THE PSYCHROMETRIC CHART: Theory and Application

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PSYCHROMETRIC CHART

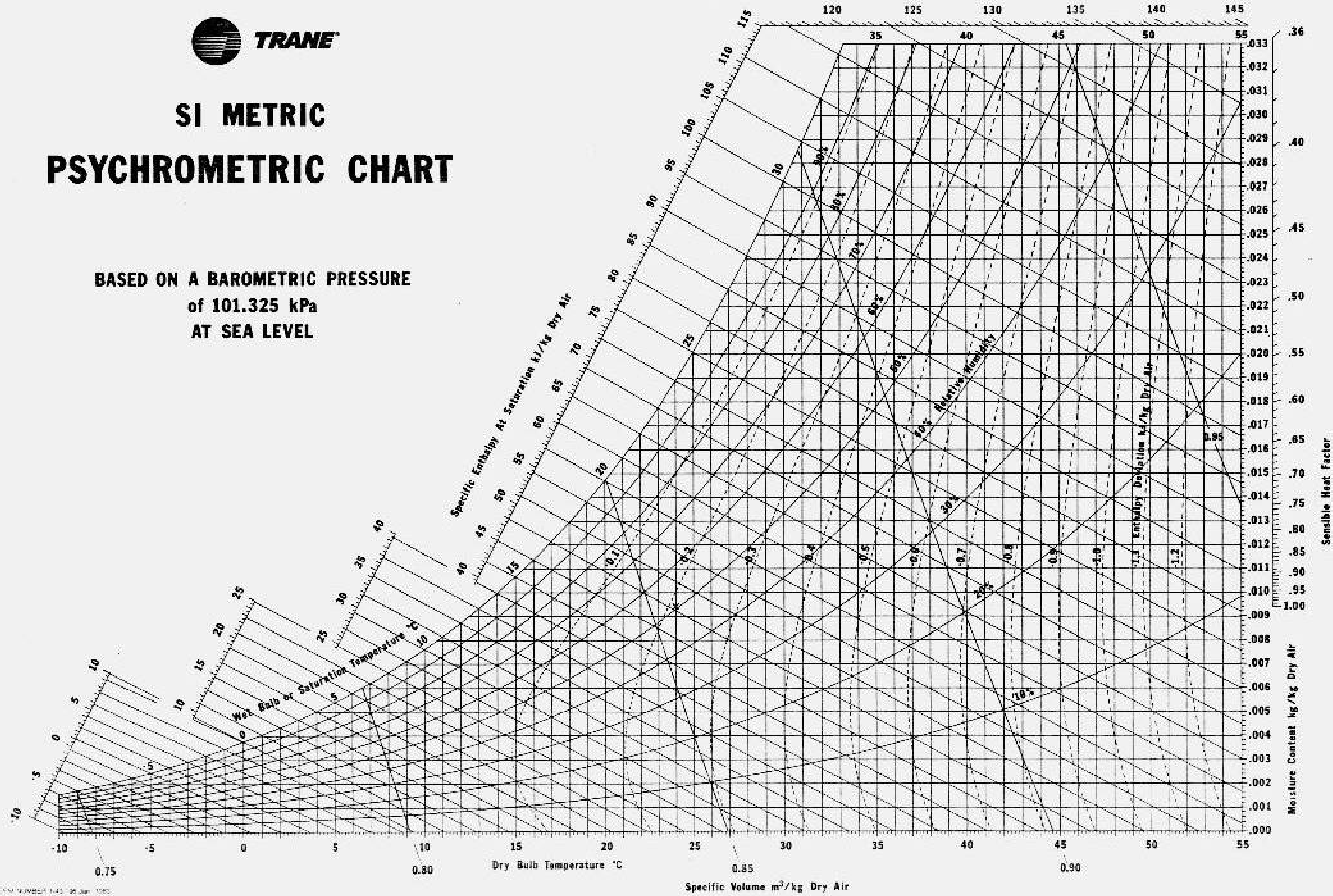
- Identify parts of the chart
- Determine moist air properties
- Use chart to analyze processes involving moist air

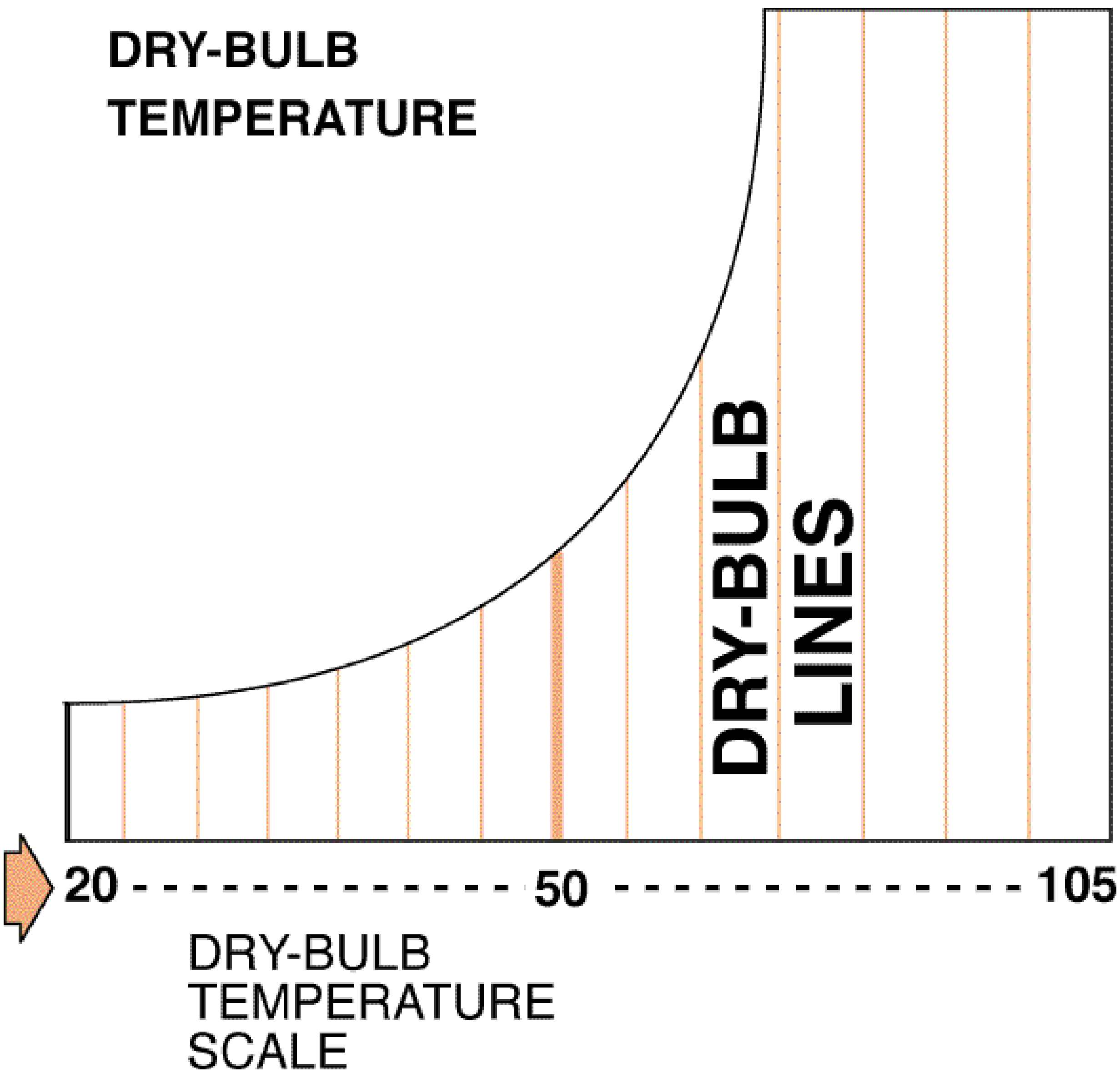
TRANE

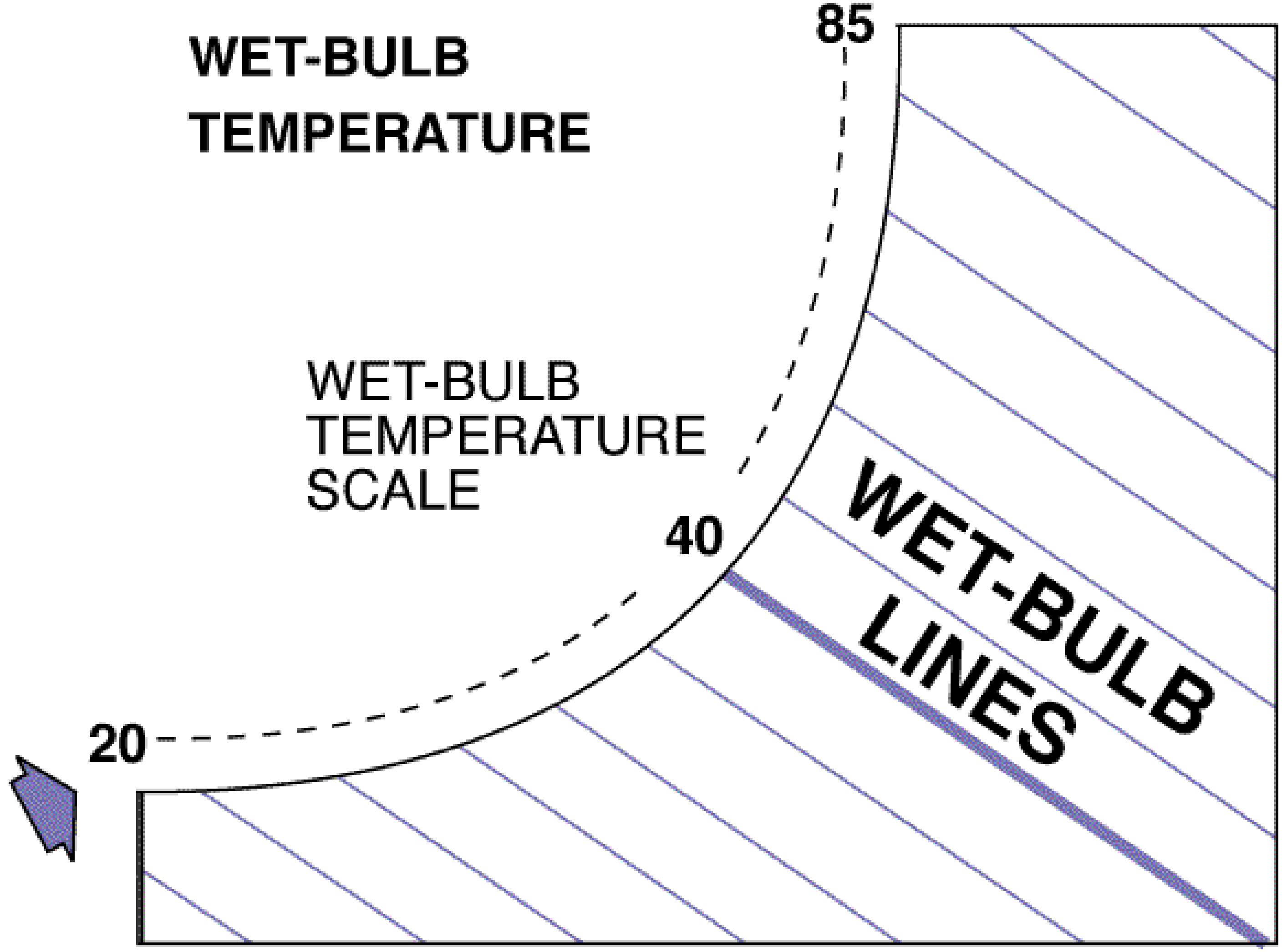
SI METRIC

PSYCHROMETRIC CHART

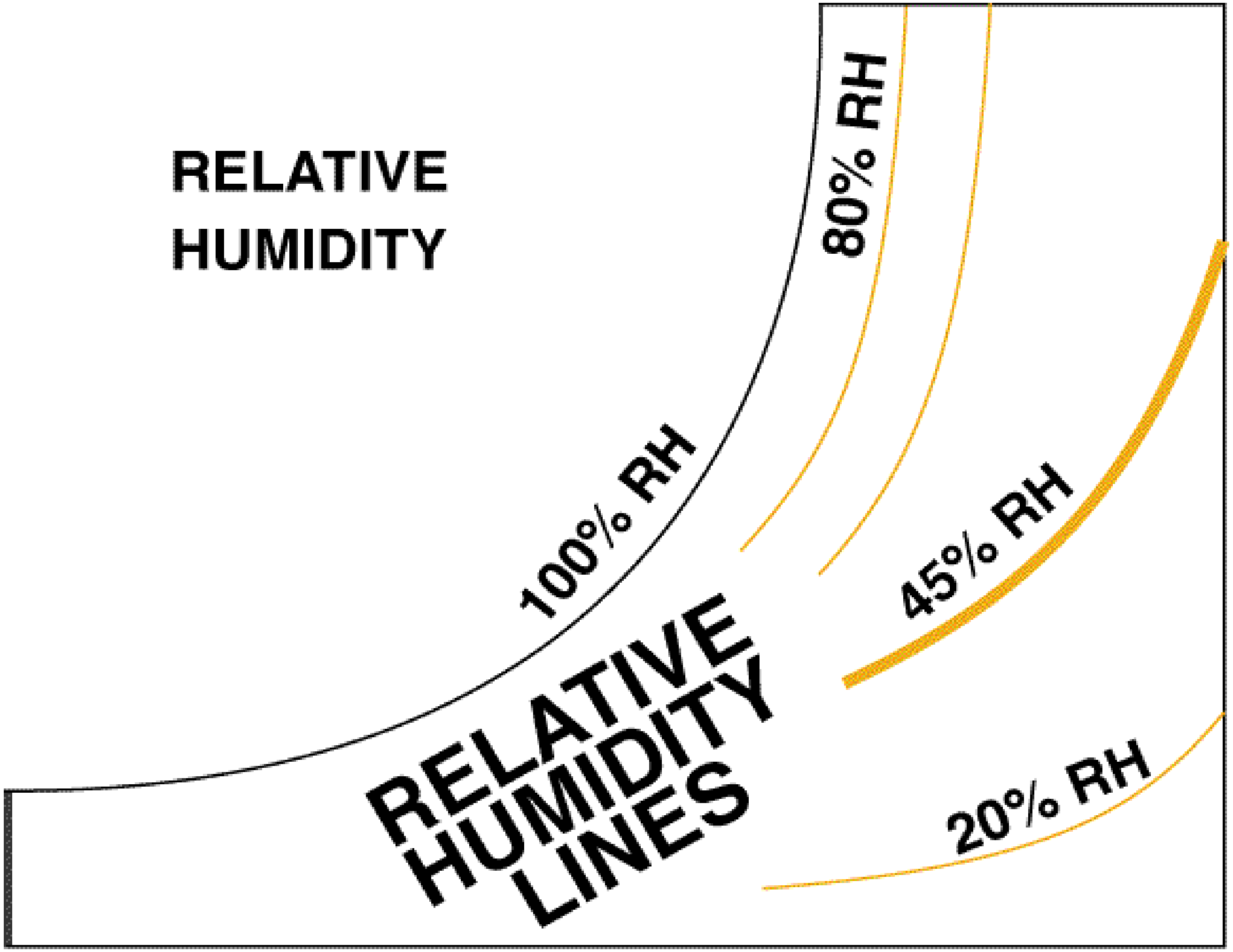
BASED ON A BAROMETRIC PRESSURE
of 101.325 kPa
AT SEA LEVEL



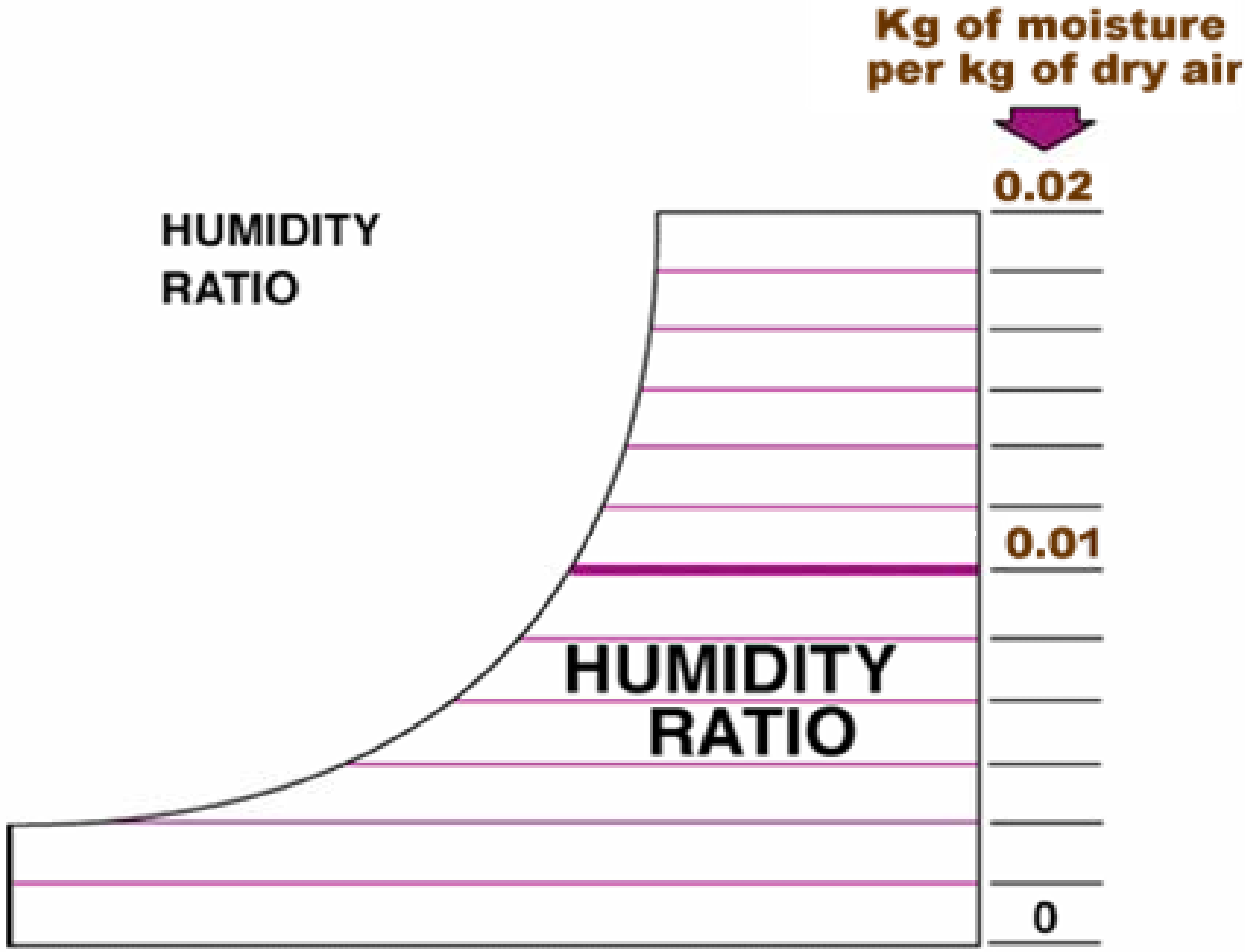

DRY-BULB
TEMPERATURE
DRY-BULB
LINES
20
50
105
DRY-BULB
TEMPERATURE
SCALE

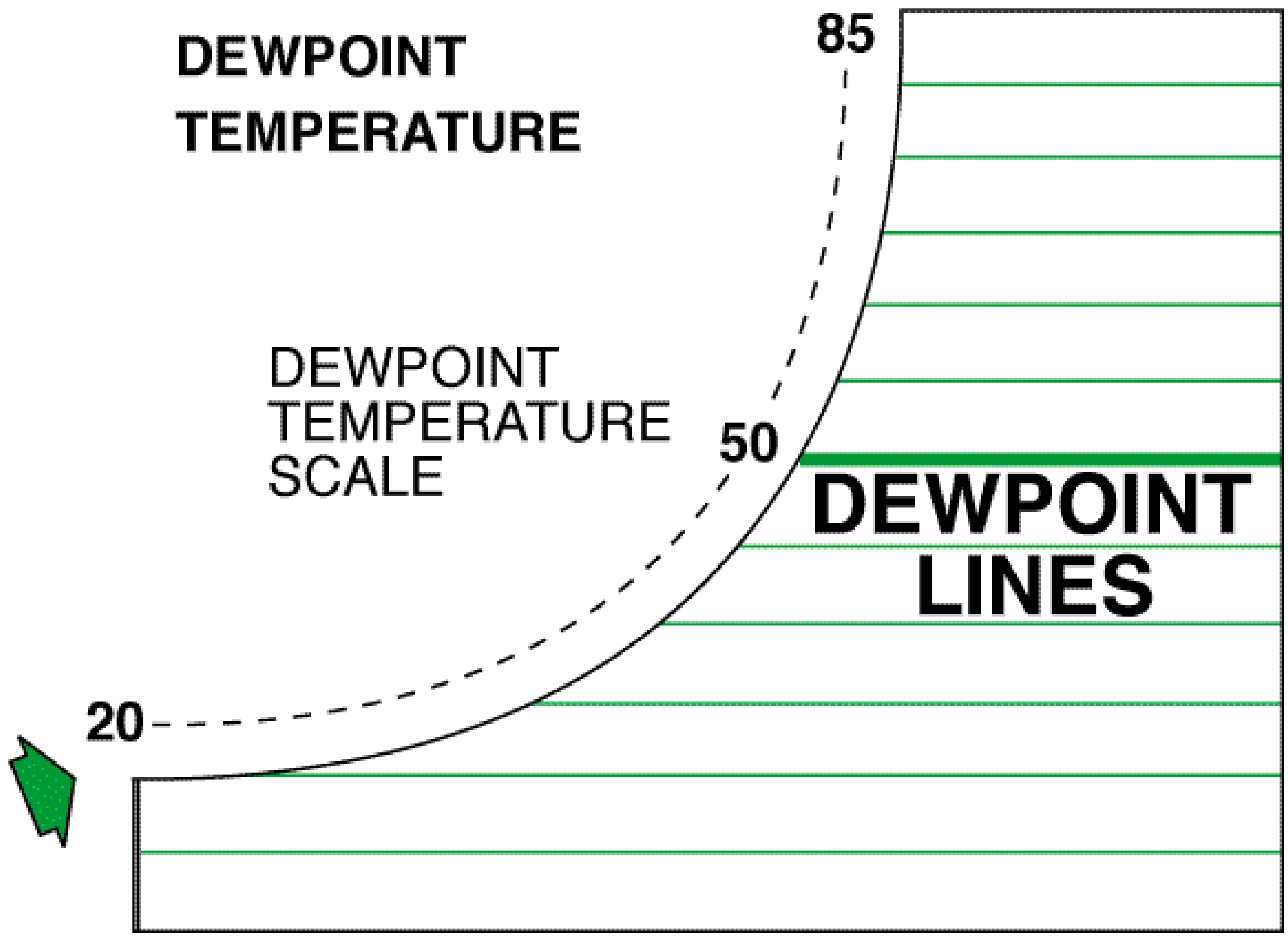

WET-BULB
TEMPERATURE
85
WET-BULB
TEMPERATURE
SCALE
40
20
WET-BULB
LINES

RELATIVE HUMIDITY

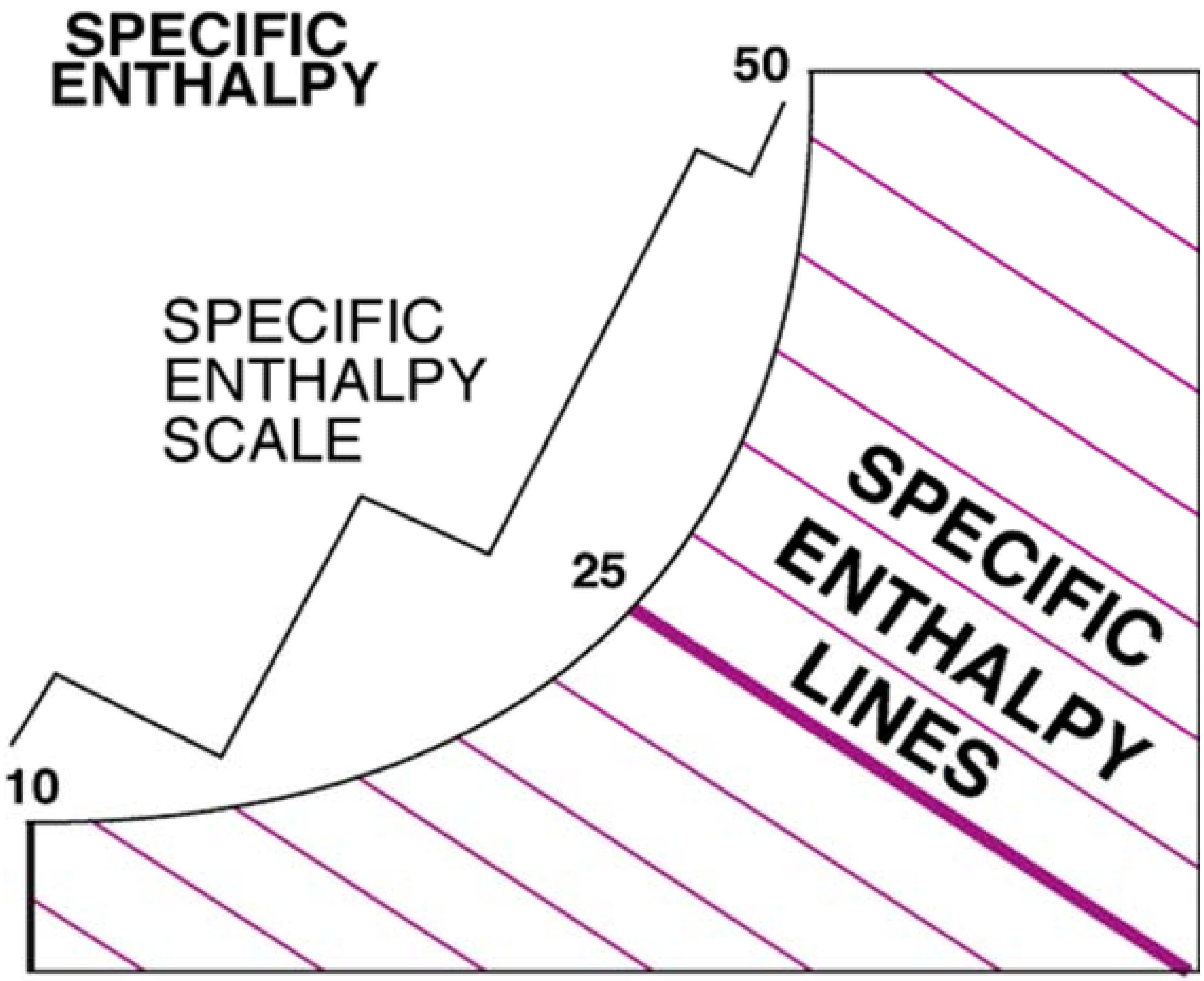


HUMIDITY RATIO

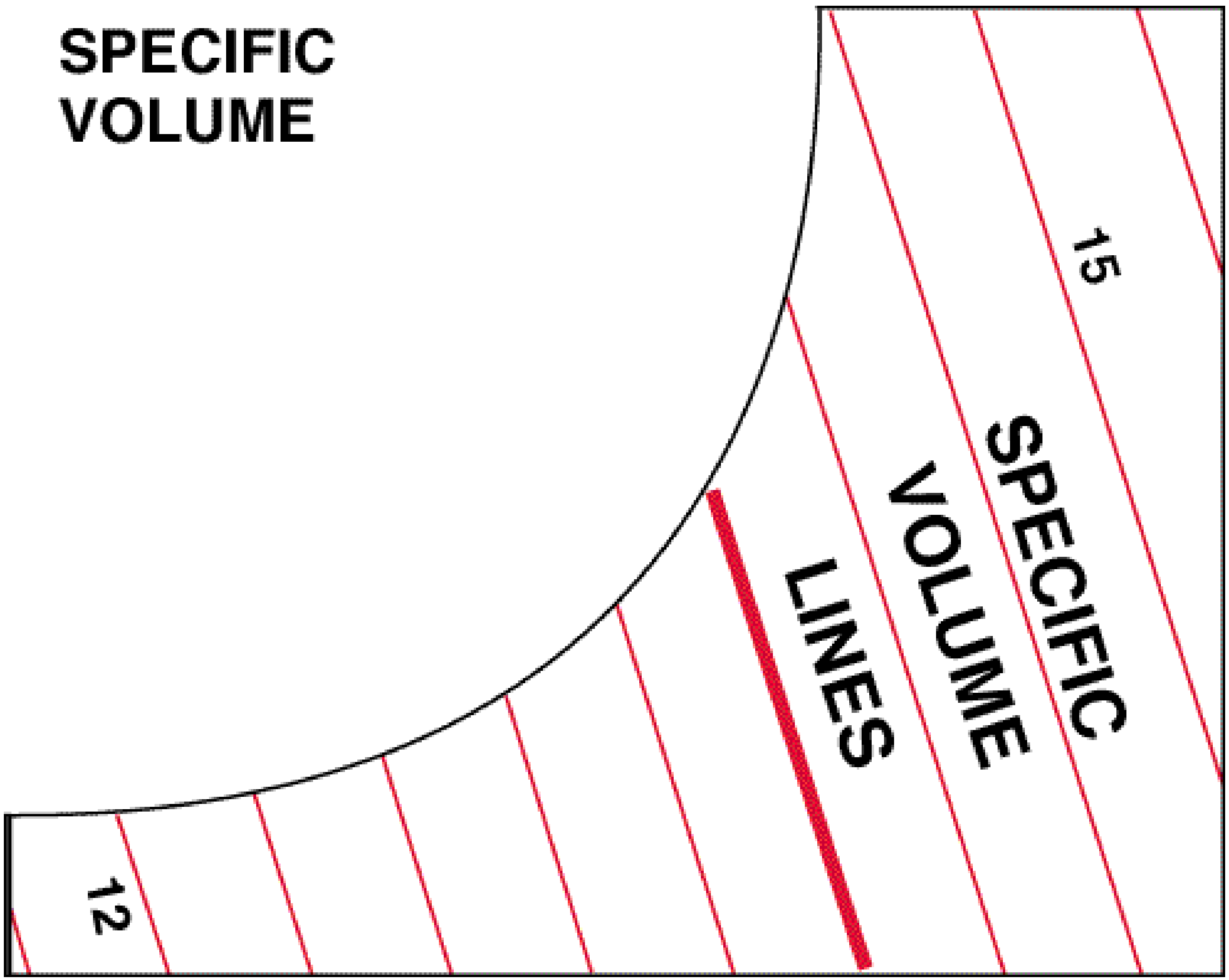




DEWPOINT
TEMPERATURE
85
DEWPOINT
TEMPERATURE
SCALE
50
DEWPOINT
LINES
20


SPECIFIC
ENTHALPY
50
SPECIFIC
ENTHALPY
SCALE
25
10
SPECIFIC
ENTHALPY
LINES

SPECIFIC VOLUME

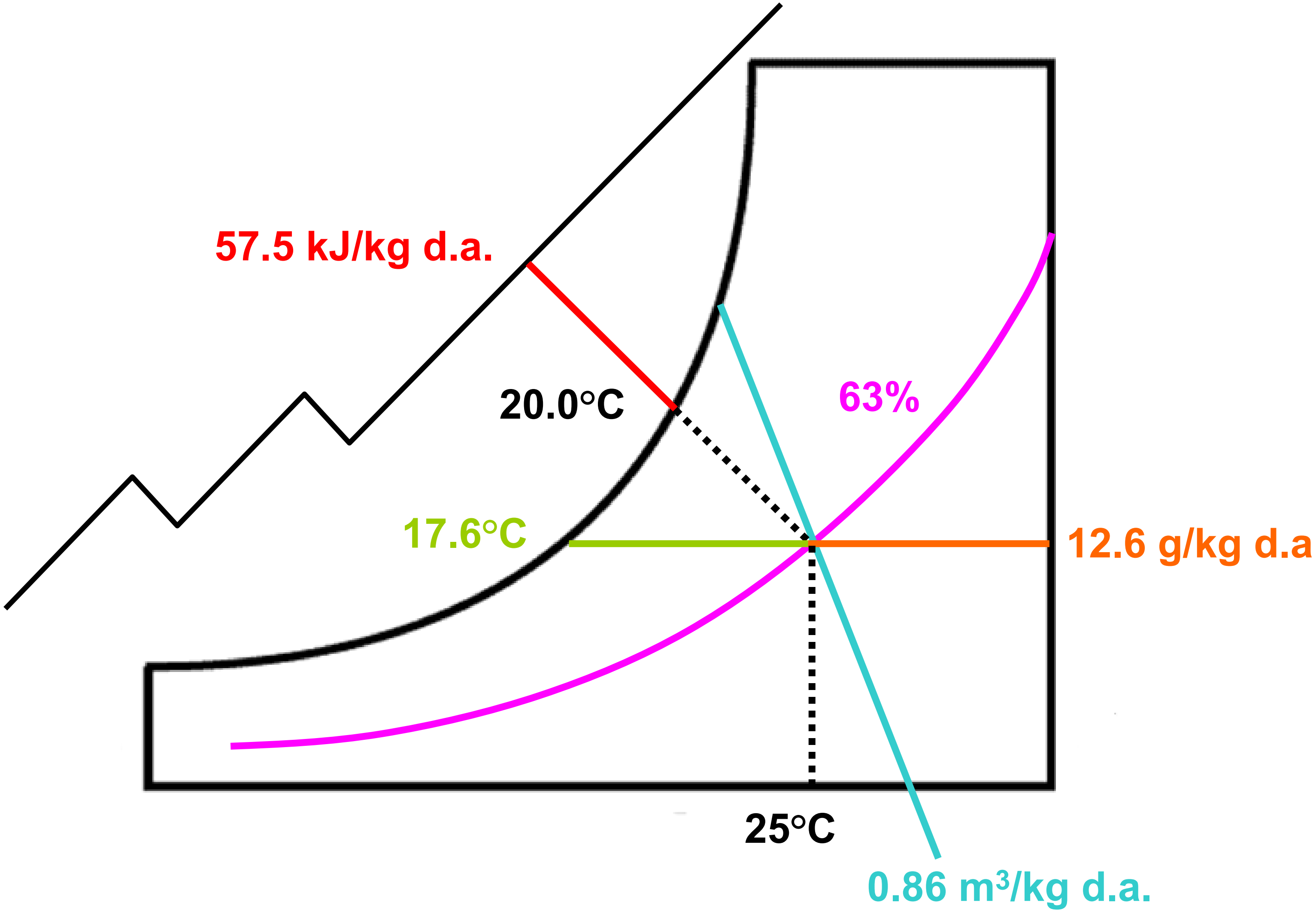


Psychrometric chart: Example 1

Given: $T = 25°C$

$T_w = 20°C$

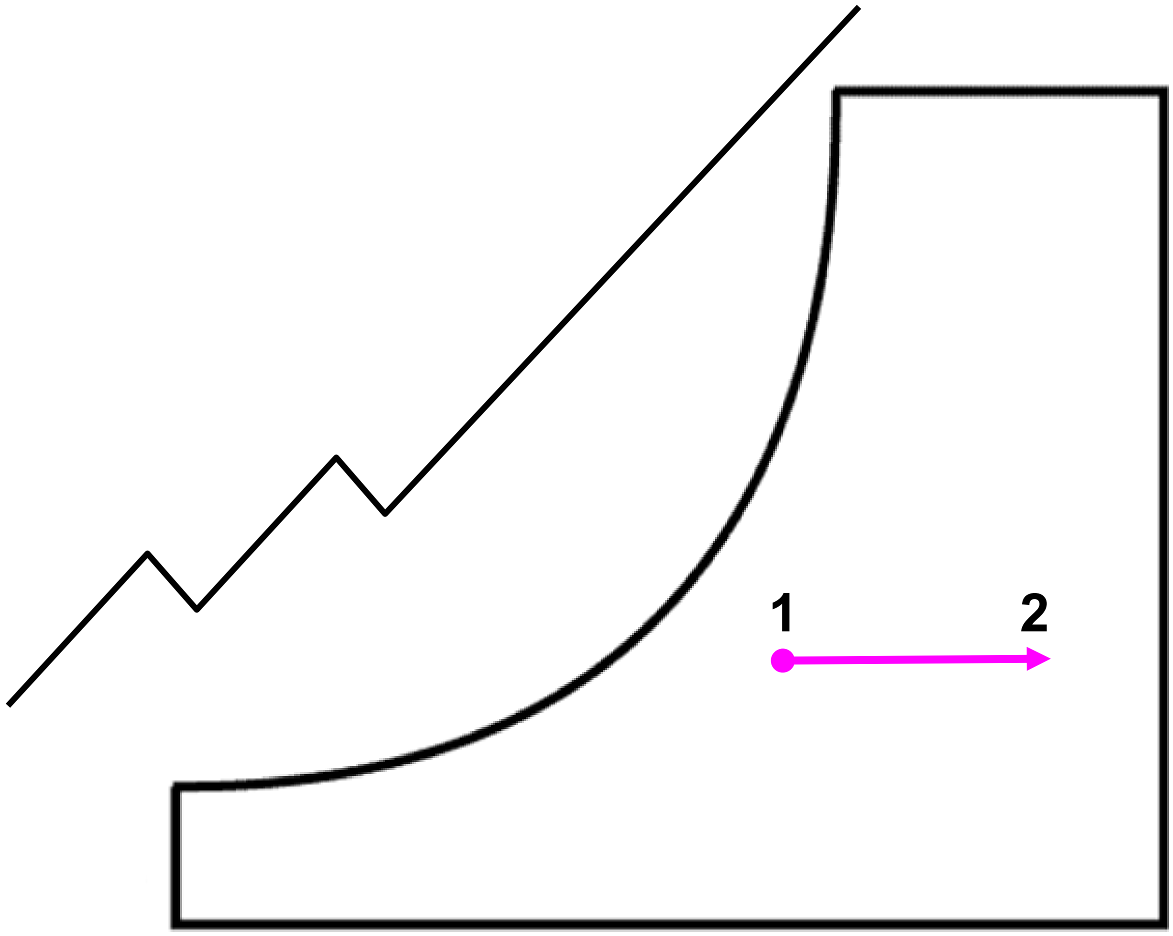
Required: (a) RH, (b) T_{dp}, (c) HR, (d) v, (e) h


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.

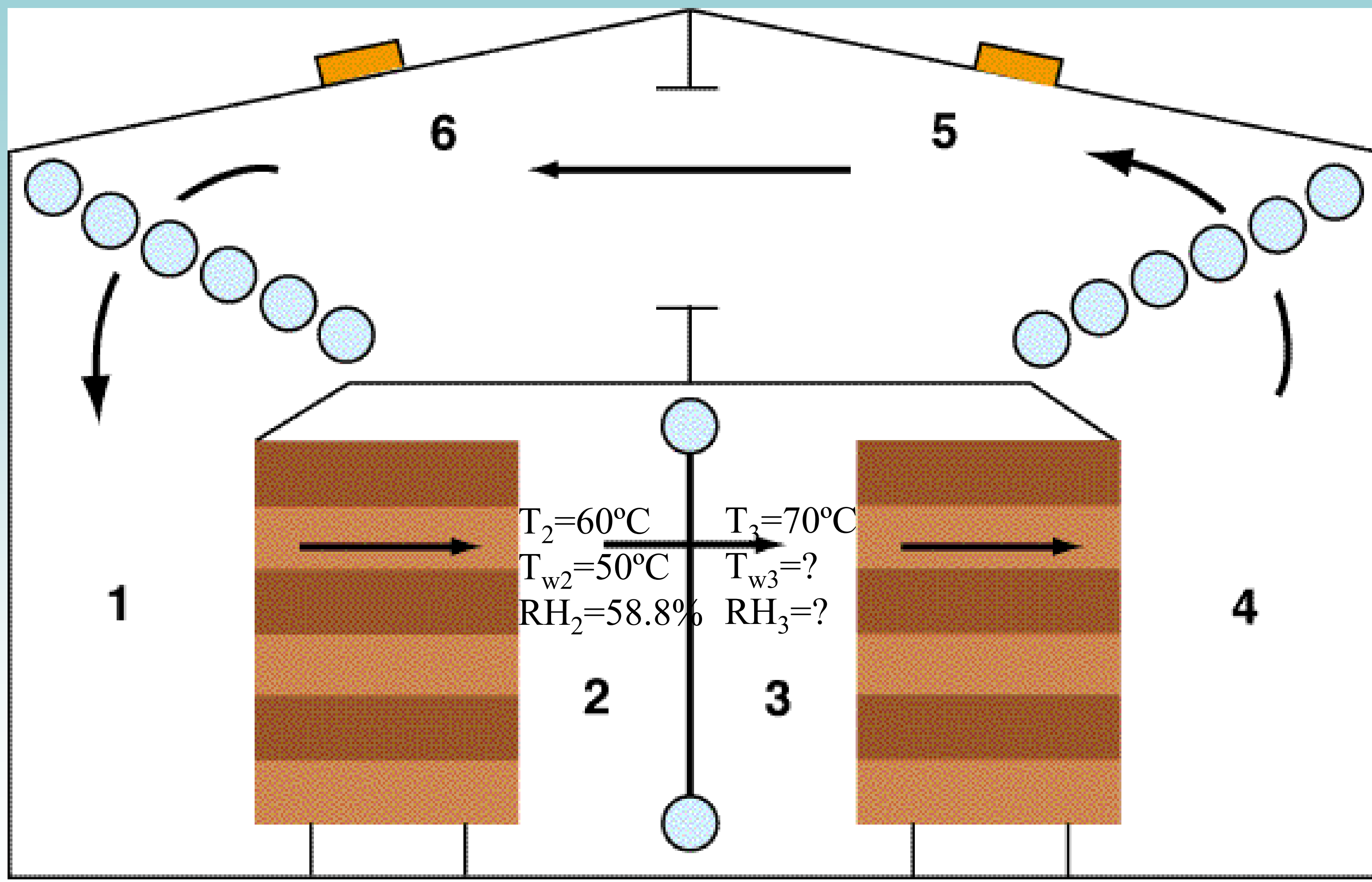
PSYCHROMETRIC PROCESSES

Sensible Heating or Cooling

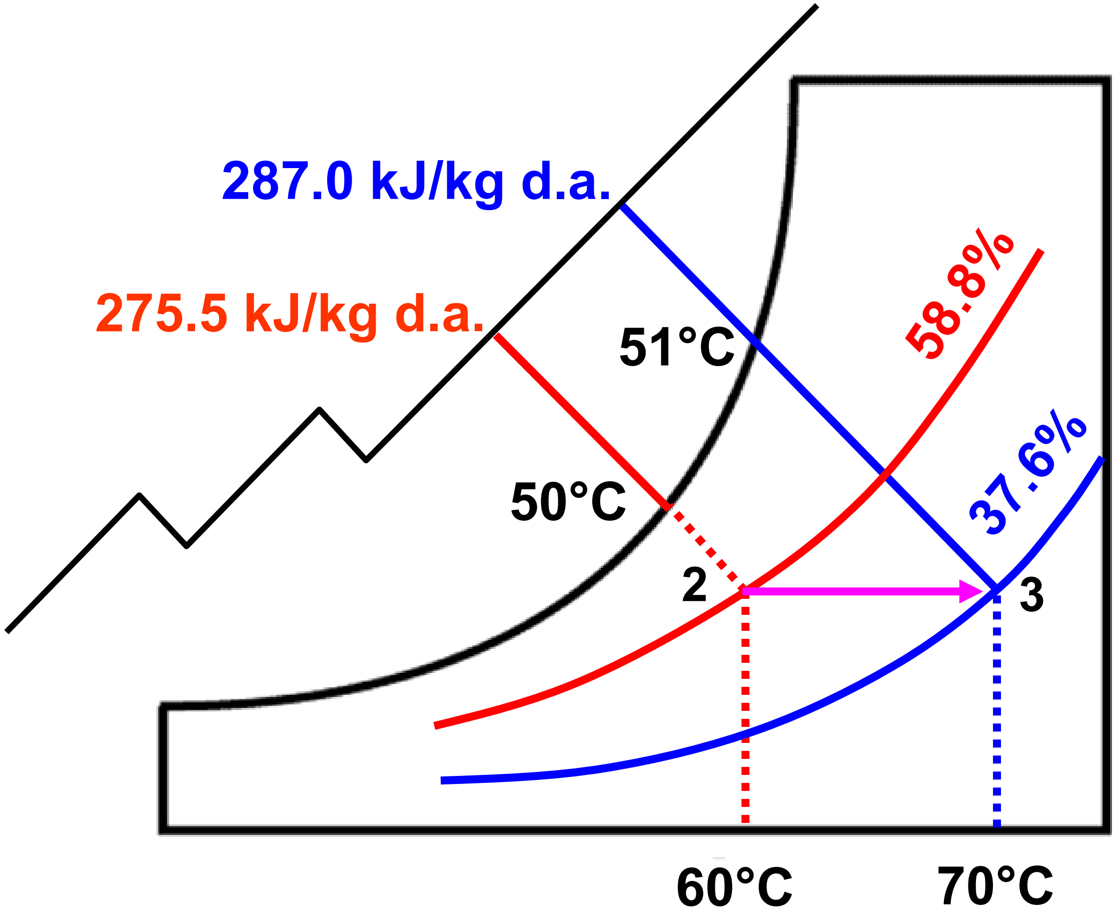
- a psychrometric process that involves the increase or decrease in the temperature of air without changing its humidity ratio
- Example: passing moist air over a room space heater and of kiln air over the heating coils


1
2

Sensible heating: Example 5



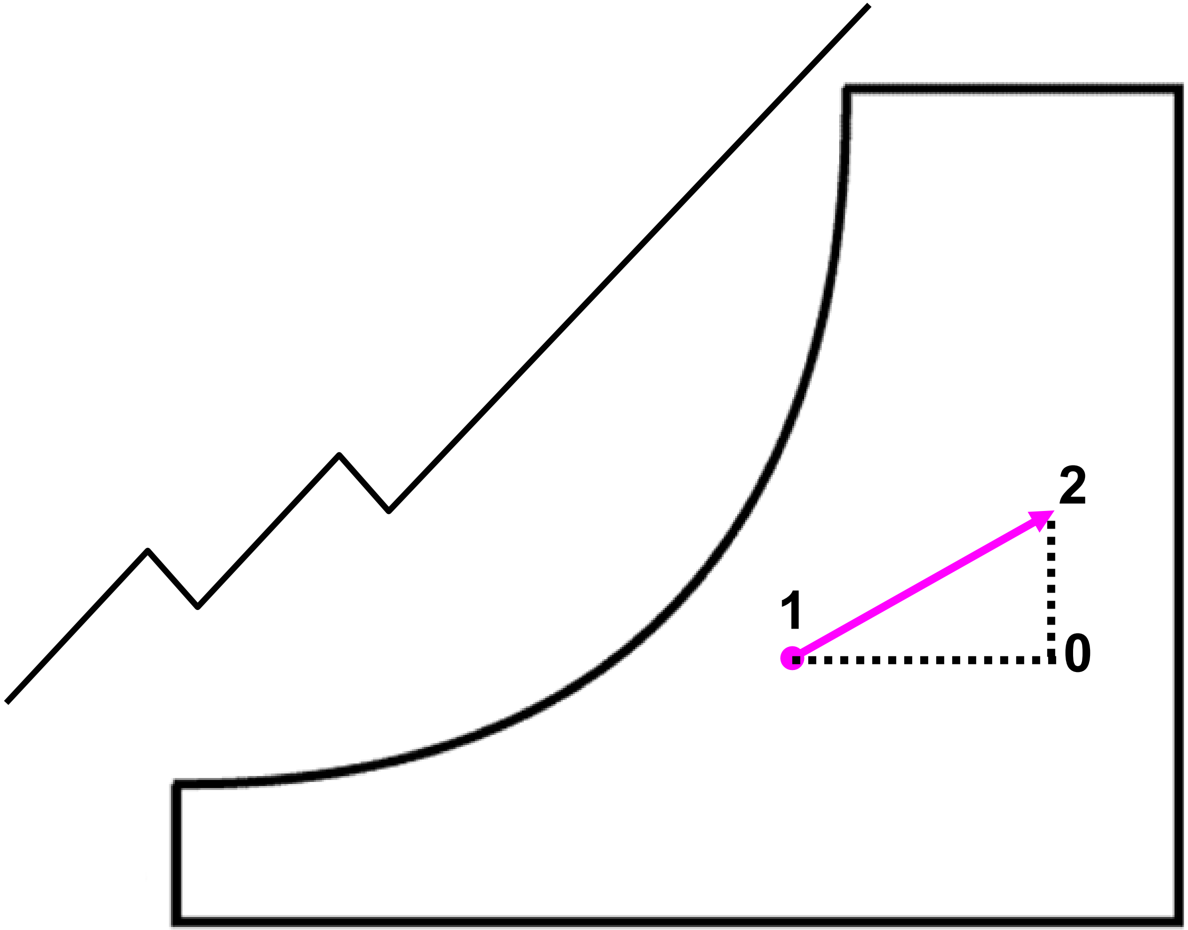
6
5
1
4
2
3
T2=60ºC
Tw2=50ºC
RH2=58.8%
T3=70ºC
Tw3=?
RH3=?



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

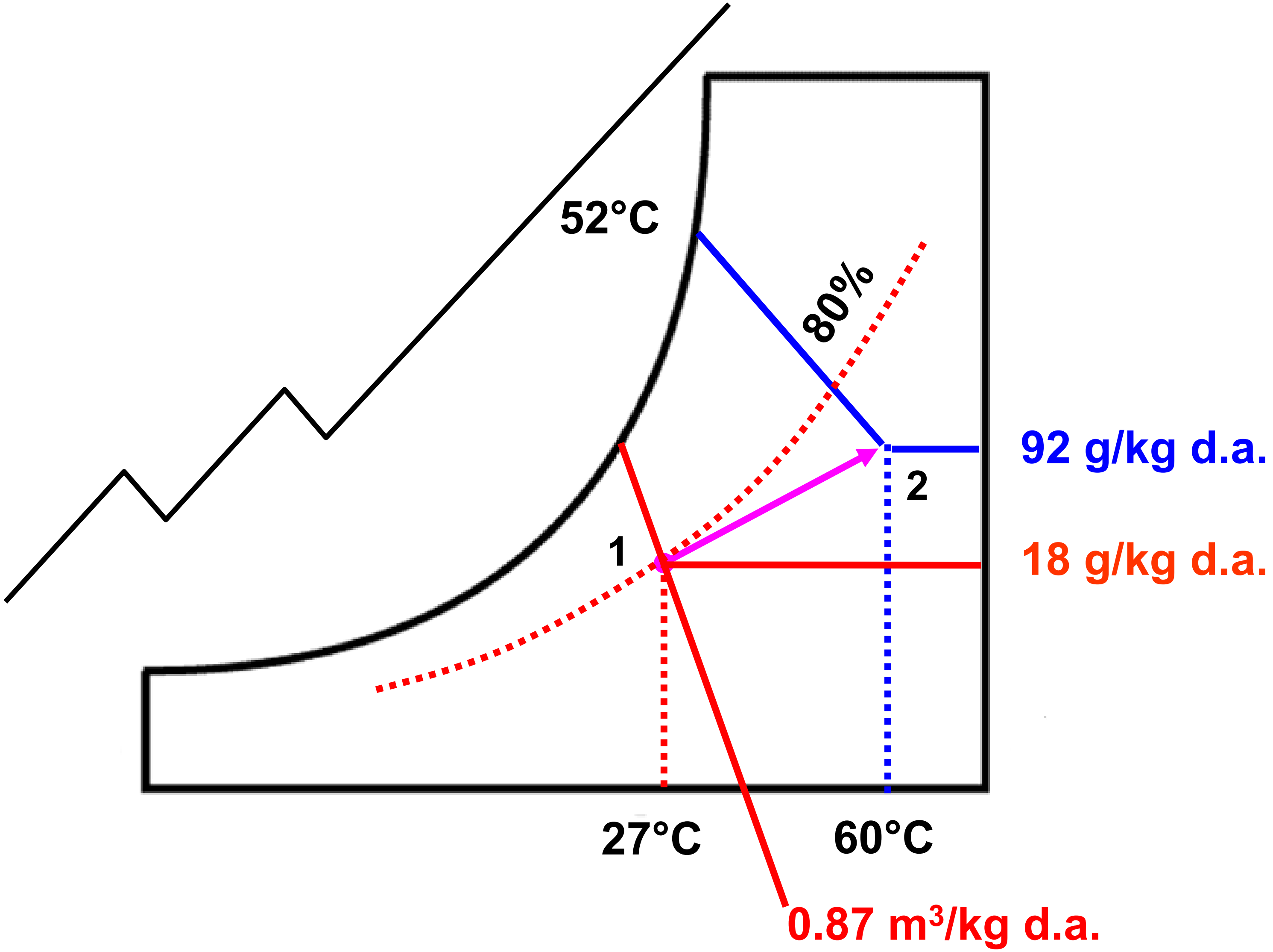
- a psychrometric process that involves the simultaneous increase in both the dry bulb temperature and humidity ratio of the air



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

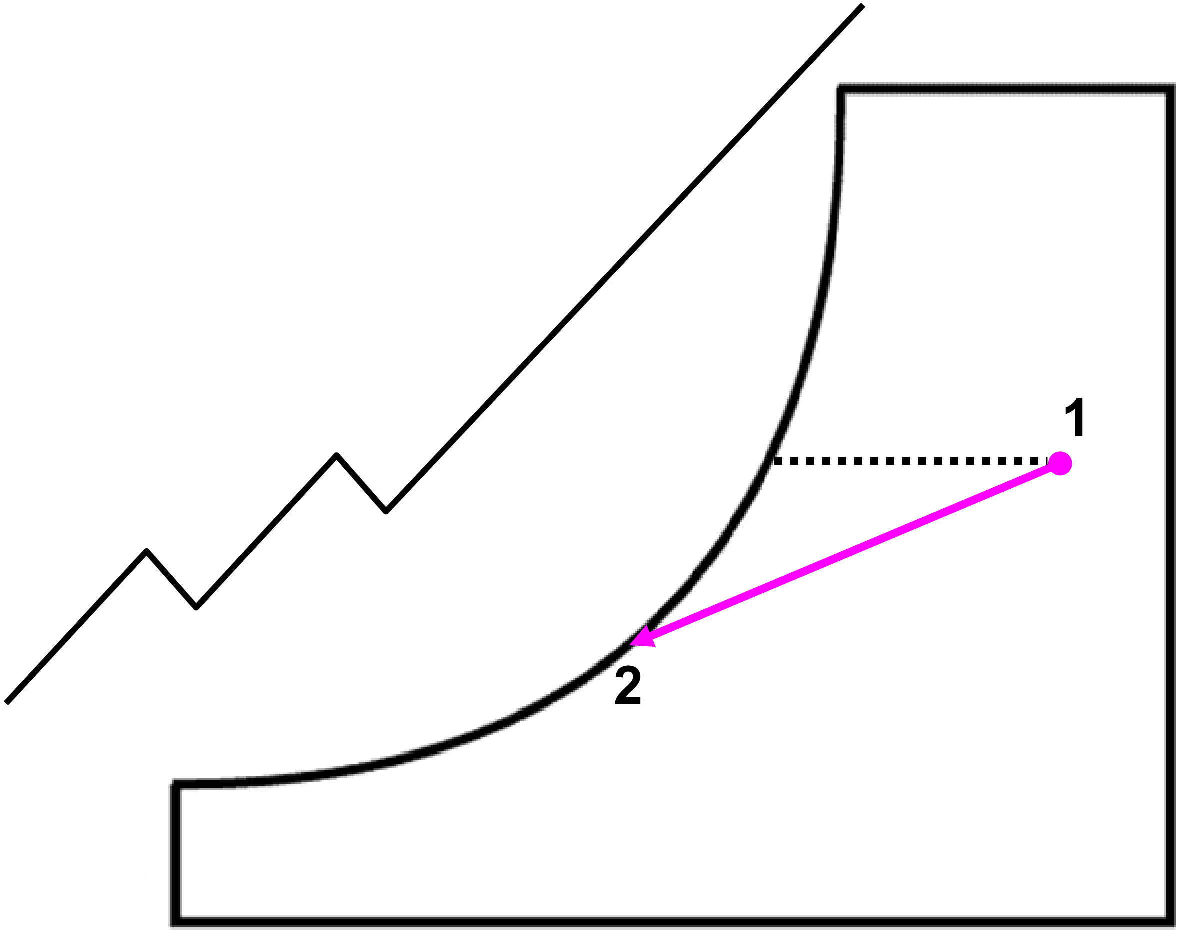
$\Delta HR = (92.0 - 18.0)$ g/kg dry air
$= 74.0$ g/kg dry air

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

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

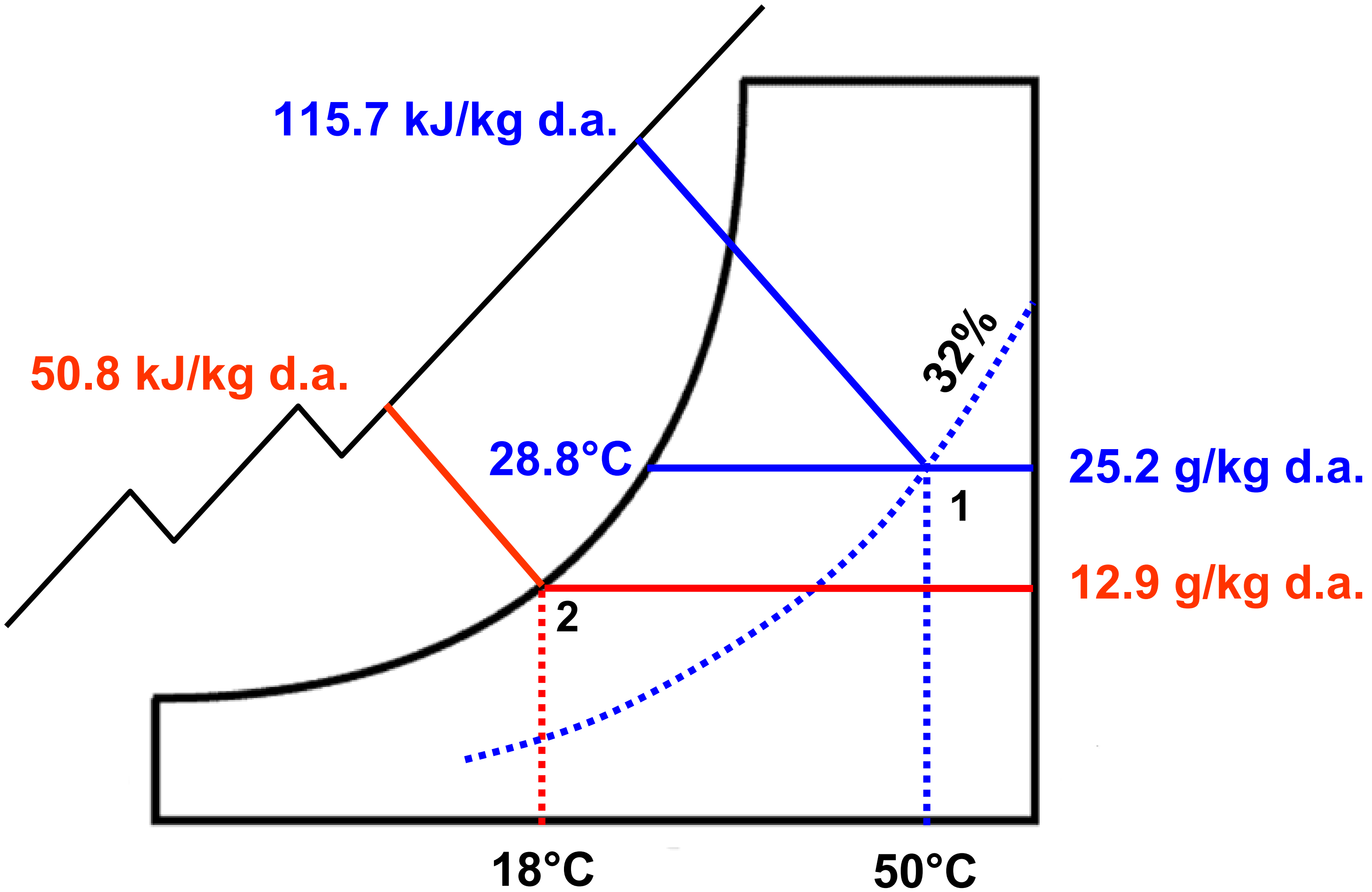
Cooling and Dehumidifying

- 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

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

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

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

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

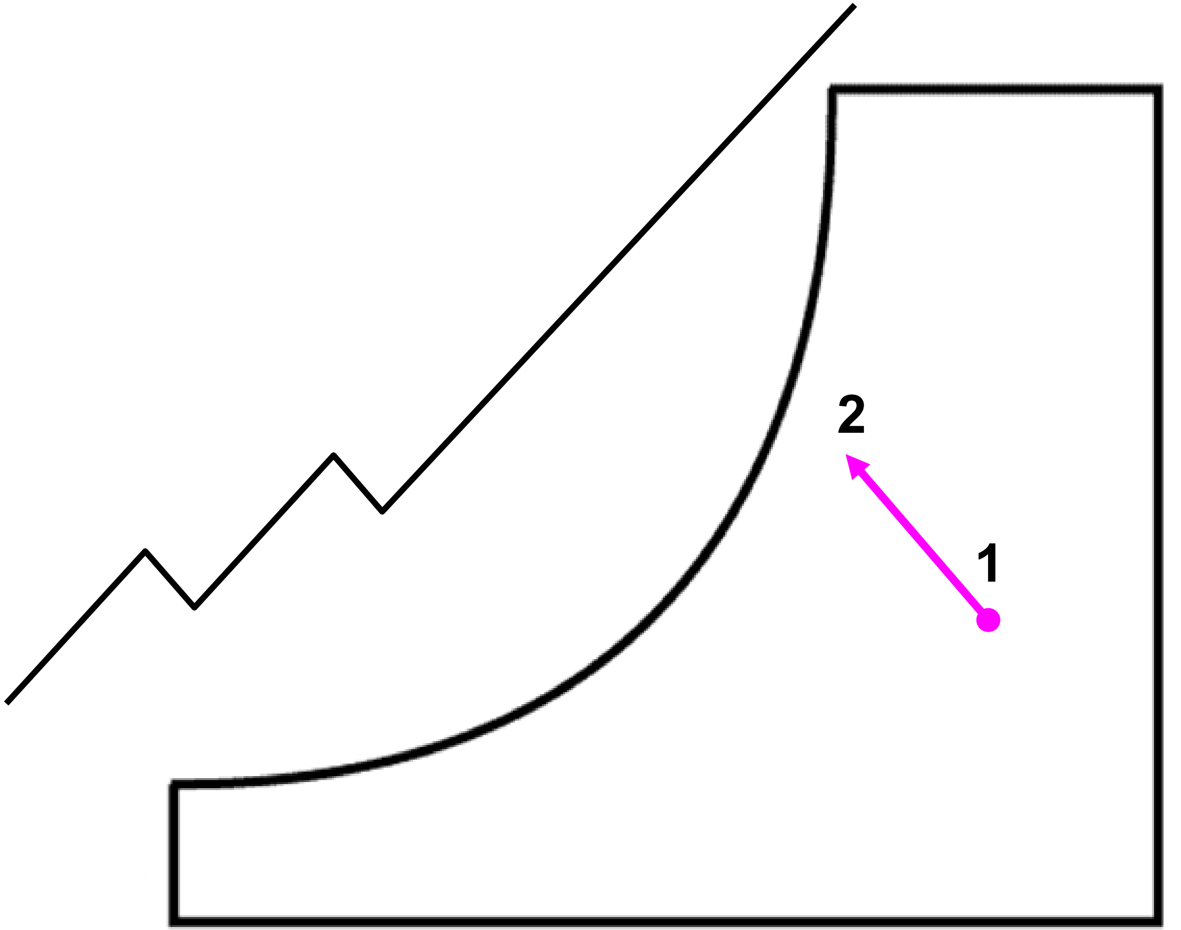
Cooling and dehumidifying: Example 9

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

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

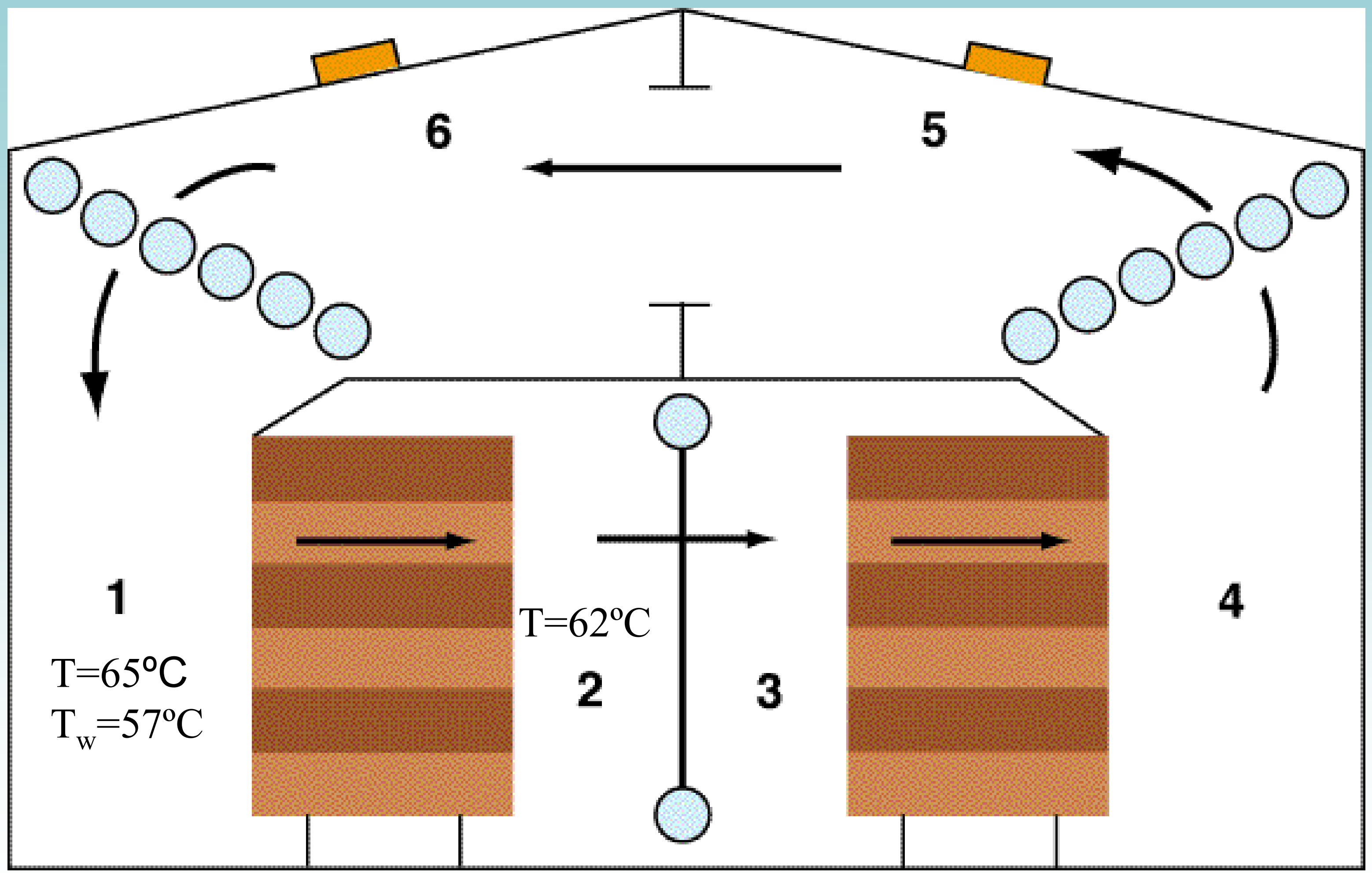
Adiabatic or Evaporative Cooling

- 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

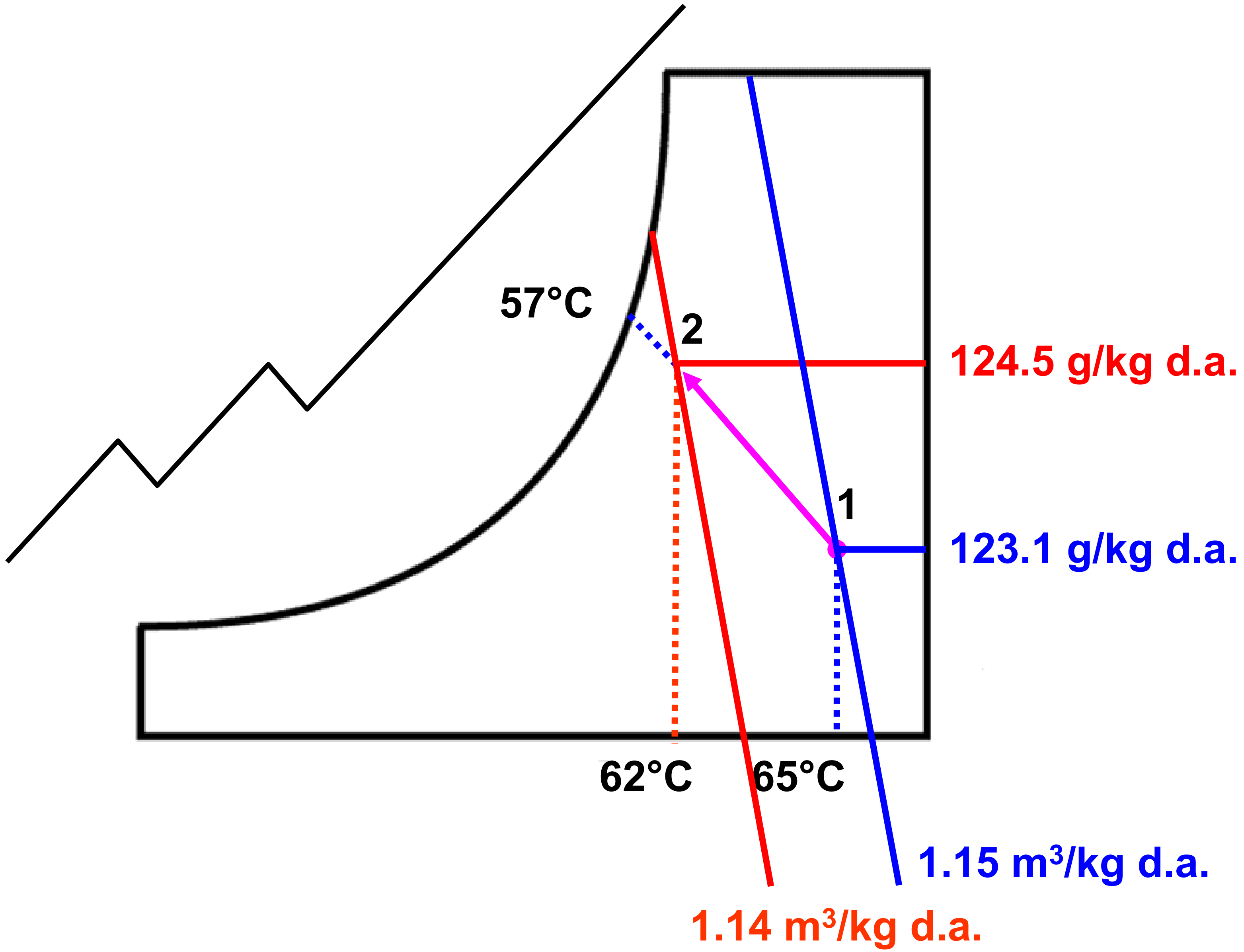
Sticker dimensions: 3.8 cm wide x 1.9 cm thick

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 = $(\Delta HR)(w_a)$

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

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

Evaporative cooling: Example 10

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

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

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

Evaporative cooling: Example 10

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

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

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

Evaporative cooling: Example 10

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

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

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

Evaporative cooling: Example 10

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

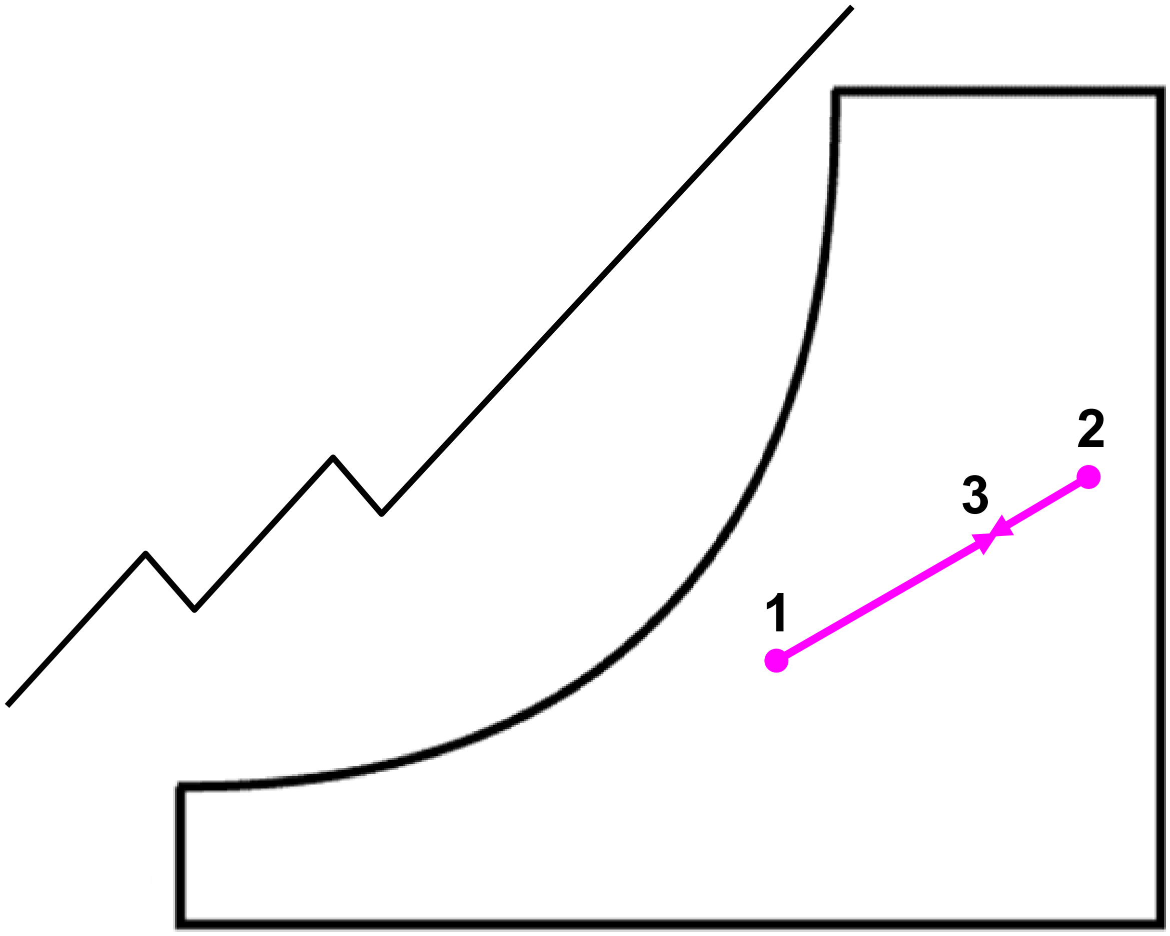
$$\text{Drying rate} = \left(w_a\right)\left(\Delta HR\right)$$

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

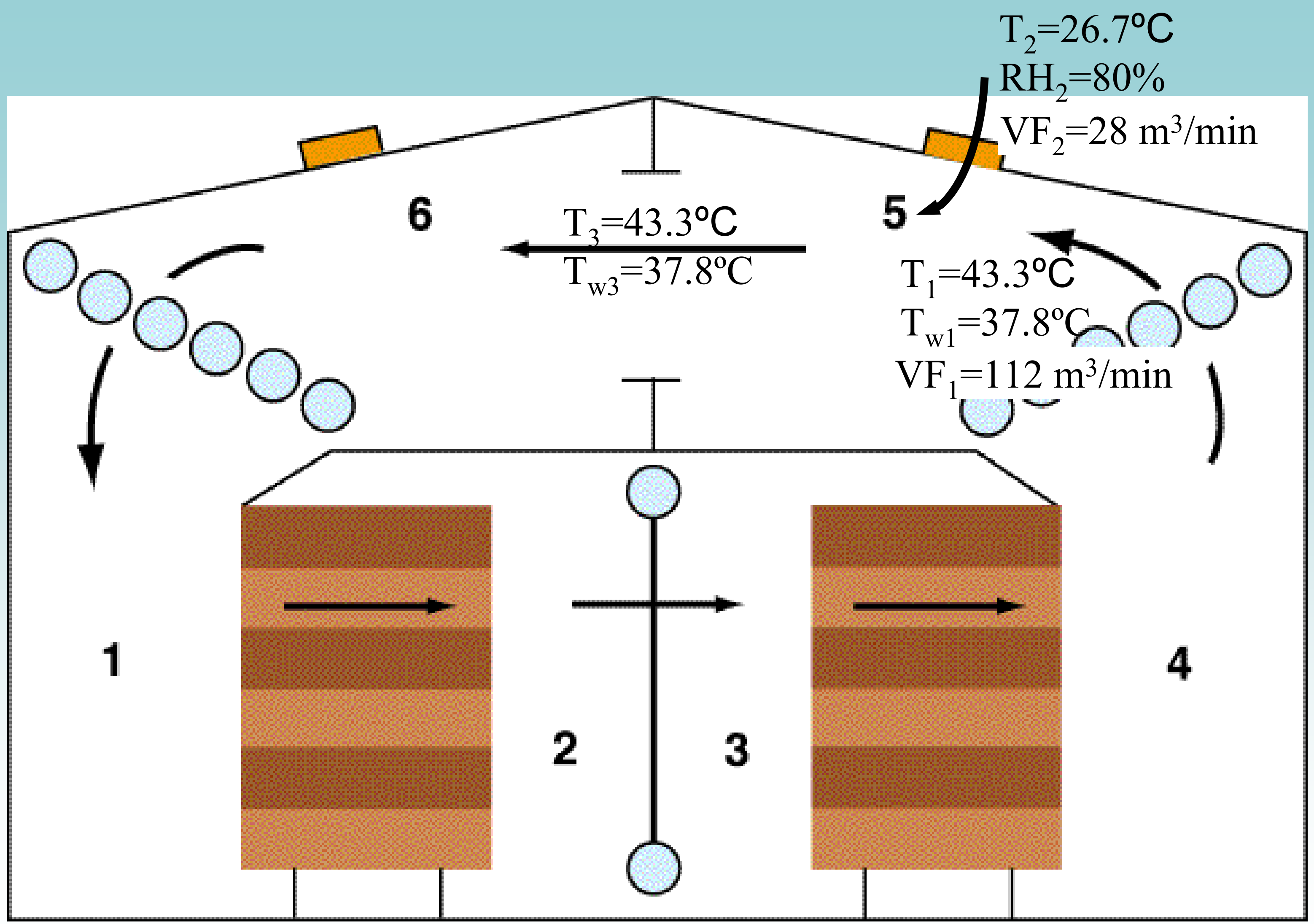
$$= 3.6\frac{\text{g}}{\text{s}} = 13.0\frac{\text{kg}}{\text{h}}$$

Adiabatic Mixing of Moist Air Stream

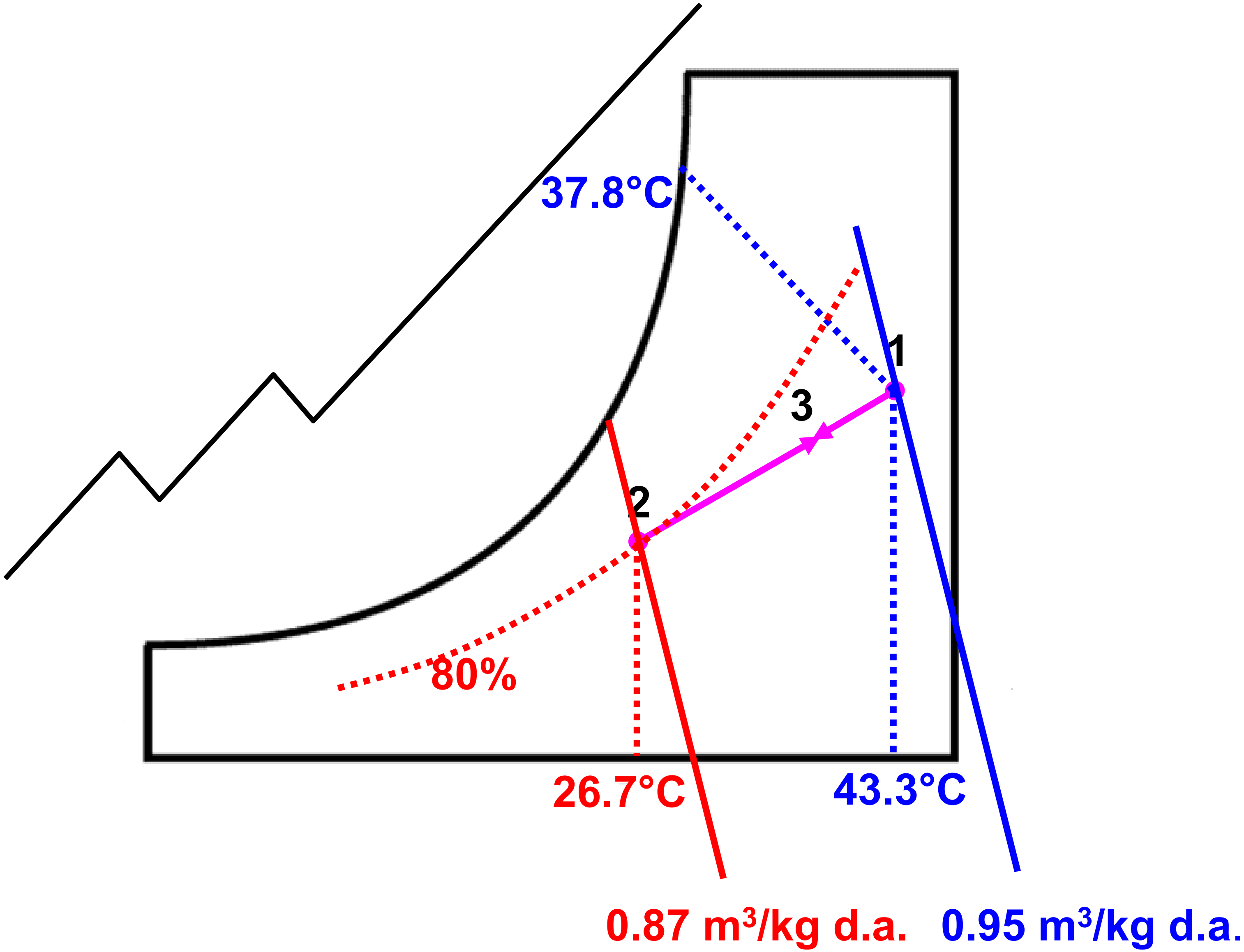
- A psychrometric process that involves no net heat loss or gain during the mixing of two air streams


2
3
1

Adiabatic mixing: Example 11



T_2=26.7ºC
RH_2=80%
VF_2=28 m³/min
6
T_3=43.3ºC
T_{w3}=37.8ºC
5
T_1=43.3ºC
T_{w1}=37.8ºC
VF_1=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

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

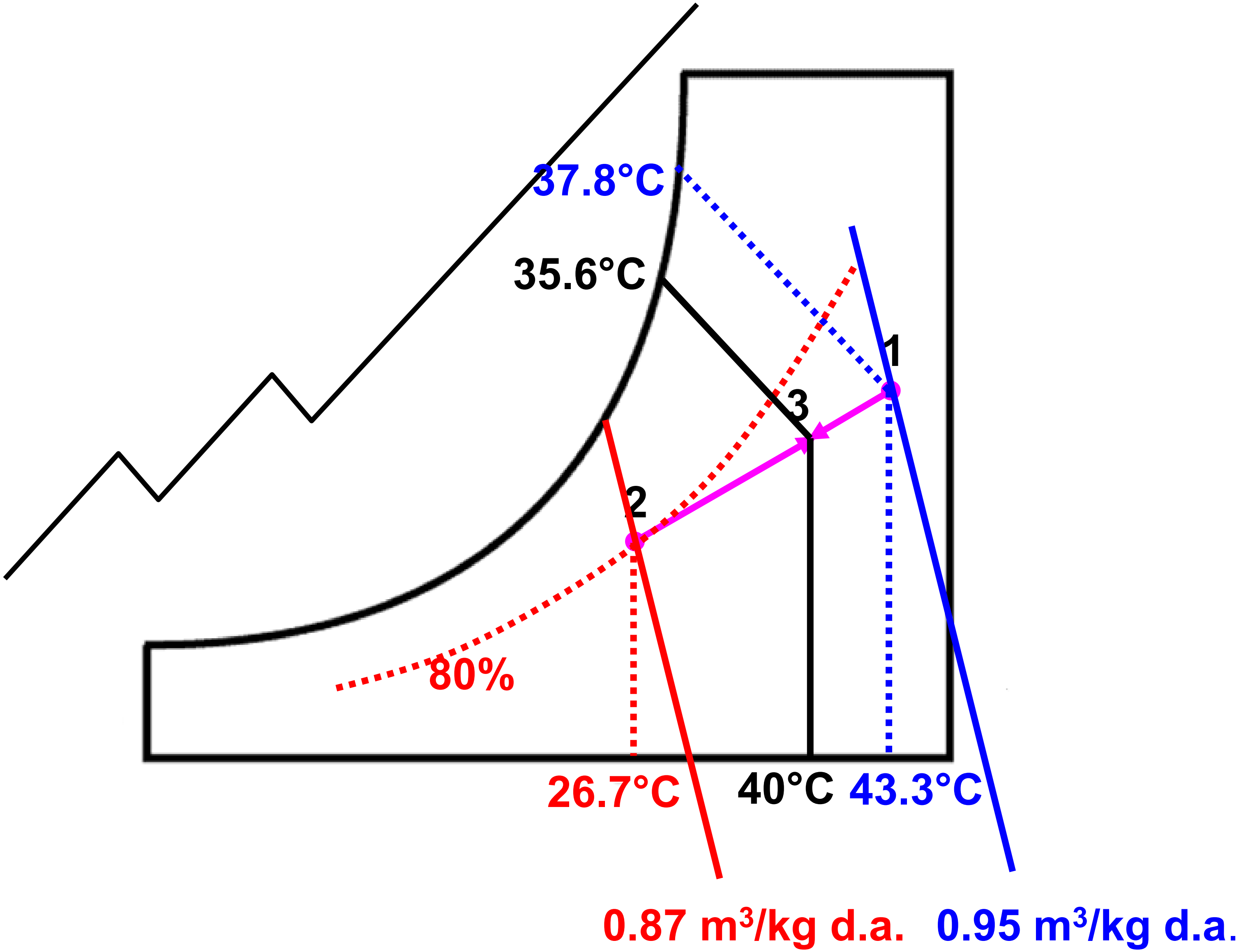
$$w_{a1} = \frac{112\ \dfrac{m^3}{\text{minute}}}{0.95\ \dfrac{m^3}{\text{kg dry air}}} = 117.9\,\frac{\text{kg dry air}}{\text{minute}}$$

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

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

$T_3 = 40.0°C$
$T_{w3} = 35.6°C$