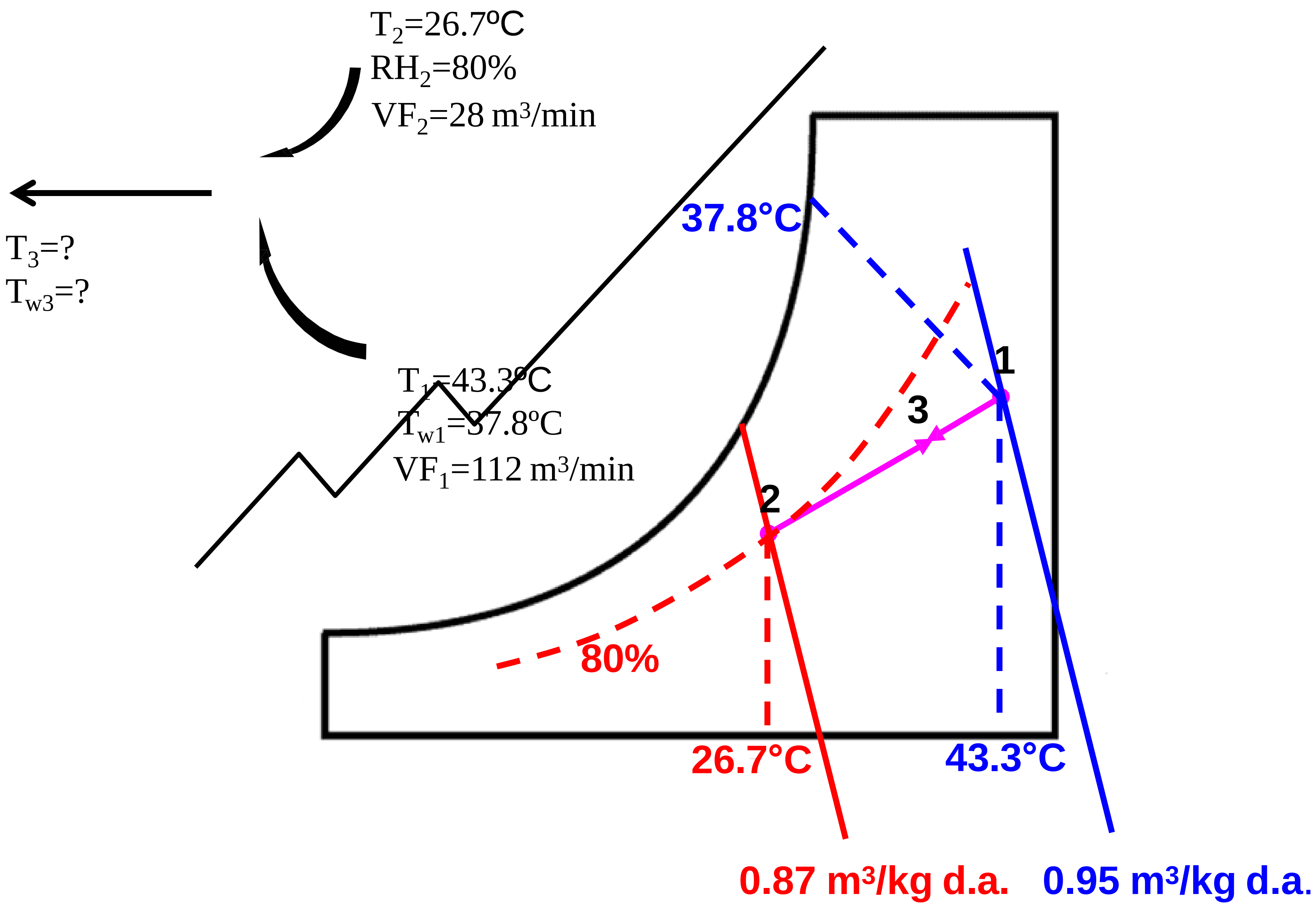
$$= 3.6\,\frac{g}{s} = 13.0\,\frac{kg}{h}$$

Adiabatic Mixing of Moist Air Stream

- A psychrometric process that involves no net heat loss or gain during the mixing of two air streams



Example: Adiabatic Mixing (contd.)



Example: Adiabatic Mixing (contd.)

$$w_{a1} = \frac{112 \frac{m^3}{\text{minute}}}{0.95 \frac{m^3}{\text{kg dry air}}} = 117.9 \frac{\text{kg dry air}}{\text{minute}}$$

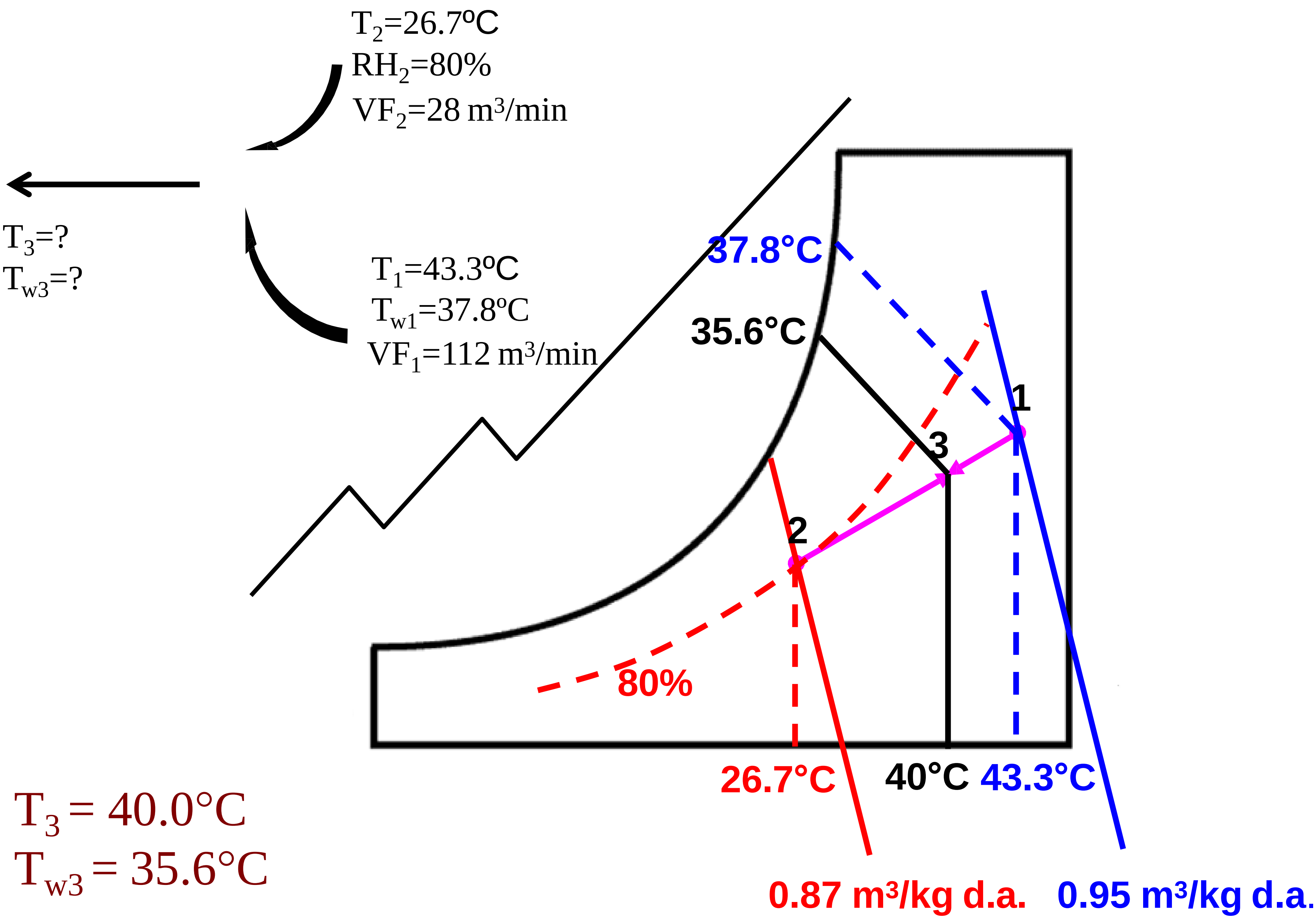
$$w_a = \frac{VF}{v}$$

$$w_{a2} = \frac{28 \frac{m^3}{\text{minute}}}{0.87 \frac{m^3}{\text{kg dry air}}} = 32.2 \frac{\text{kg dry air}}{\text{minute}}$$

$$\frac{\text{line 1-3}}{\text{line 1-2}} = \frac{w_{a2}}{w_{a2} + w_{a1}} = \frac{32.2}{32.2 + 117.9} = 0.21$$

Therefore, length of line segment 1-3 is 0.21 times the length of line 1-2

Example: Adiabatic Mixing (contd.)



$T_3 = 40.0°C$

$T_{w3} = 35.6°C$