THE PSYCHROMETRIC CHART: Theory and Application

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PSYCHROMETRIC CHART

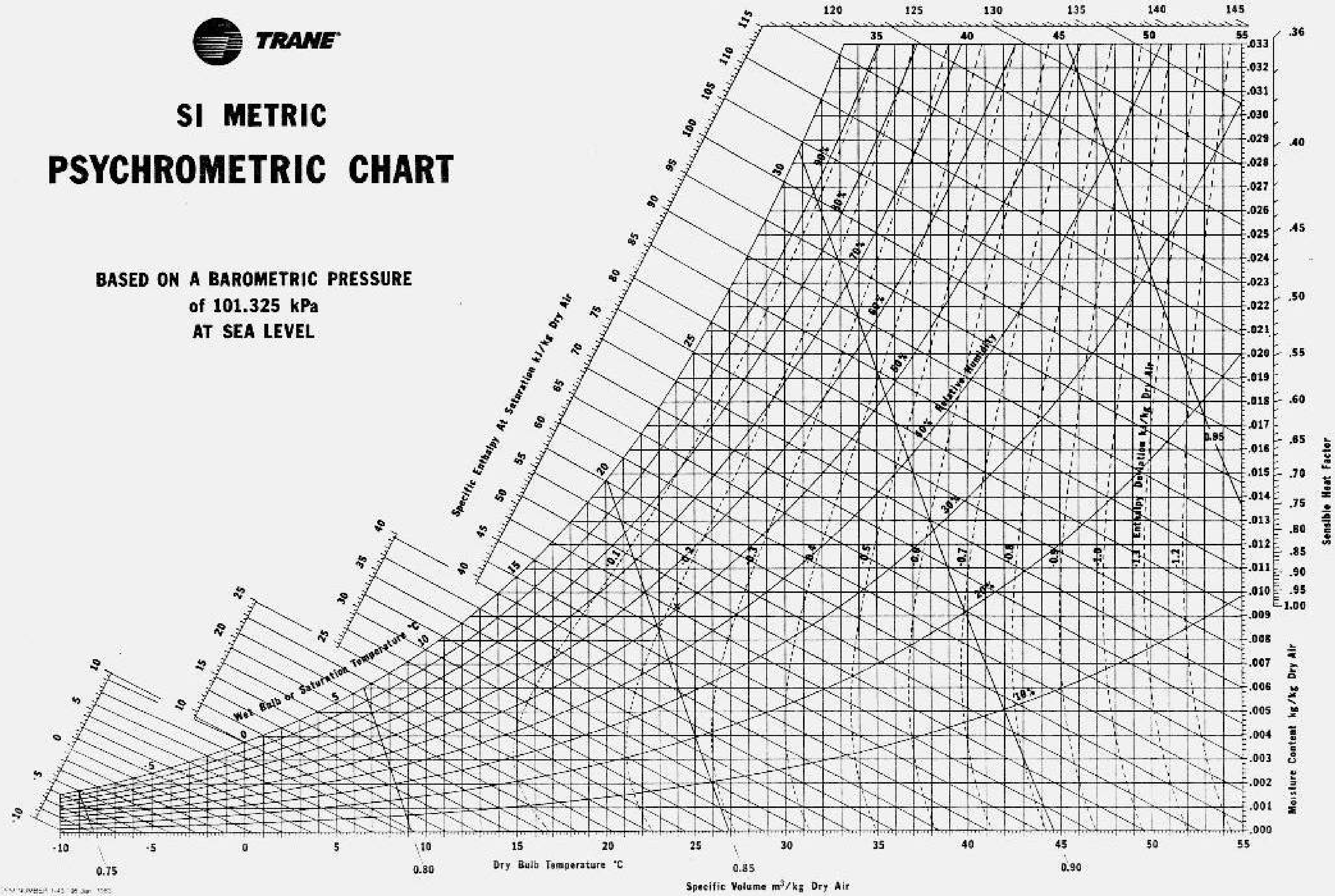
- Identify parts of the chart
- Determine moist air properties
- Use chart to analyze processes involving moist air

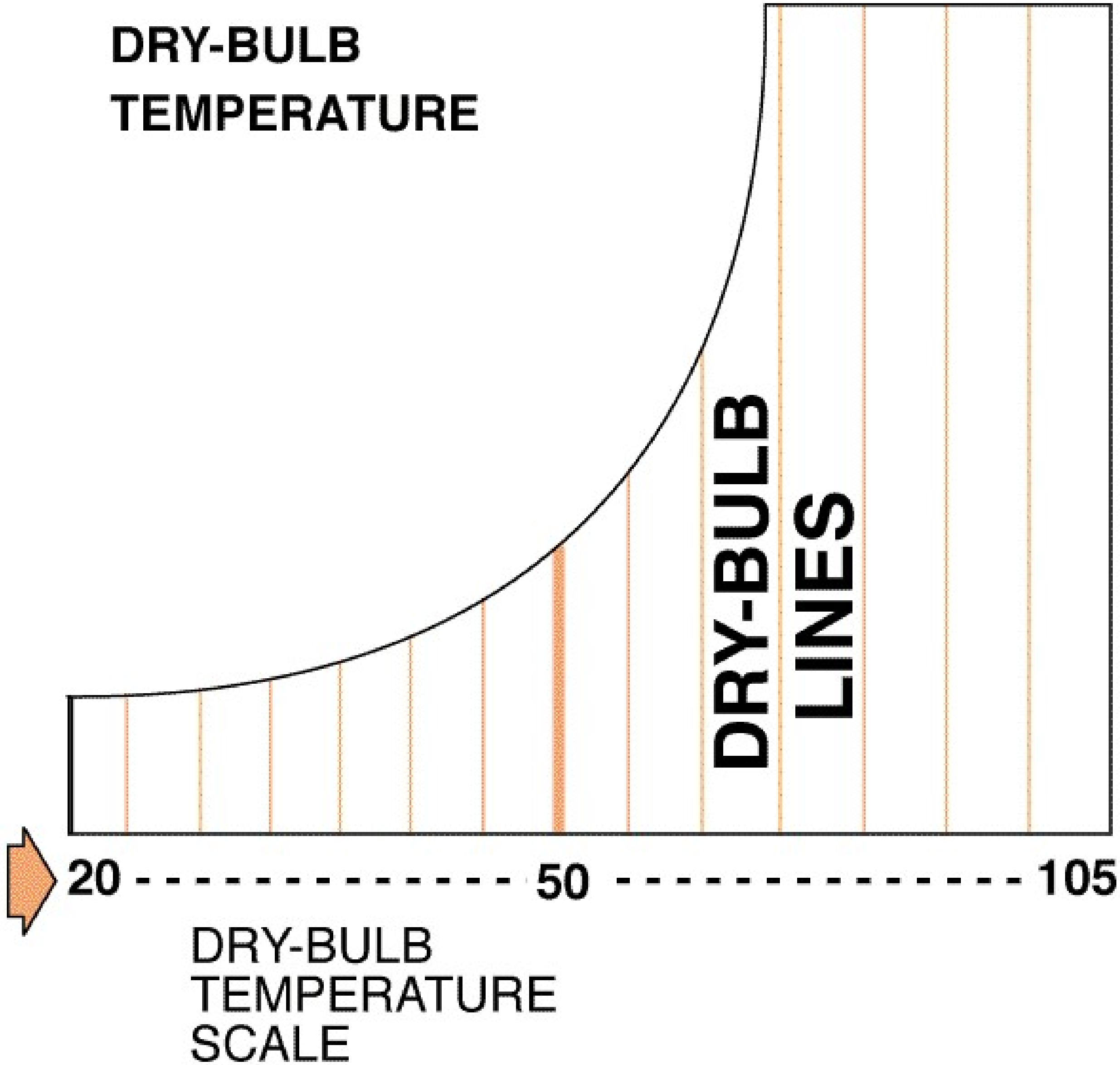
TRANE

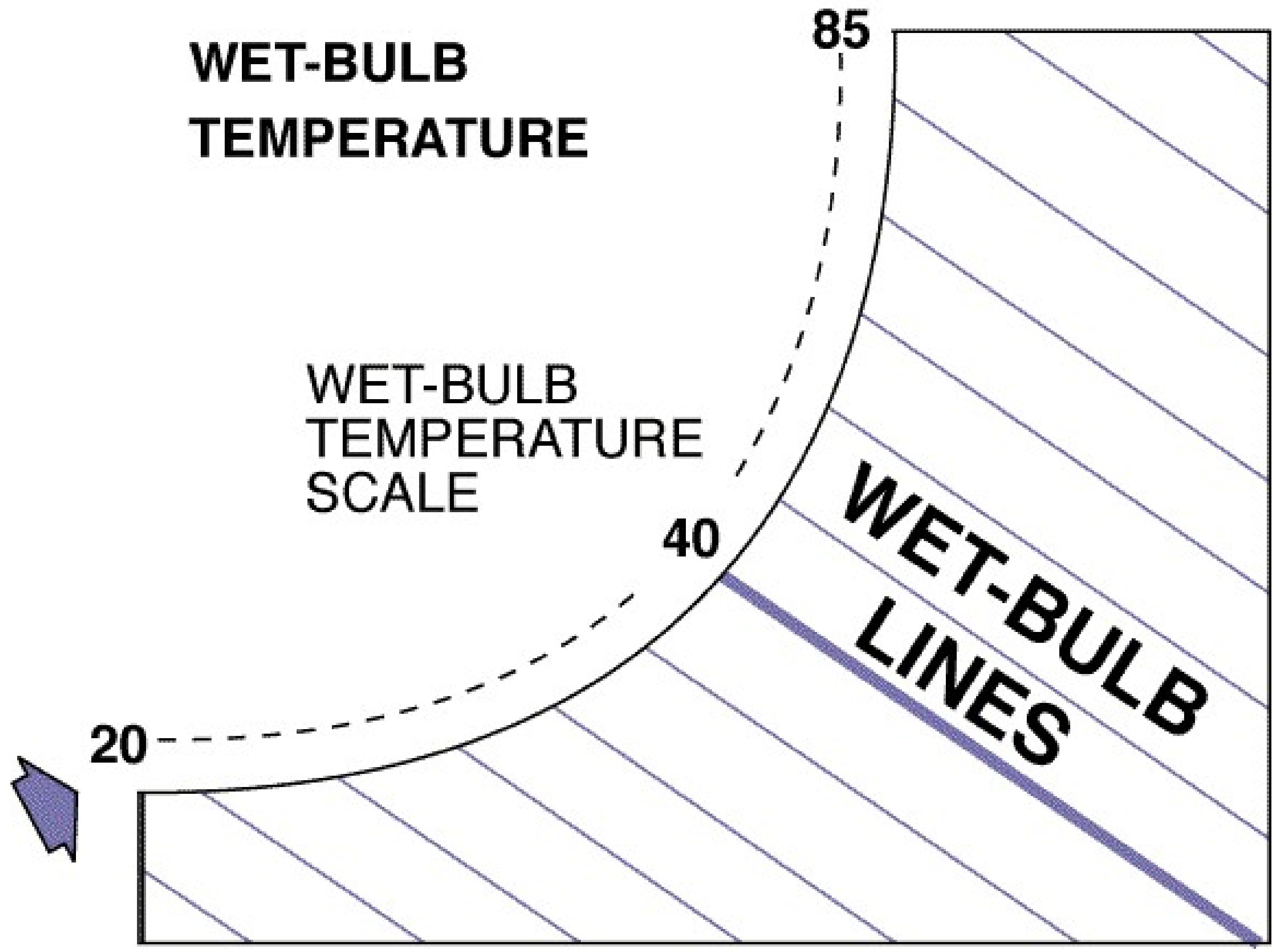
SI METRIC

PSYCHROMETRIC CHART

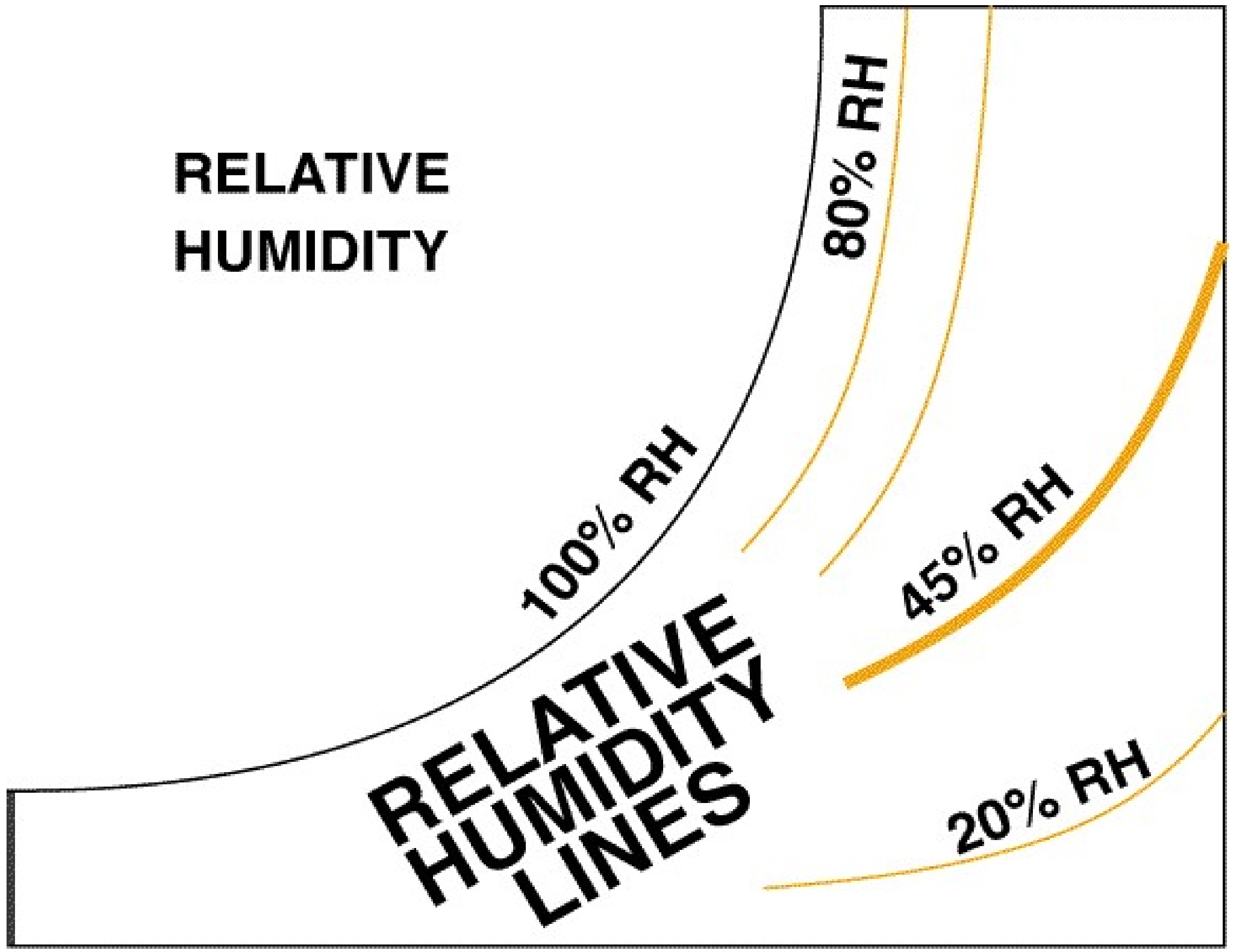
BASED ON A BAROMETRIC PRESSURE of 101.325 kPa AT SEA LEVEL



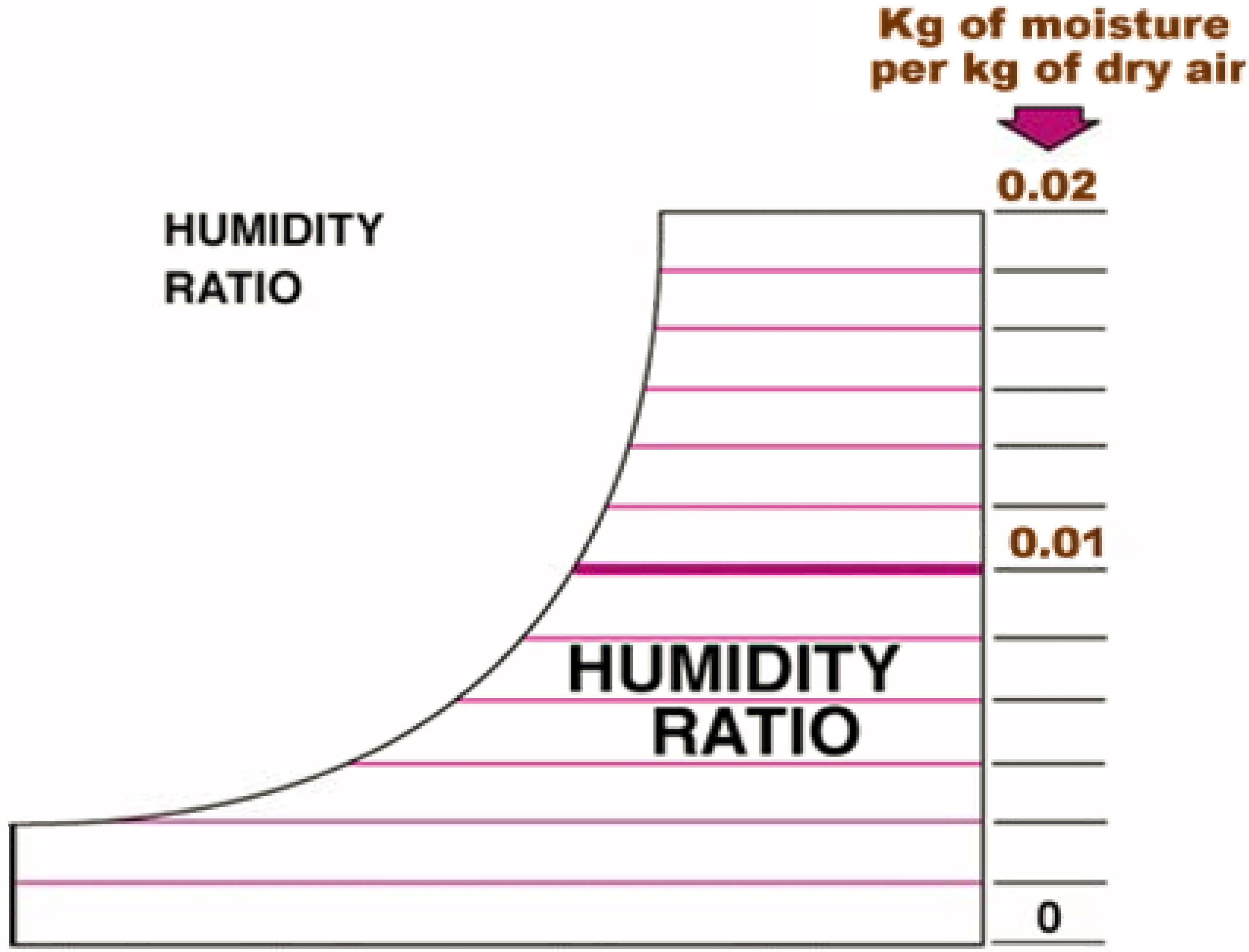

DRY-BULB
TEMPERATURE
DRY-BULB
LINES
20
50
105
DRY-BULB
TEMPERATURE
SCALE

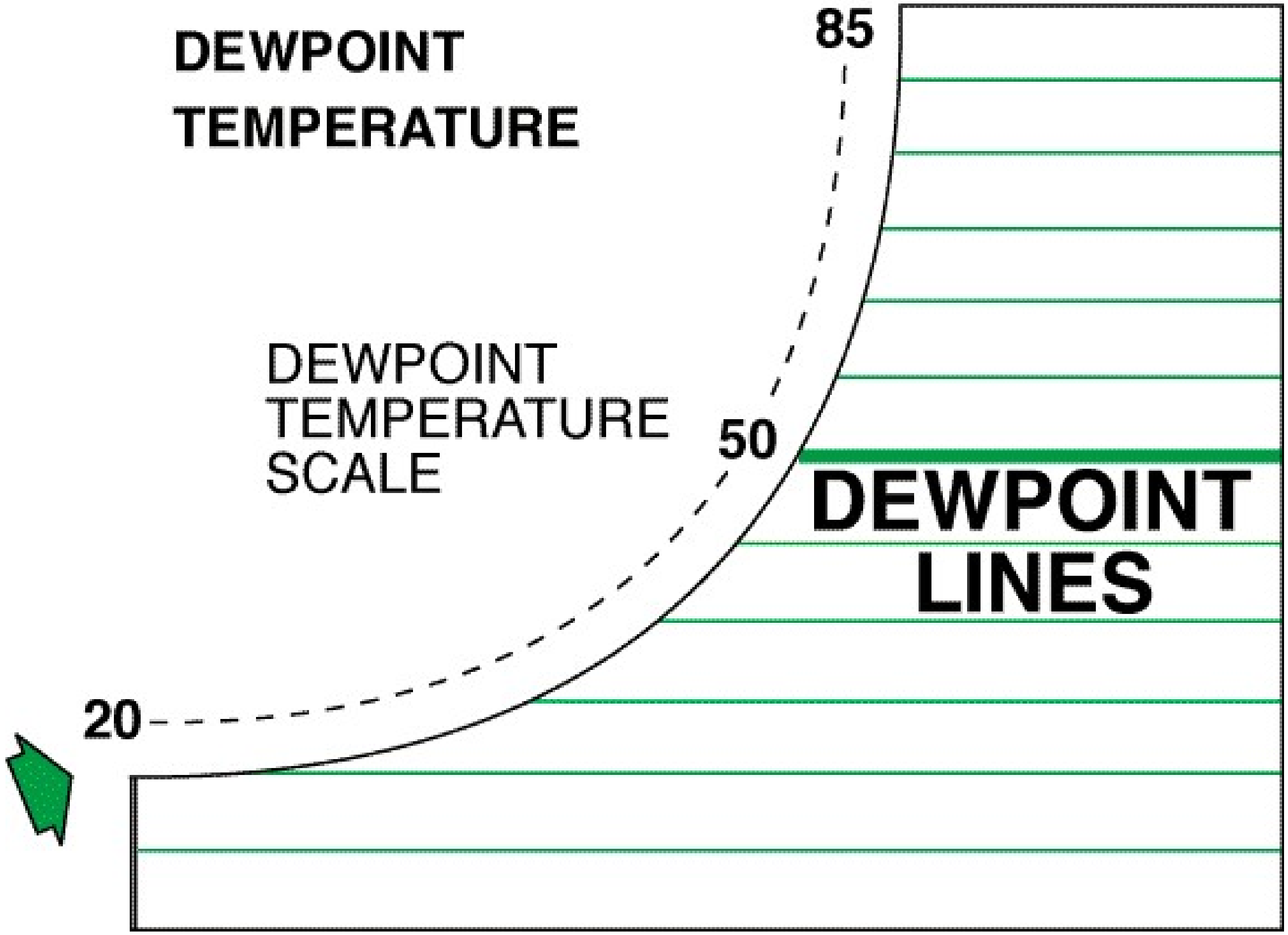


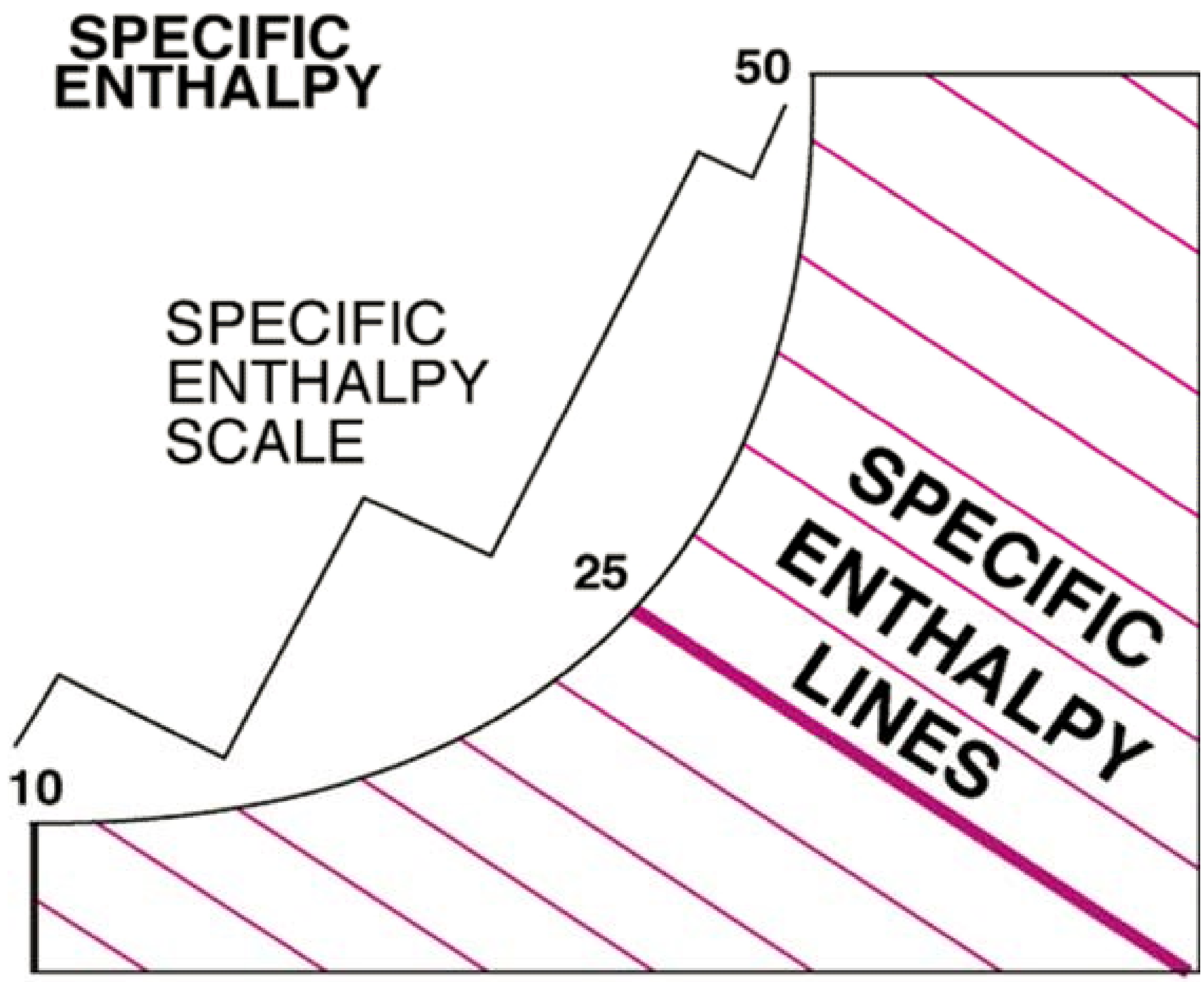
WET-BULB
TEMPERATURE
85
WET-BULB
TEMPERATURE
SCALE
40
20
WET-BULB
LINES



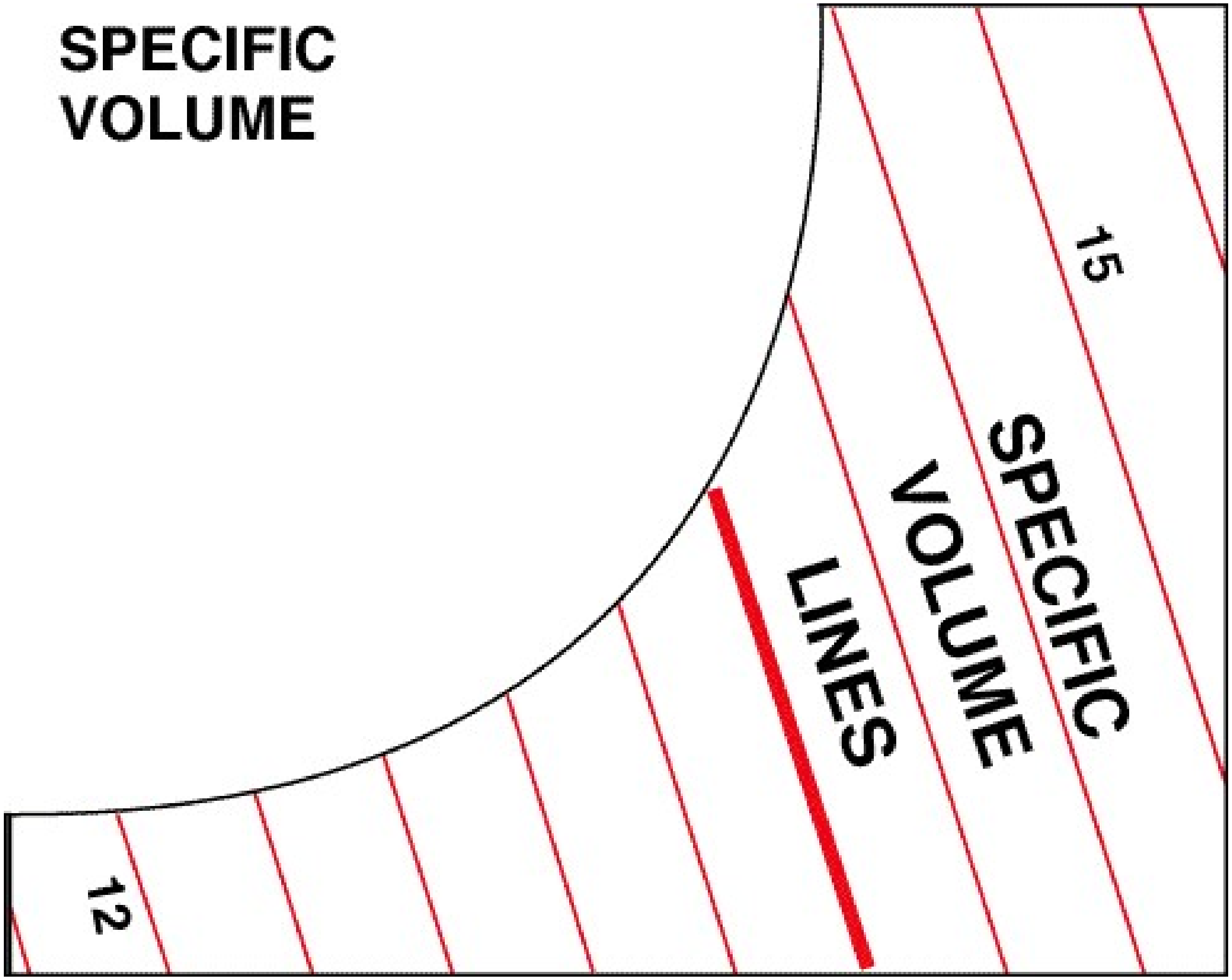
RELATIVE
HUMIDITY
80% RH
100% RH
45% RH
RELATIVE
HUMIDITY
LINES
20% RH


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
50
SPECIFIC
ENTHALPY
SCALE
25
10
SPECIFIC
ENTHALPY
LINES

SPECIFIC VOLUME

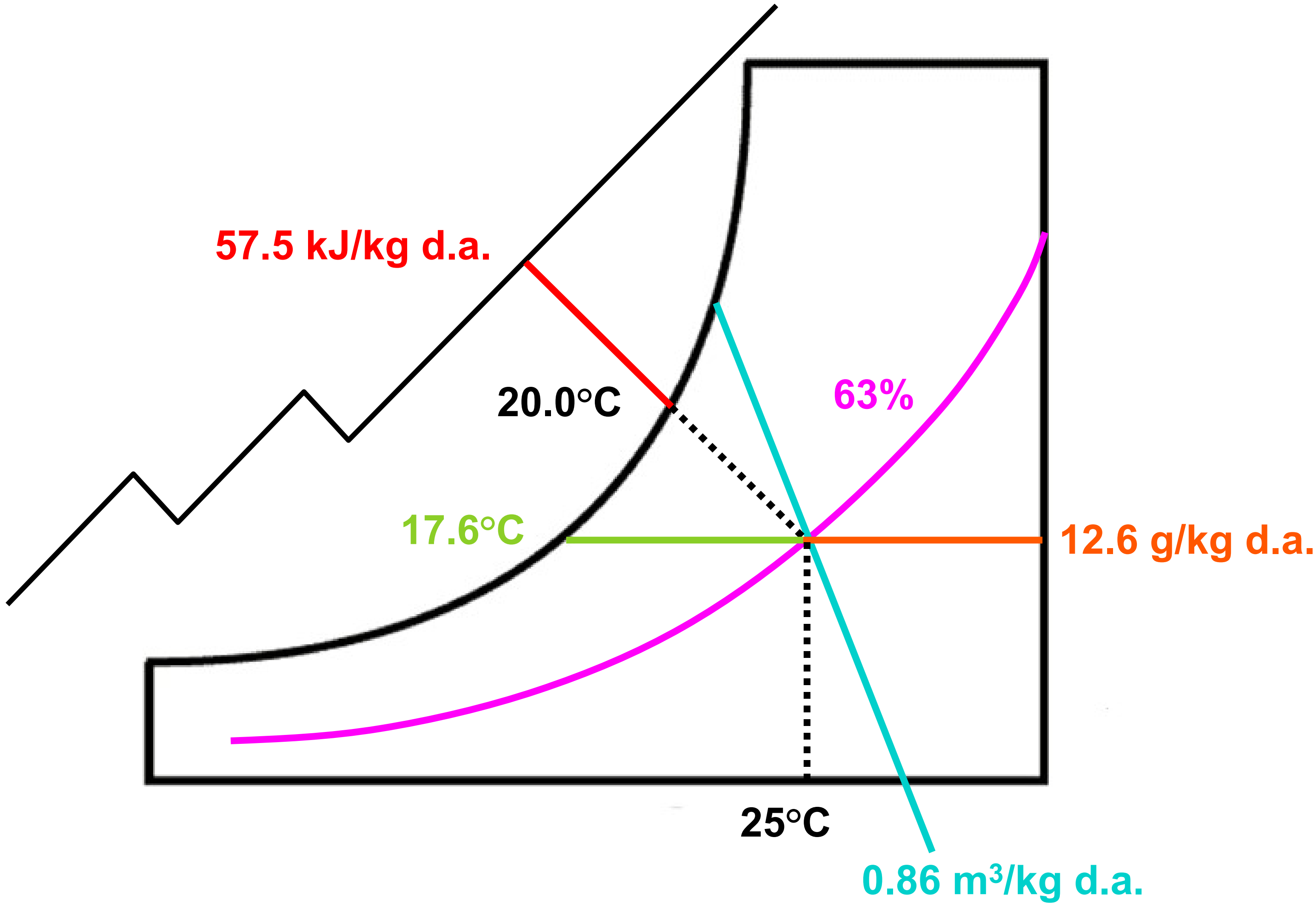


Psychrometric chart: Example 1

Given: $T = 25°C$

$T_w = 20°C$

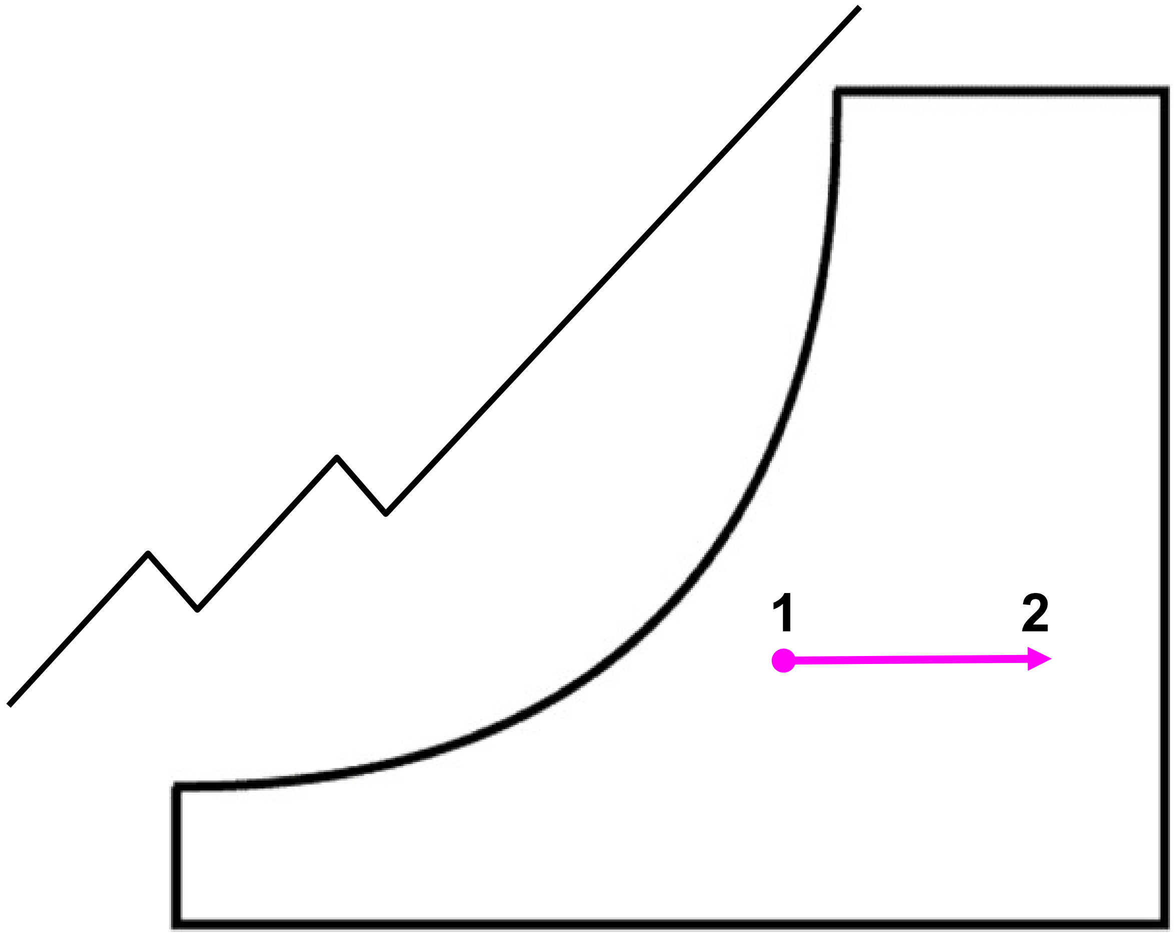
Required: (a) RH, (b) T_{dp}, (c) HR, (d) v, (e) h


57.5 kJ/kg d.a.
20.0°C
63%
17.6°C
12.6 g/kg d.a.
25°C
0.86 m³/kg d.a.

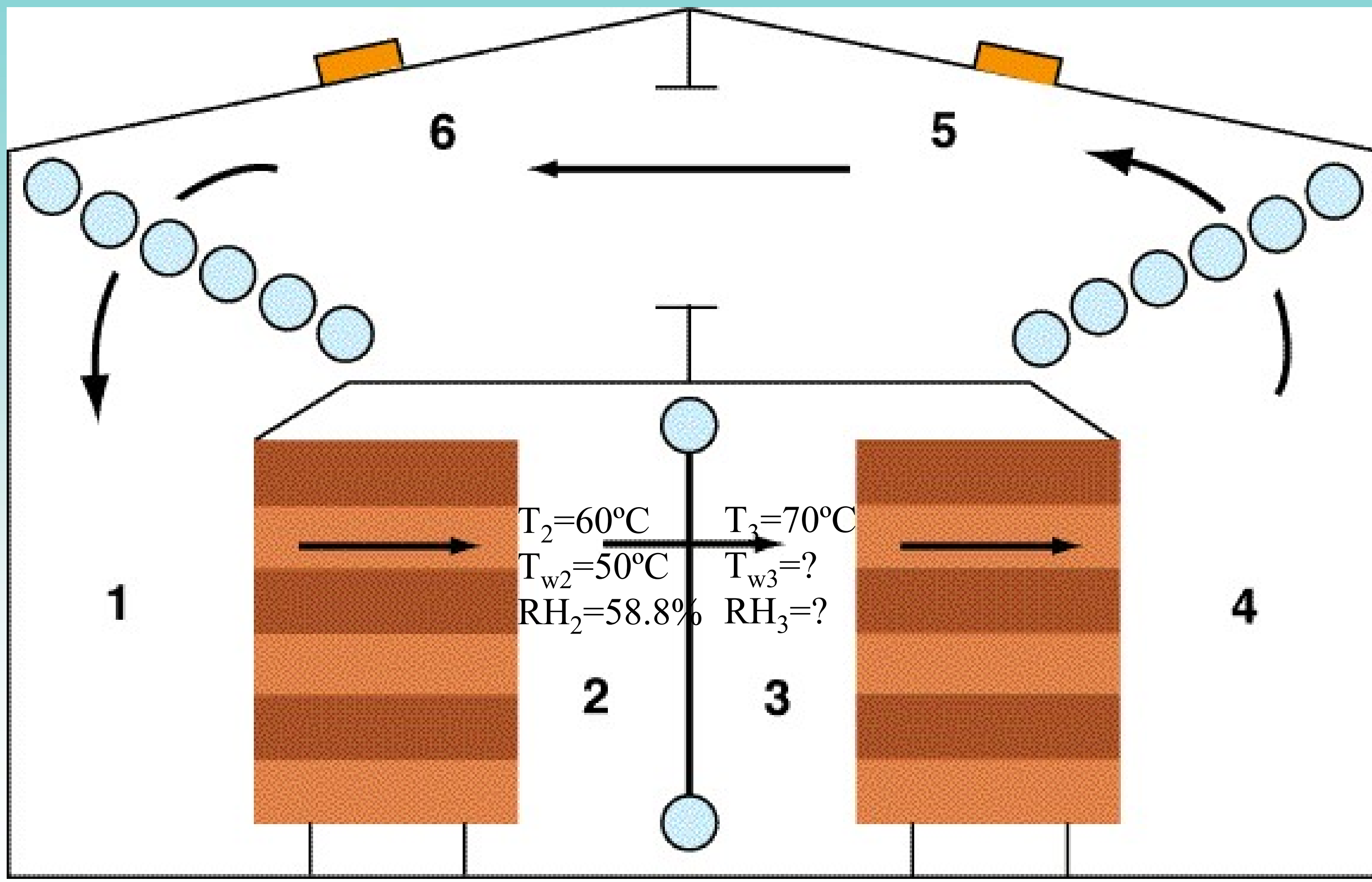
PSYCHROMETRIC PROCESSES

Sensible Heating or Cooling

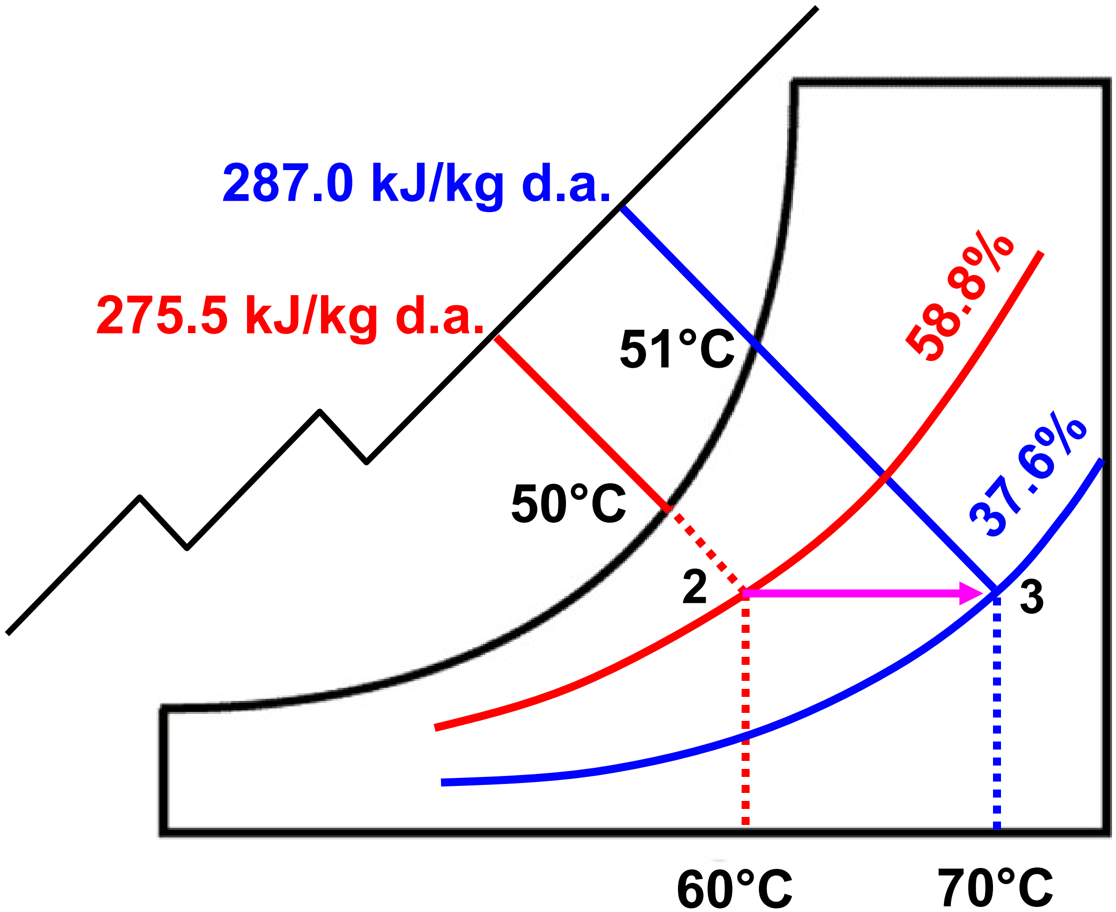
- a psychrometric process that involves the increase or decrease in the temperature of air without changing its humidity ratio
- Example: passing moist air over a room space heater and of kiln air over the heating coils


1
2

Sensible heating: Example 5

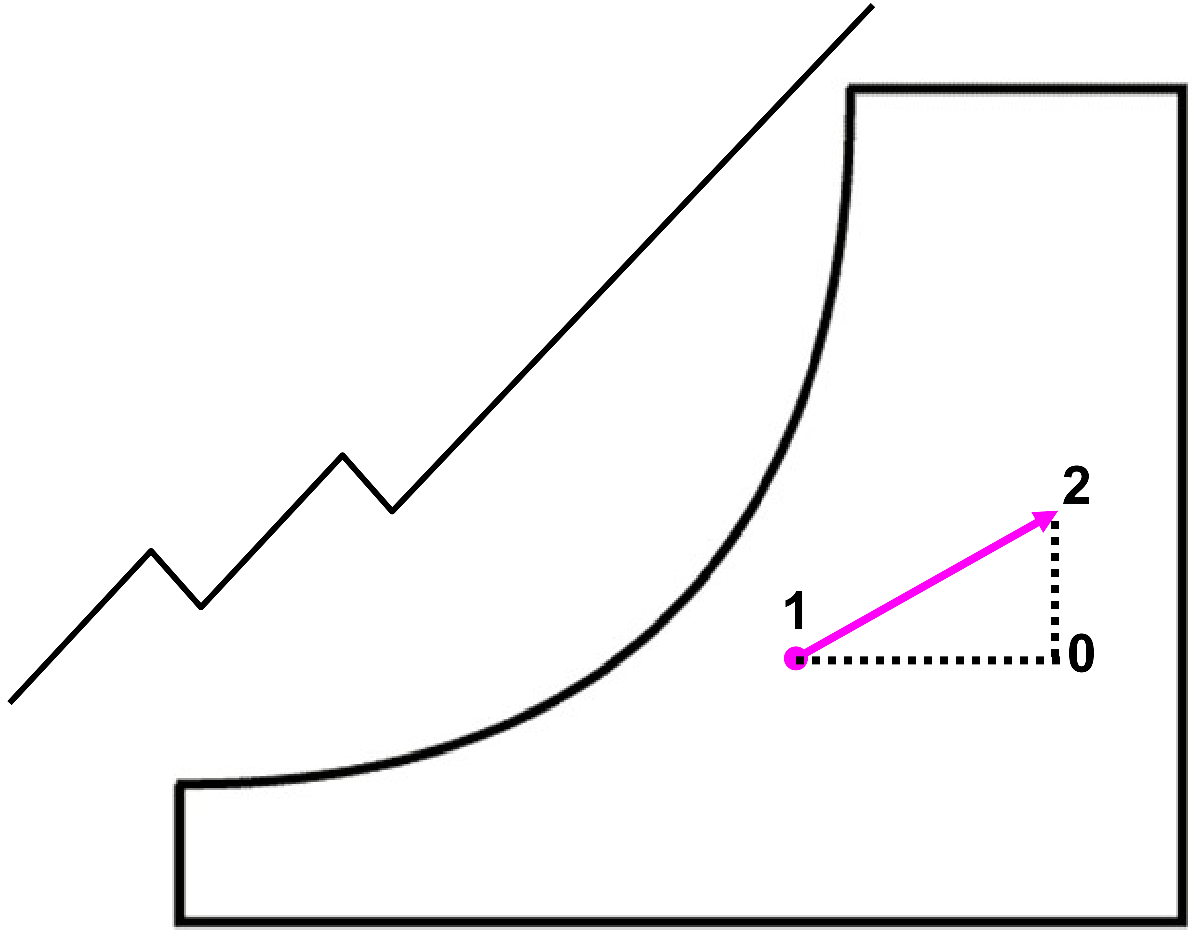


6
5
1
T_2=60ºC
T_{w2}=50ºC
RH_2=58.8%
T_3=70ºC
T_{w3}=?
RH_3=?
4
2
3


287.0 kJ/kg d.a.
275.5 kJ/kg d.a.
51°C
50°C
58.8%
37.6%
2
3
60°C
70°C

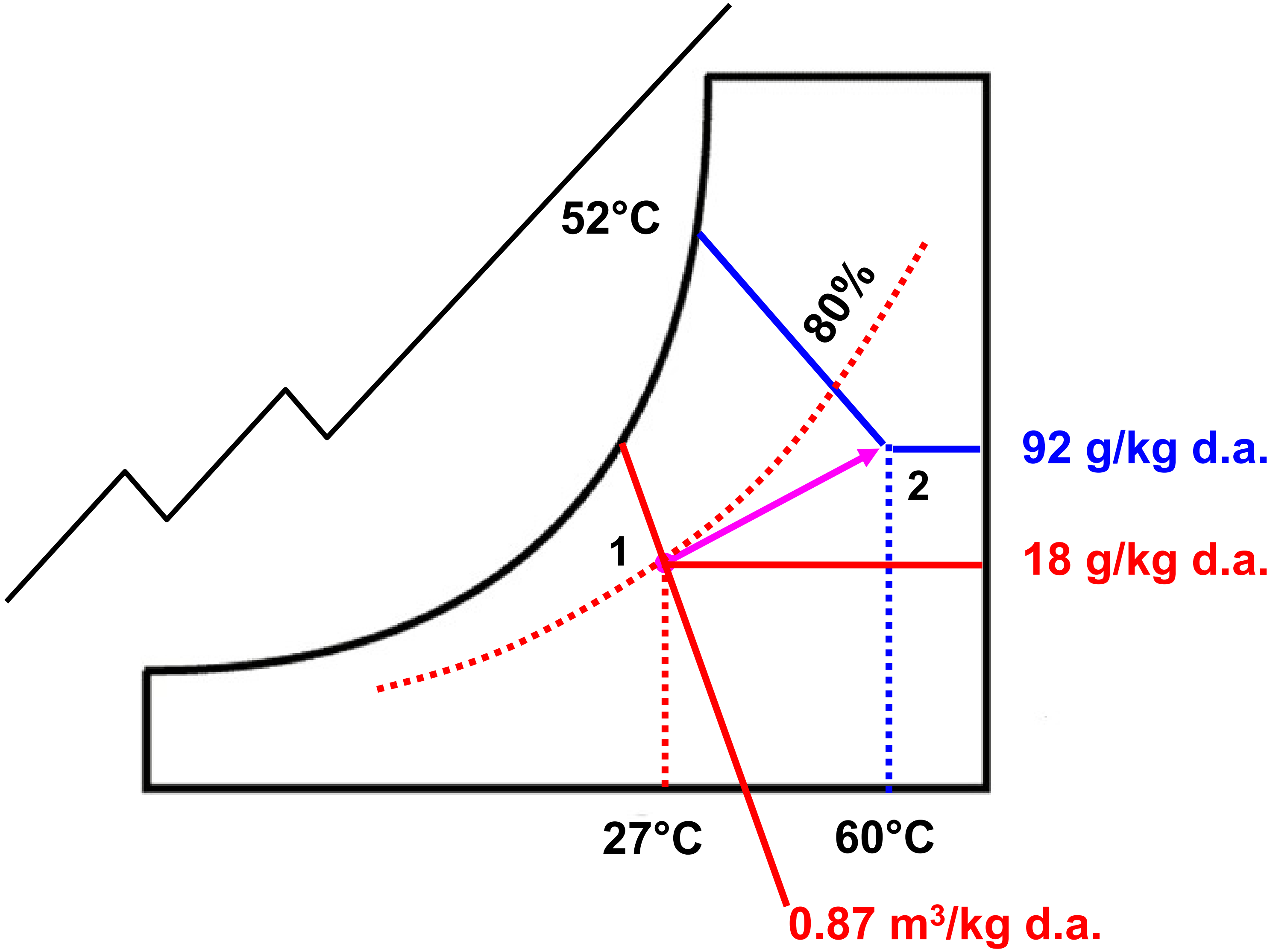
Heating and Humidifying

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


2
1
0

Heating and humidifying: Example 7

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?



52°C
80%
92 g/kg d.a.
2
1
18 g/kg d.a.
27°C
60°C
0.87 m³/kg d.a.

Heating and humidifying: Example 7

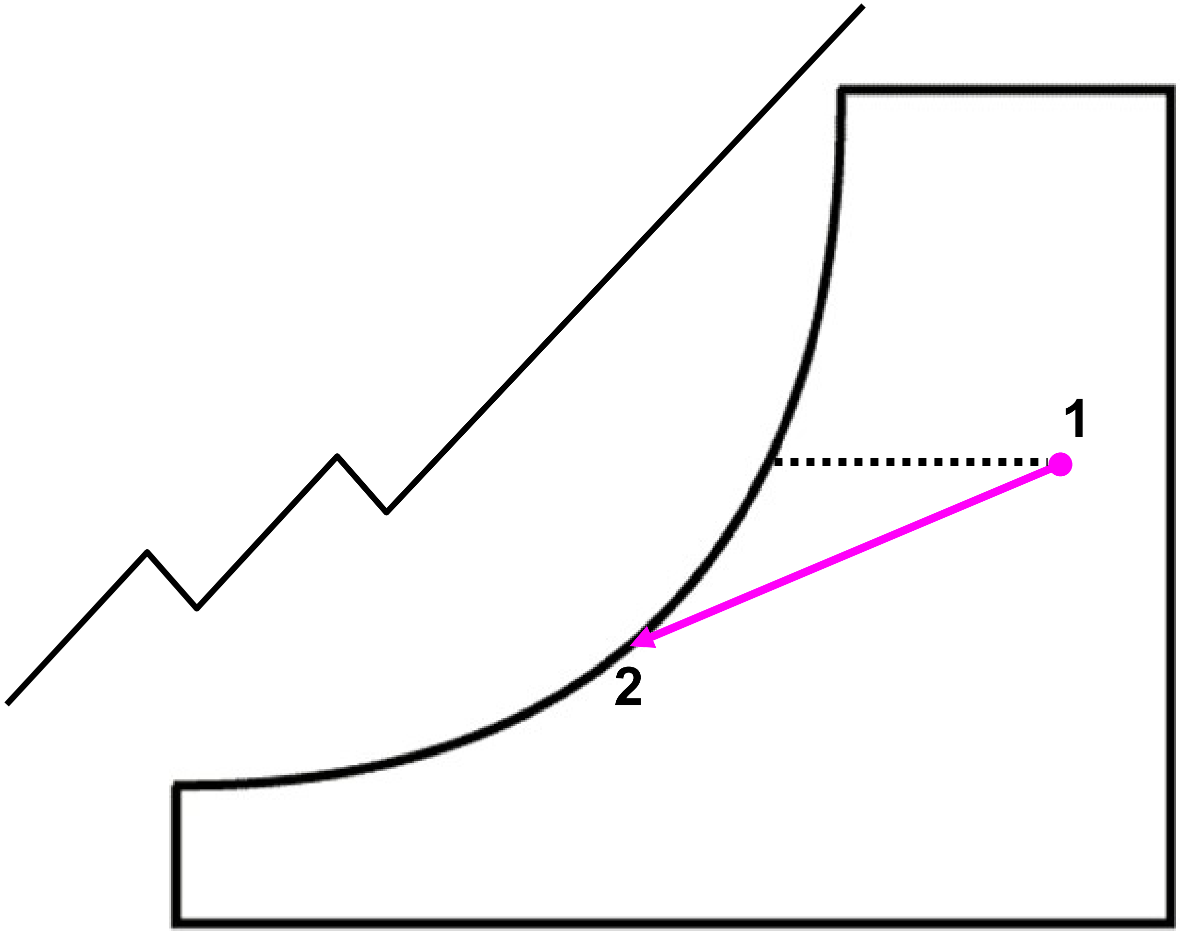
$$\Delta HR = (92.0 - 18.0) \text{ g/kg dry air}$$
$$= 74.0 \text{ g/kg dry air}$$

$$w_{a1} = \text{drying rate}/\Delta HR$$
$$= (12.5 \text{ kg/hour})/(0.074 \text{ kg/kg dry air})$$
$$= 168.9 \text{ kg dry air/hour}$$

$$VF_1 = (w_{a1})(v_1)$$
$$= (168.9 \text{ kg dry air/hour})(0.87 \text{ m}^3\text{/kg dry air})$$
$$= 147 \text{ m}^3\text{/hour} = 2.45 \text{ m}^3\text{/minute}$$

Cooling and Dehumidifying

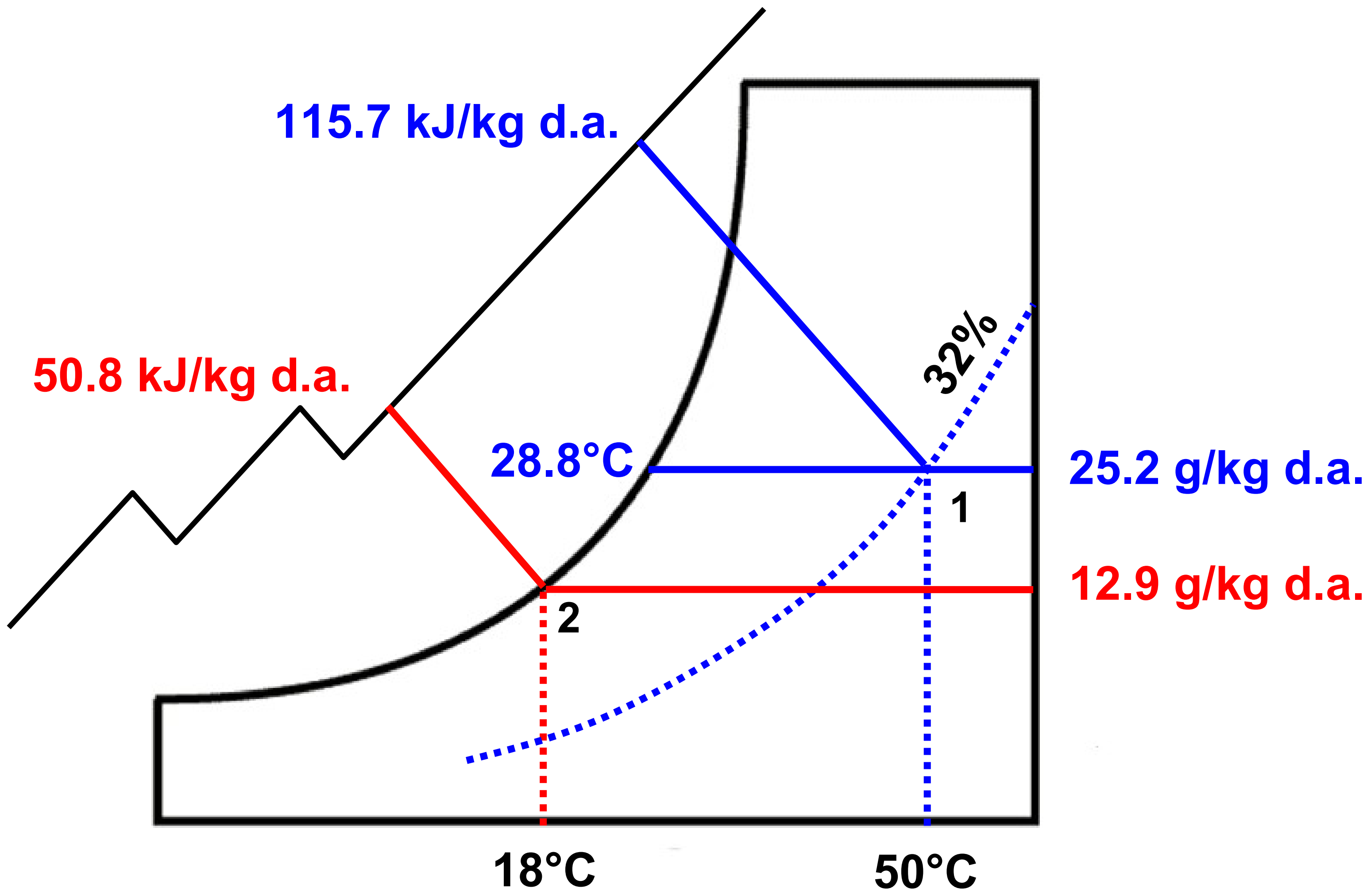
- a psychrometric process that involves the removal of water from the air as the air temperature falls below the dew-point temperature



1
2

Cooling and dehumidifying: Example 9

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.


115.7 kJ/kg d.a.
50.8 kJ/kg d.a.
32%
28.8°C
25.2 g/kg d.a.
1
12.9 g/kg d.a.
2
18°C
50°C

Cooling and dehumidifying: Example 9

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

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

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

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

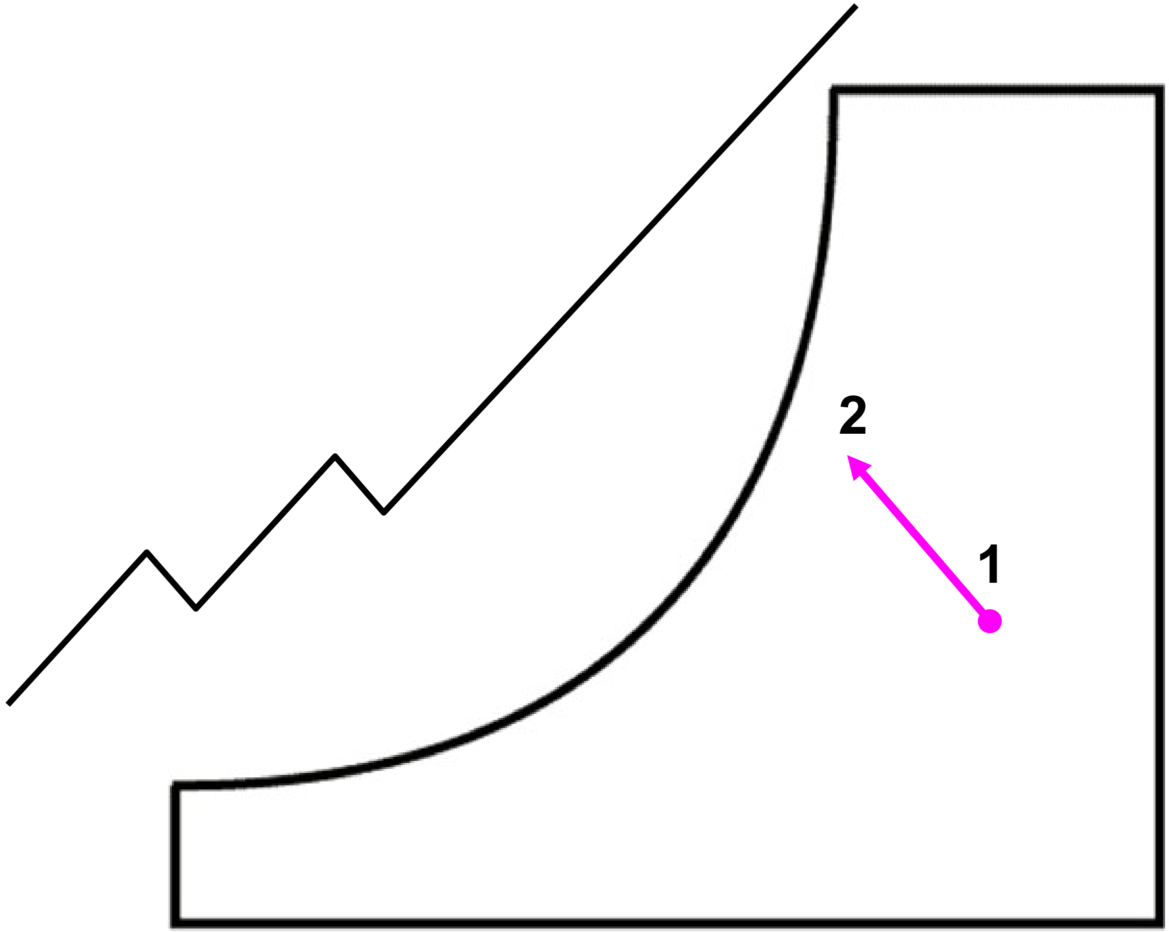
Cooling and dehumidifying: Example 9

$$\Delta h = (115.7 - 50.8) \text{ kJ/kg dry air}$$
$$= 64.9 \text{ kJ/kg dry air}$$

$$q = (\Delta h)(w_a)$$
$$= \left[64.9 \frac{\text{kJ}}{\text{kg dry air}}\right]\left[325.2 \frac{\text{kg dry air}}{\text{h}}\right]$$
$$= 21105.7 \frac{\text{kJ}}{\text{h}} = 5.9 \text{ kW}$$

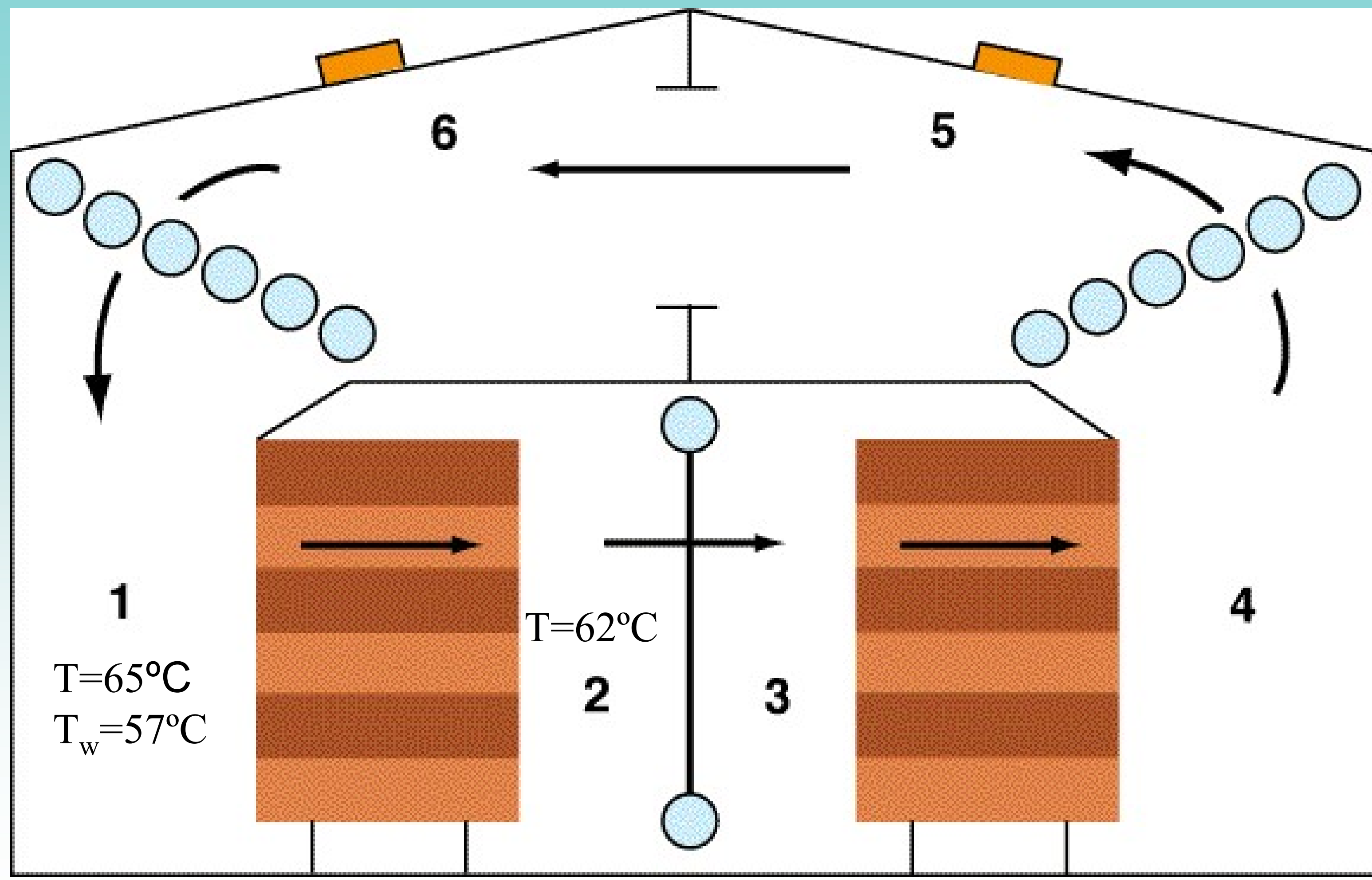
Adiabatic or Evaporative Cooling

- 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


2
1

Evaporative cooling: Example 10

Referring to Figure 21, 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.


6
5
1
T=65ºC
T_w=57ºC
T=62ºC
2
3
4

Evaporative cooling: Example 10

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

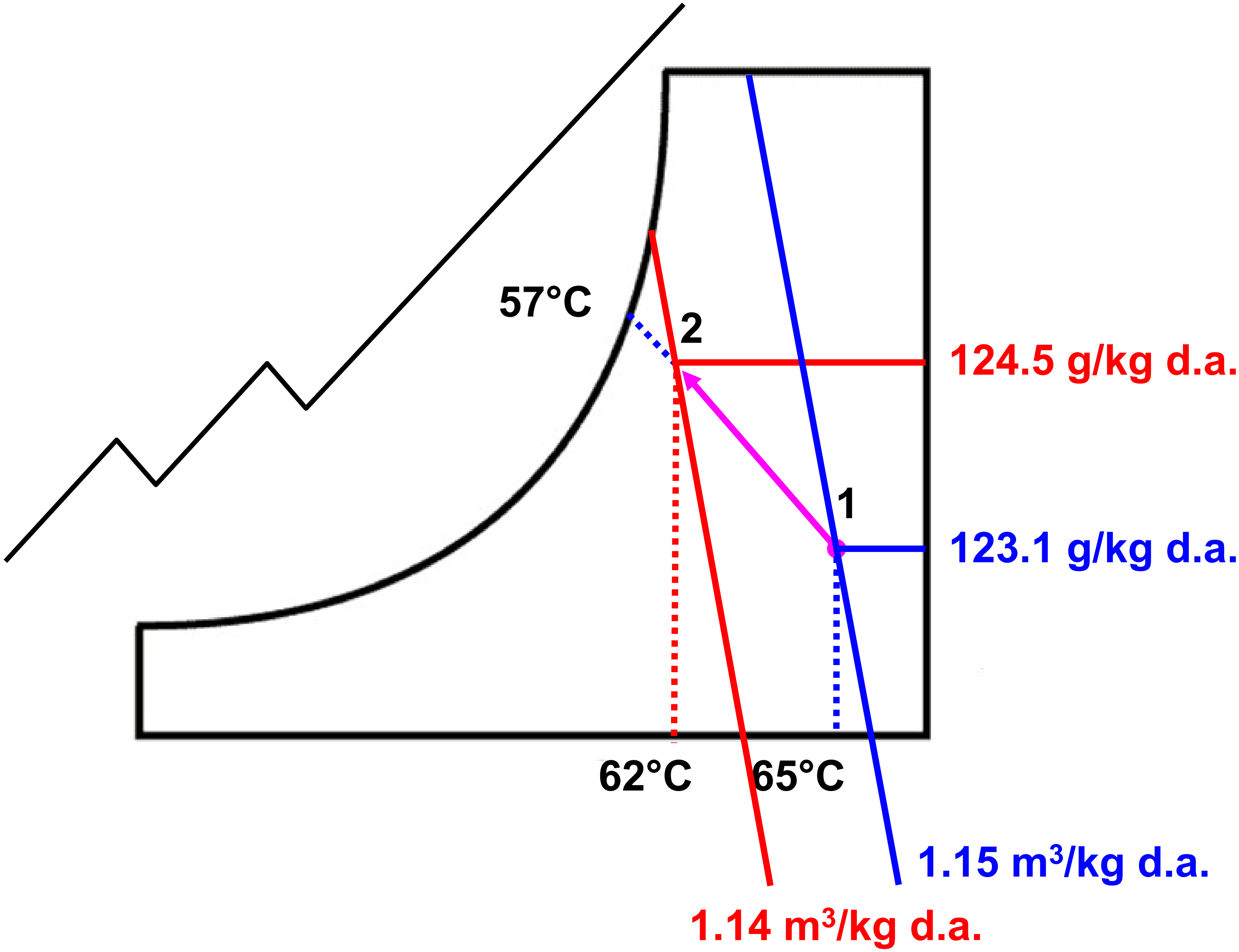
Sticker dimensions: 3.8 cm wide x 1.9 cm thick

Sticker spacing = 0.6 m

Required: (a) Properties of the air at state point 2 relative to that at state point 1

(b) Drying rate

Solution:


57°C
2
124.5 g/kg d.a.
1
123.1 g/kg d.a.
62°C
65°C
1.15 m³/kg d.a.
1.14 m³/kg d.a.

Evaporative cooling: Example 10

(a) 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

Evaporative cooling: Example 10

(b) Drying rate = $\left(\Delta HR\right)\left(w_a\right)$

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

$$VF = \left(A\right)\left(\text{air flow rate}\right)$$

Evaporative cooling: Example 10

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

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

$$A = 1.47\ m^2$$

Evaporative cooling: Example 10

$$A = 1.47\ \text{m}^2$$

$$\text{VF} = (\text{A})(\text{air flow rate})$$

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

Evaporative cooling: Example 10

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

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

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

Evaporative cooling: Example 10

$$w_a = 2.6\frac{\text{kg dry air}}{\text{s}}$$

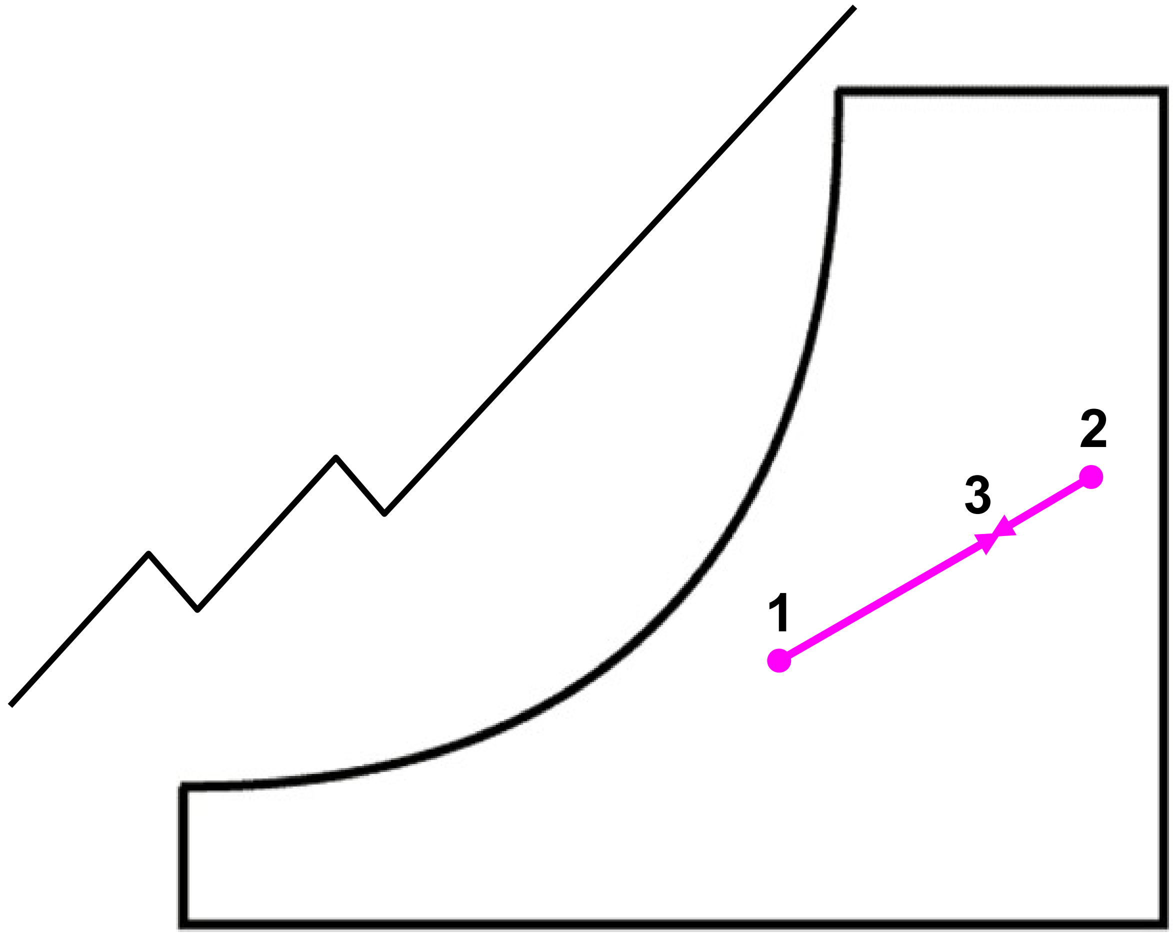
$$\text{Drying rate} = (w_a)(\Delta HR)$$

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

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

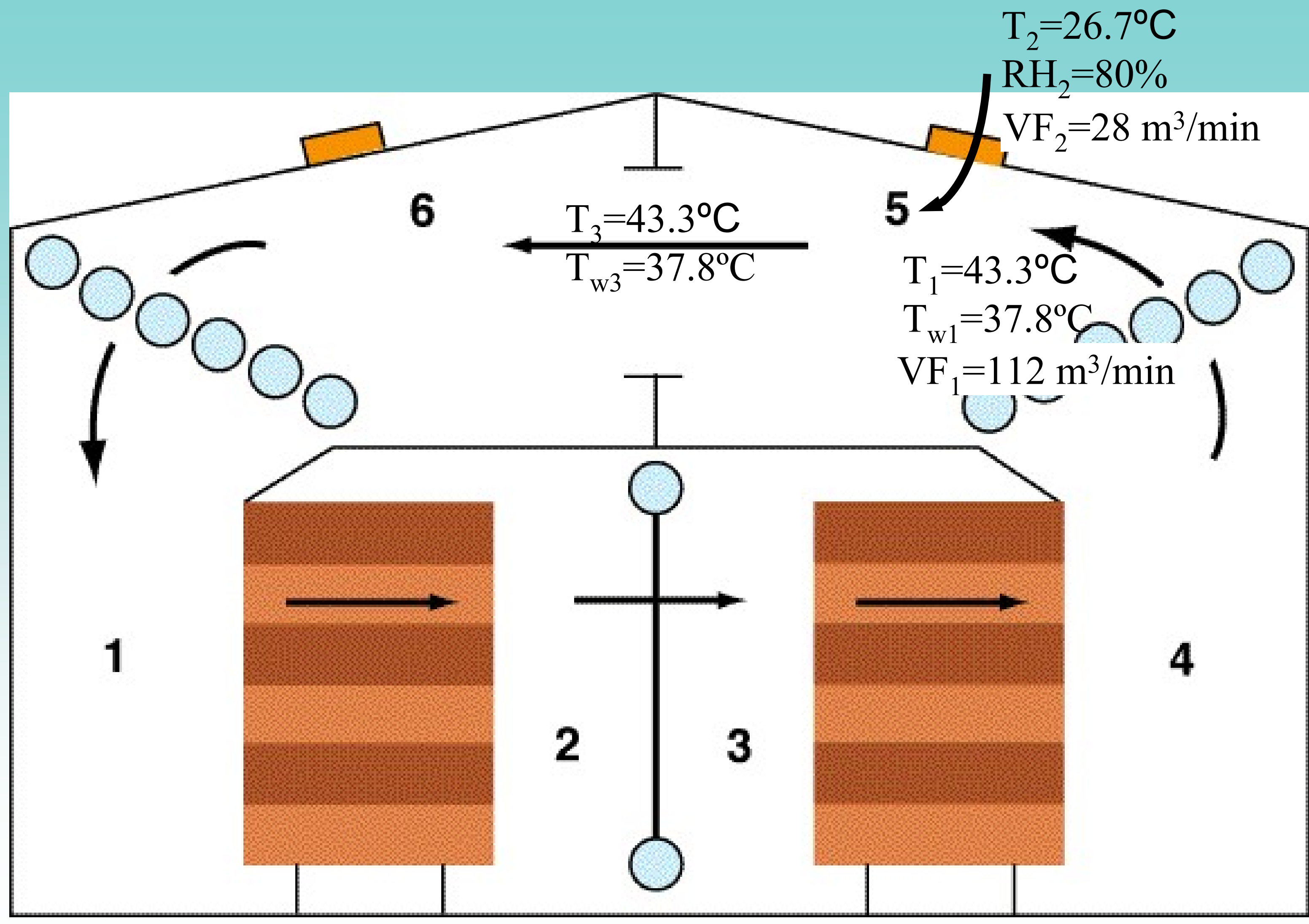
Adiabatic Mixing of Moist Air Stream

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

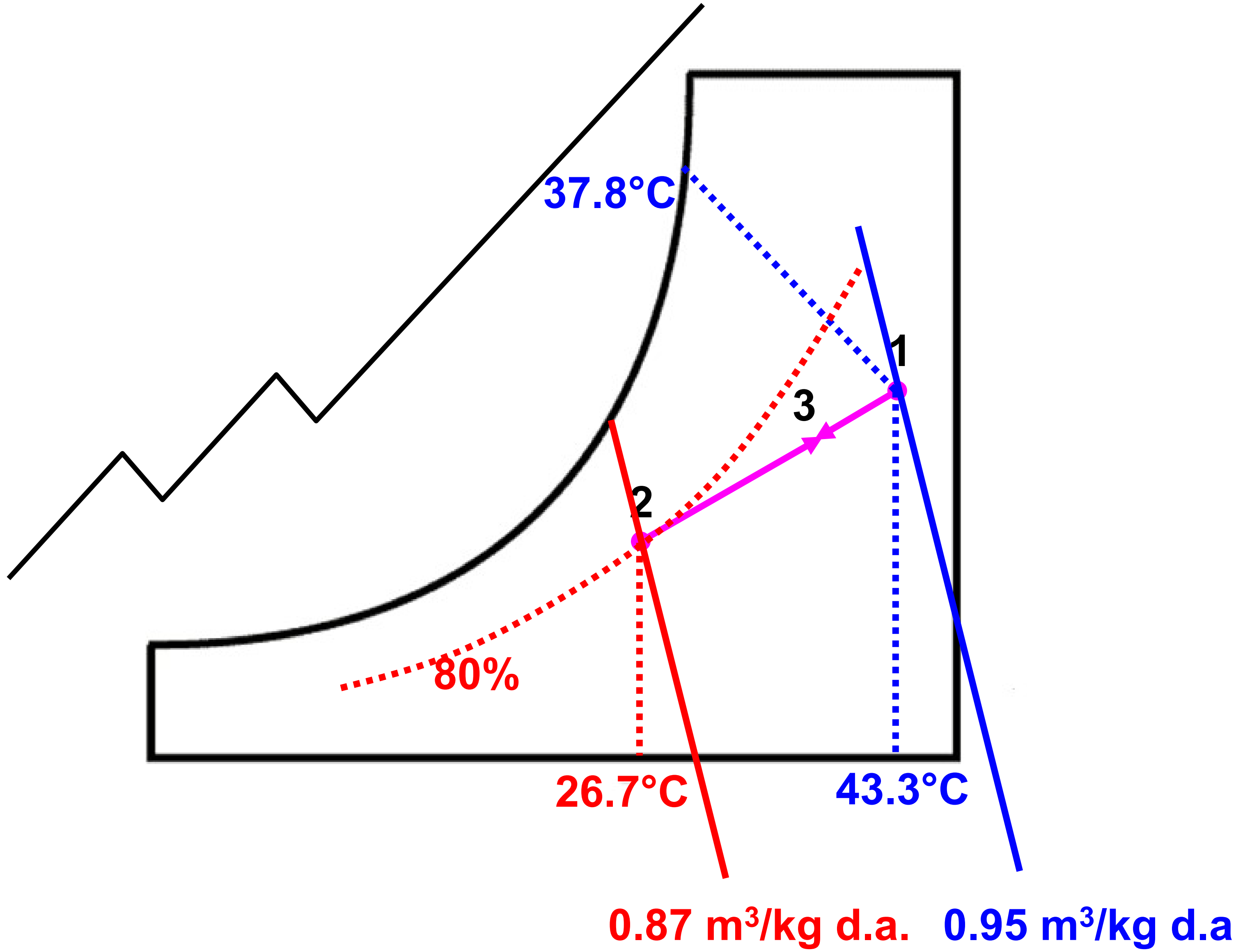


2
3
1

Adiabatic mixing: Example 11



T2=26.7ºC
RH2=80%
VF2=28 m3/min
6
T3=43.3ºC
Tw3=37.8ºC
5
T1=43.3ºC
Tw1=37.8ºC
VF1=112 m3/min
1
2
3
4


37.8°C
1
3
2
80%
26.7°C
43.3°C
0.87 m³/kg d.a.
0.95 m³/kg d.a.

Adiabatic mixing: Example 11

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

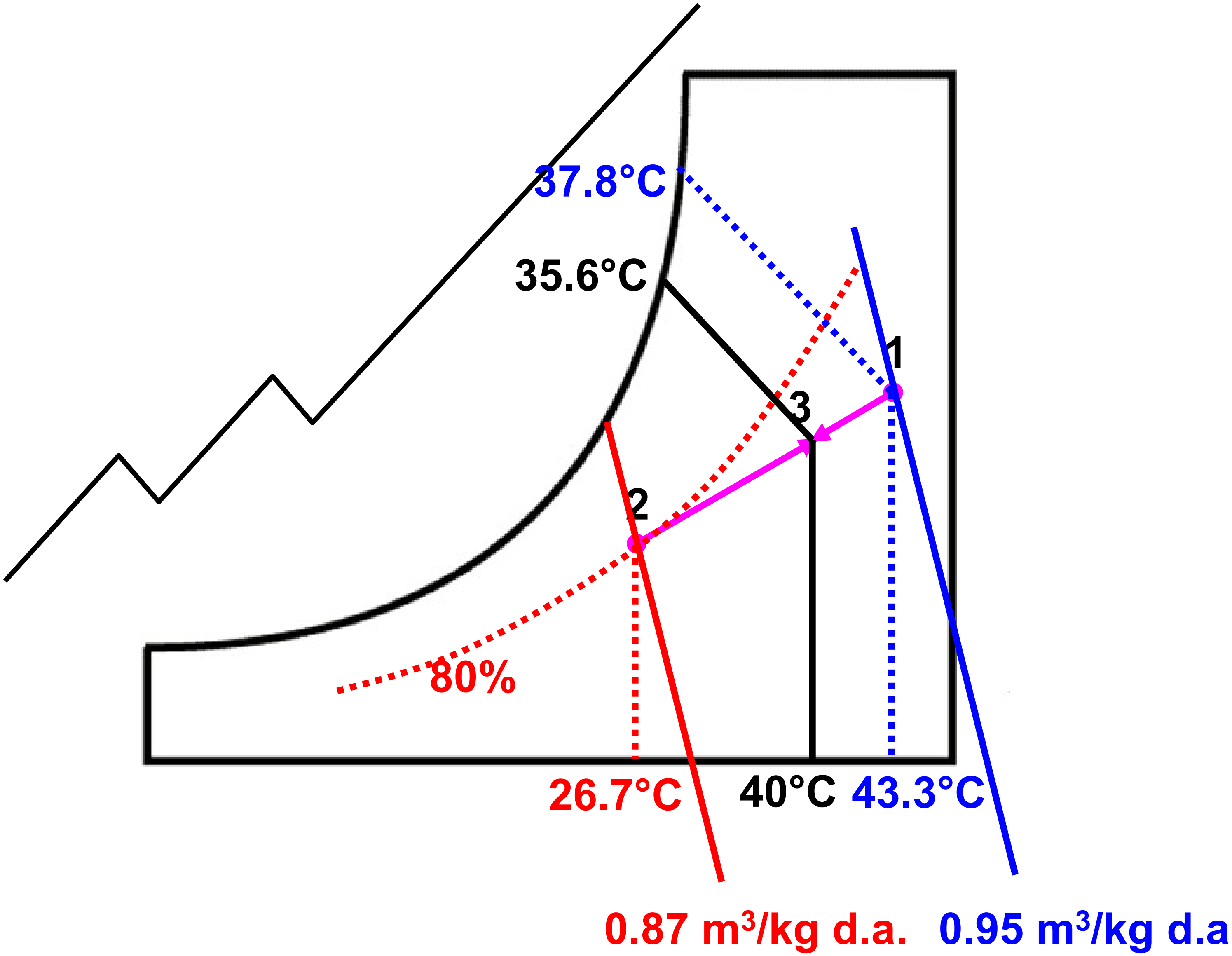
$$w_{a1} = \frac{112 \dfrac{m^3}{\text{minute}}}{0.95 \dfrac{m^3}{\text{kg dry air}}} = 117.9 \frac{\text{kg dry air}}{\text{minute}}$$

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

Adiabatic mixing: Example 11

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

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



37.8°C
35.6°C
1
3
2
80%
26.7°C
40°C
43.3°C
0.87 m³/kg d.a.
0.95 m³/kg d.a.

Adiabatic mixing: Example 11

$T_3 = 40.0°C$
$T_{w3} = 35.6°C$