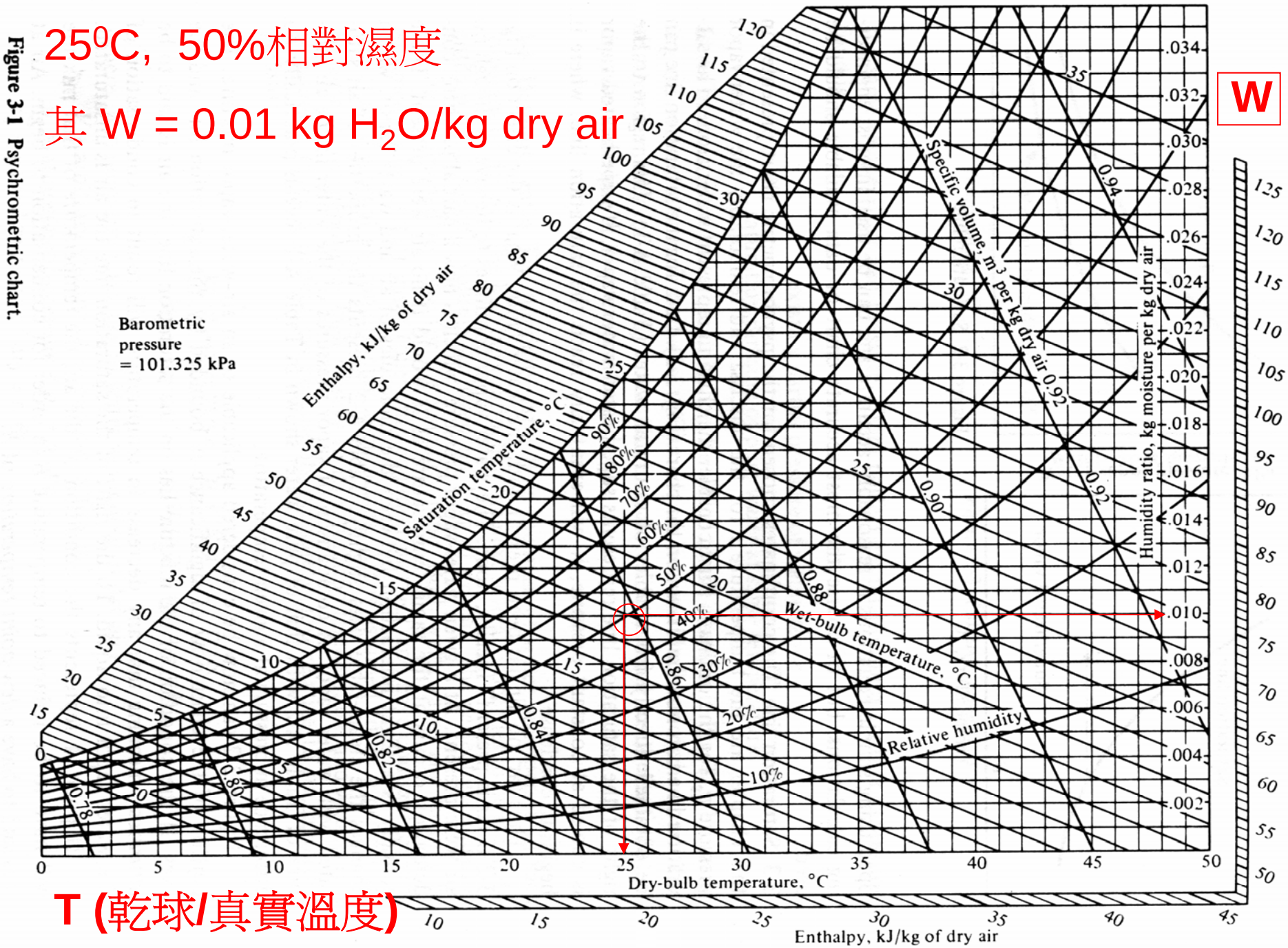
4.
Psychrometric Chart
(濕度線圖)

授課時間: 1 week

Composition of Humid Air (濕空氣)


25⁰C，50%相對濕度
其 W = 0.01 kg H2O/kg dry air
W
T (乾球/真實溫度)
Figure 3-1 Psychrometric chart.
Barometric pressure = 101.325 kPa
Enthalpy, kJ/kg of dry air
Saturation temperature, °C
Specific volume, m³ per kg dry air
Humidity ratio, kg moisture per kg dry air
Wet-bulb temperature, °C
Relative humidity
Dry-bulb temperature, °C
Enthalpy, kJ/kg of dry air

Humidity Ratio(濕度比, W)

■ 濕度比 = **W** = m_s / m_a

= kg of water vapor / kg of dry air

= $(p_s V/R_s T) / (p_a V/R_a T) = (p_s/p_a) / (R_s/R_a)$

= $[p_s/(p_t-p_s)] / (R_s/R_a) = [p_s/(p_t-p_s)] / (M_a/M_s)$

= **$(0.622)\ [p_s/(p_t-p_s)]$**

Note: 假設水蒸氣與乾空氣均爲理想氣體

$pV = (m/M)R_u T = m(R_u/M)T = mRT$

R_u = 8.3143 (J/gmole-K) = 宇宙氣體常數

M_a = 28.97 (g/gmole) = 乾空氣之分子量

M_s = 18.015 (g/gmole) =水蒸氣之分子量

p_t = 海平面濕空氣之總壓 =$p_a + p_s$=101.325 kPa

水蒸氣分壓 (p_s)

$$W = (0.622)\left(\frac{p_s}{p_t - p_s}\right) = (0.622)\left(\frac{p_s}{101.325 - p_s}\right)$$

where p_t = 101.325 kPa = atmospheric pressure

Hence,

$$p_s = \left(\frac{W}{W + 0.622}\right)(p_t) = \left(\frac{W}{W + 0.622}\right)(101.325)$$

在任何一個溫度下，均相對著有一個飽和蒸氣壓(Table A-1)，當空氣中水蒸氣之分壓操過此飽和蒸氣壓時，水蒸氣會由空氣中冷凝為液態水。

Relative Humidity (相對濕度, ϕ)

- 相對濕度 = ϕ
  = 真實之水蒸氣分壓 / 相同溫度下水蒸氣之飽和壓力
  = $\mathbf{p_s / p_{s,sat}}$

  由前面得知: $W = (0.622)\,[p_s / (p_t - p_s)]$

  $W_{sat} = (0.622)\,[p_{s,sat} / (p_t - p_{s,sat})]$

- 相對濕度 = ϕ

  $= [W\,(p_t - p_s)] / [W_{sat}\,(p_t - p_{s,sat})]$

  $\approx (W / W_{sat})$

Note : $p_t >> p_{s,sat}$

Specific Enthalpy of Humid Air (*h*)

$$h = c_p\, t + W\, h_g$$

where h_g = specific enthalpy of saturated water vapor at t

c_p = 1.0 kJ/kg-K dry air

t = dry-bulb temperature (乾球溫度，即真實之氣溫)

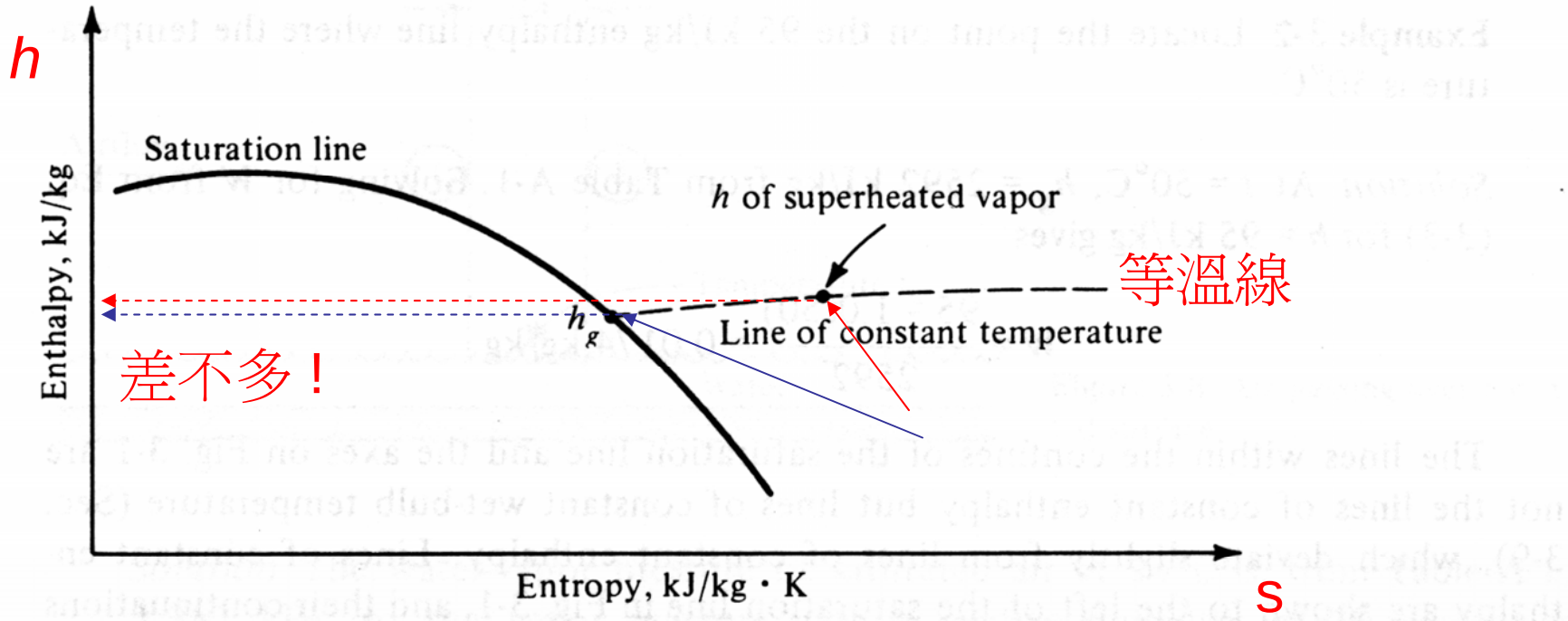
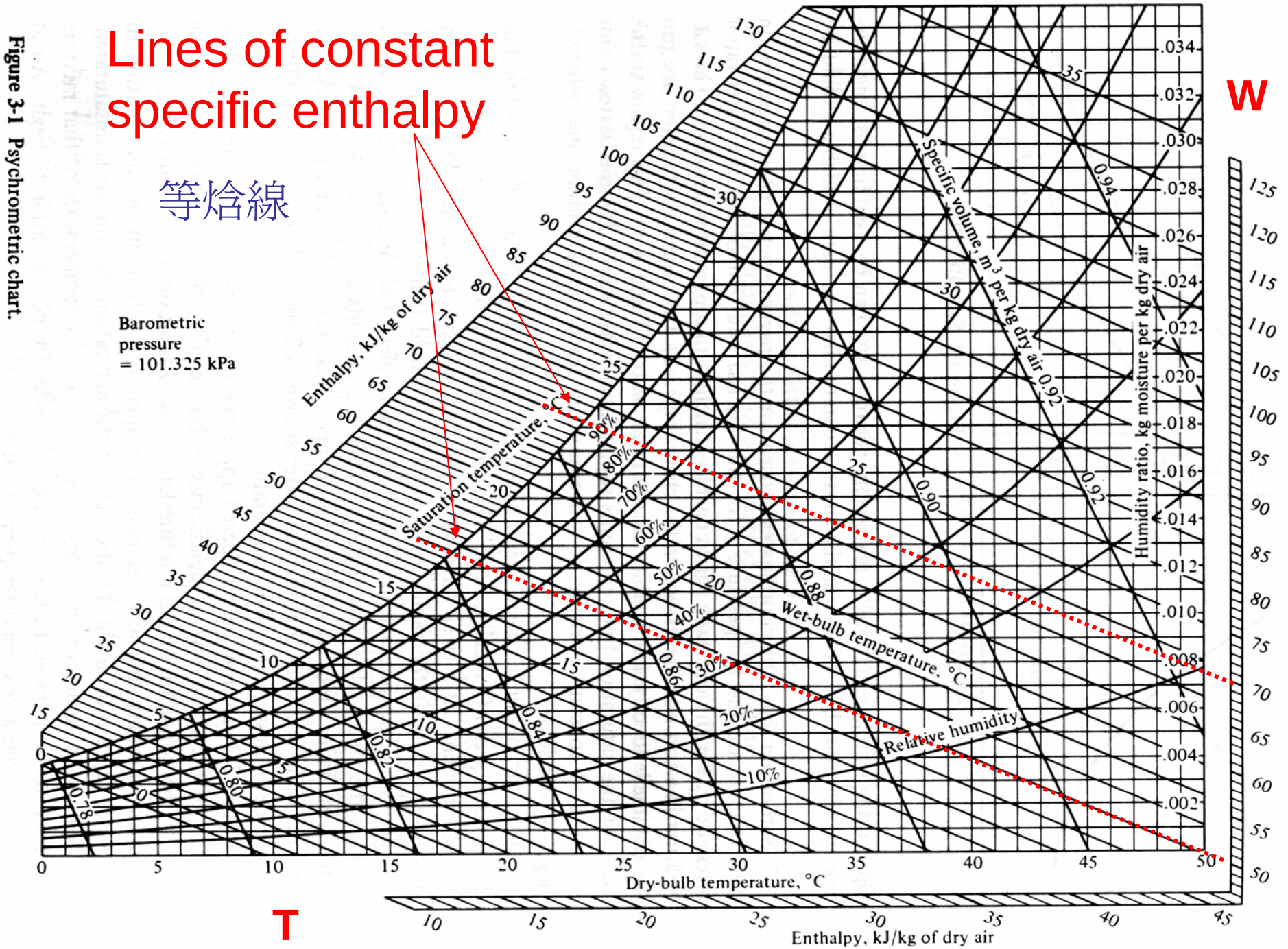


Figure 3-5 Line of constant temperature shows that the enthalpy of superheated water vapor is approximately equal to the enthalpy of saturated vapor at the same temperature.


Lines of constant specific enthalpy
等焓線
W
T
Figure 3-1 Psychrometric chart.
Barometric pressure = 101.325 kPa
Enthalpy, kJ/kg of dry air
Saturation temperature, °C
Specific volume, m³ per kg dry air
Humidity ratio, kg moisture per kg dry air
Wet-bulb temperature, °C
Relative humidity
Dry-bulb temperature, °C
Enthalpy, kJ/kg of dry air

Specific Volume (v)-乾空氣之比容

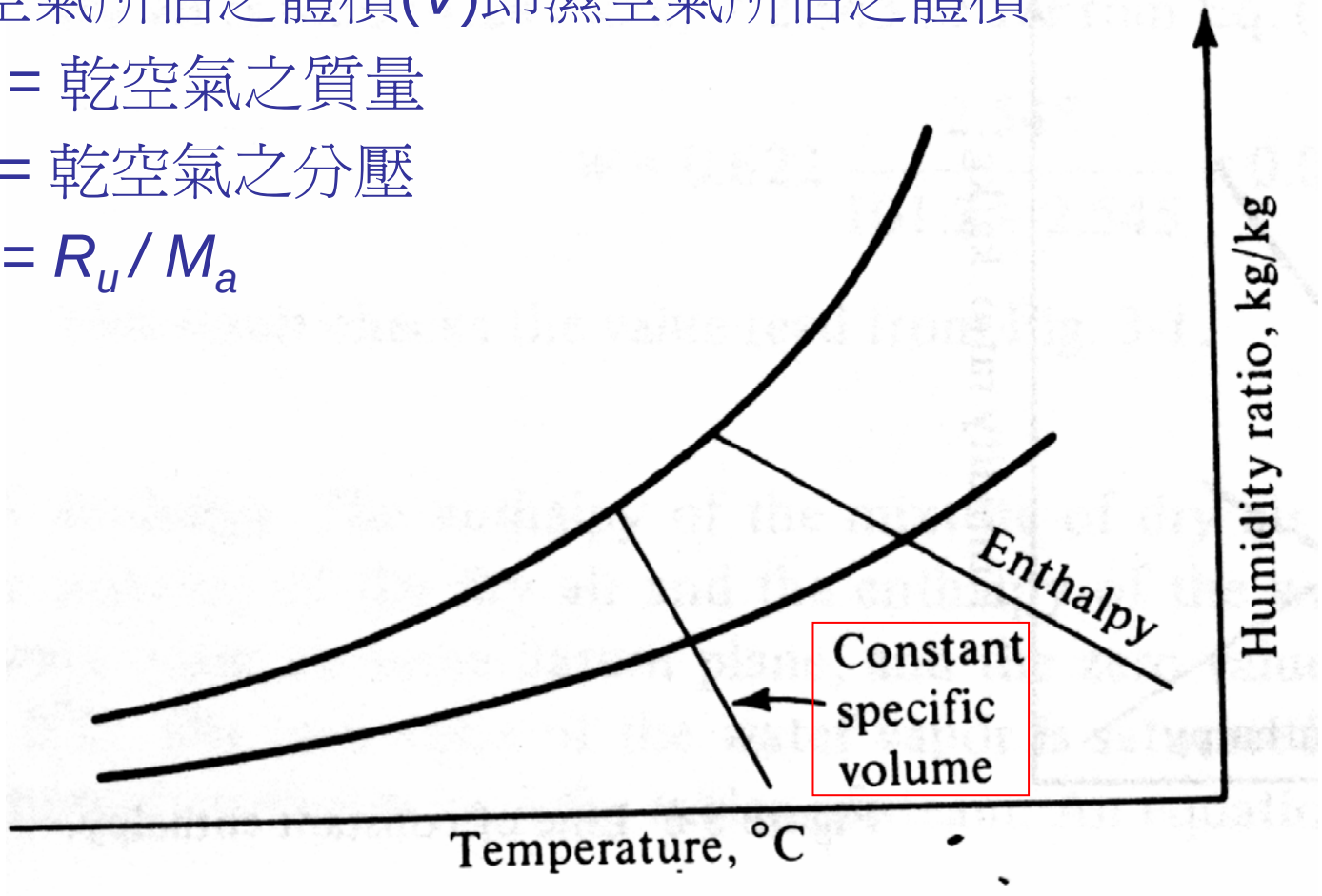
$$v = \frac{V}{m_a} = \frac{R_a T}{p_a} = \frac{R_a T}{p_t - p_s} = \frac{R_a T}{101.325 - p_s}$$

- 乾空氣所佔之體積(V)即濕空氣所佔之體積

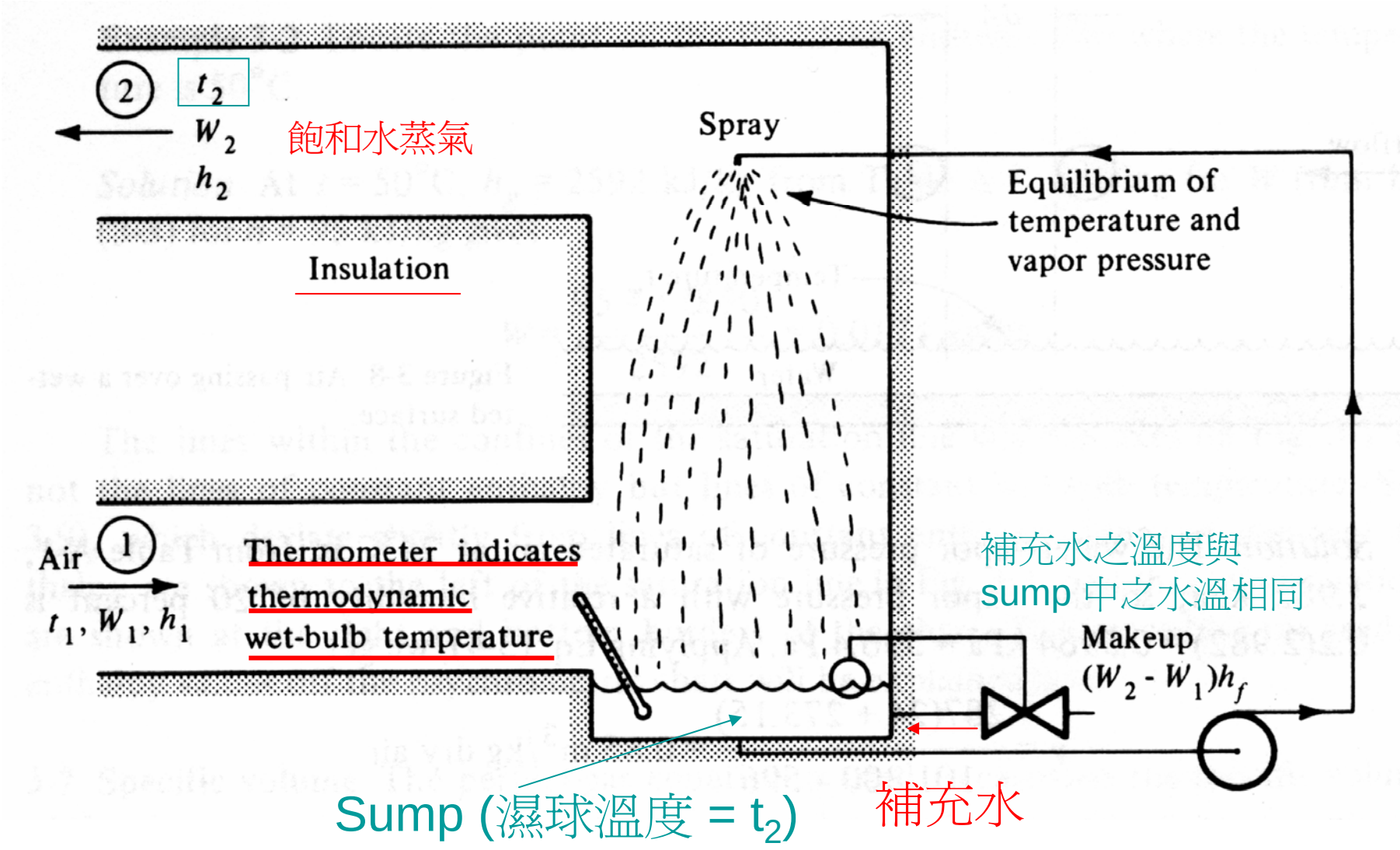
  m_a = 乾空氣之質量

  P_a = 乾空氣之分壓

  $R_a = R_u / M_a$



Wet-Bulb temperature (濕球溫度)



能量平衡 (Based on 每公斤之空氣):

$$h_2 = h_1 + h_f(W_2 - W_1)$$

或

$$h_f(t_2) = (h_2 - h_1) / (W_2 - W_1)$$

其中　h_f 爲濕球溫度(t_2)相對之飽和水之焓值

(t_2 : state "1" 濕空氣相對之濕球溫度）

■決定Psychrometric Chart 上 之等濕球溫度線

能量平衡 (Based on 每公斤之空氣):

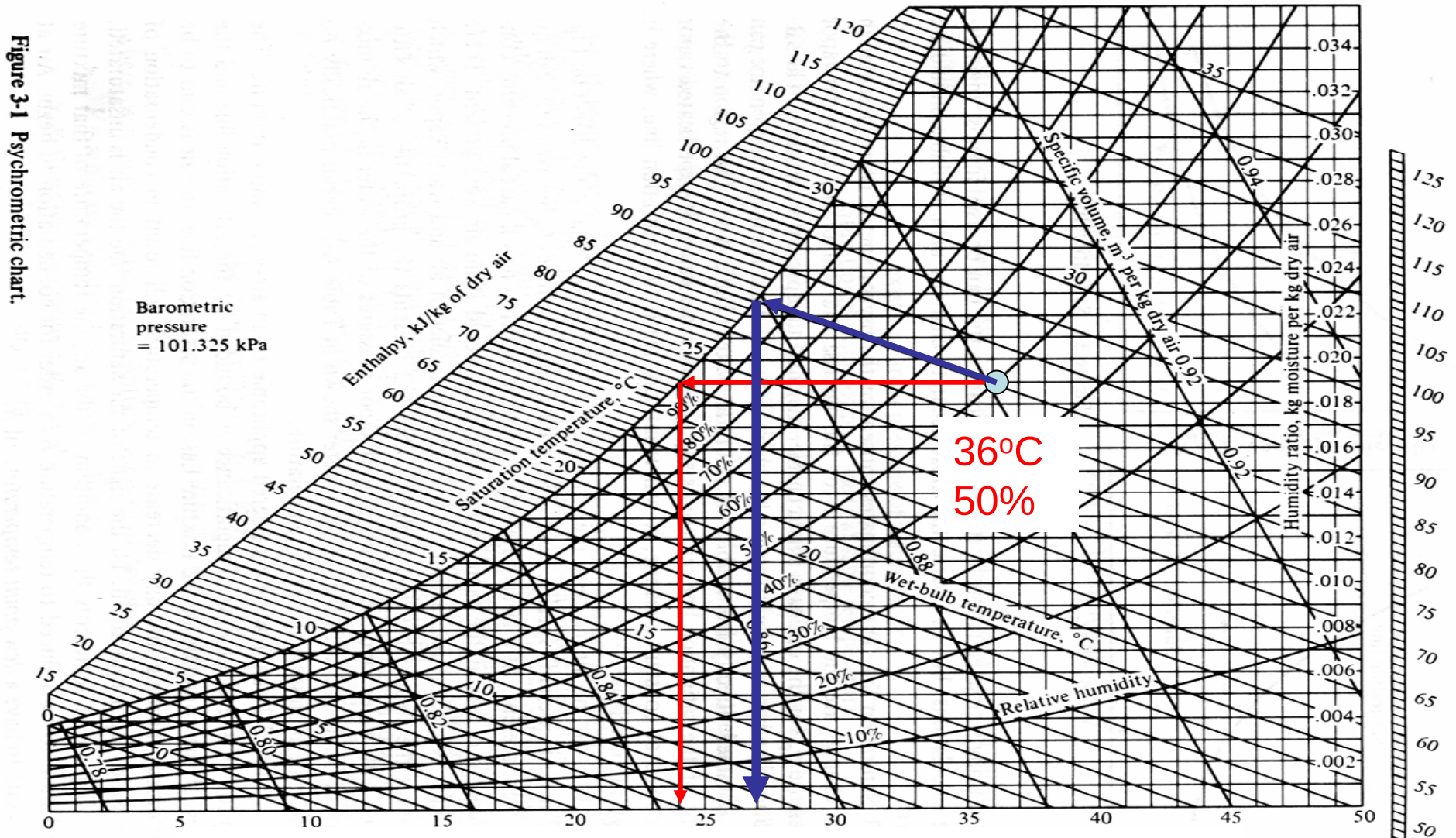
$$h_f(t_2) = (h_{2,sat} - h_1) / (W_{2,sat} - W_1)$$

其中　h_f 爲濕球溫度(t_2)相對之飽和水之焓值
(t_2 : state "1" 濕空氣相對之濕球溫度）

Note:

針對飽和線上之一點(溫度 t_2)，連結所有符合上式之 h_1 與 W_1 所相對之點，可於 Psychrometric Chart 上獲得一條等濕球溫度線

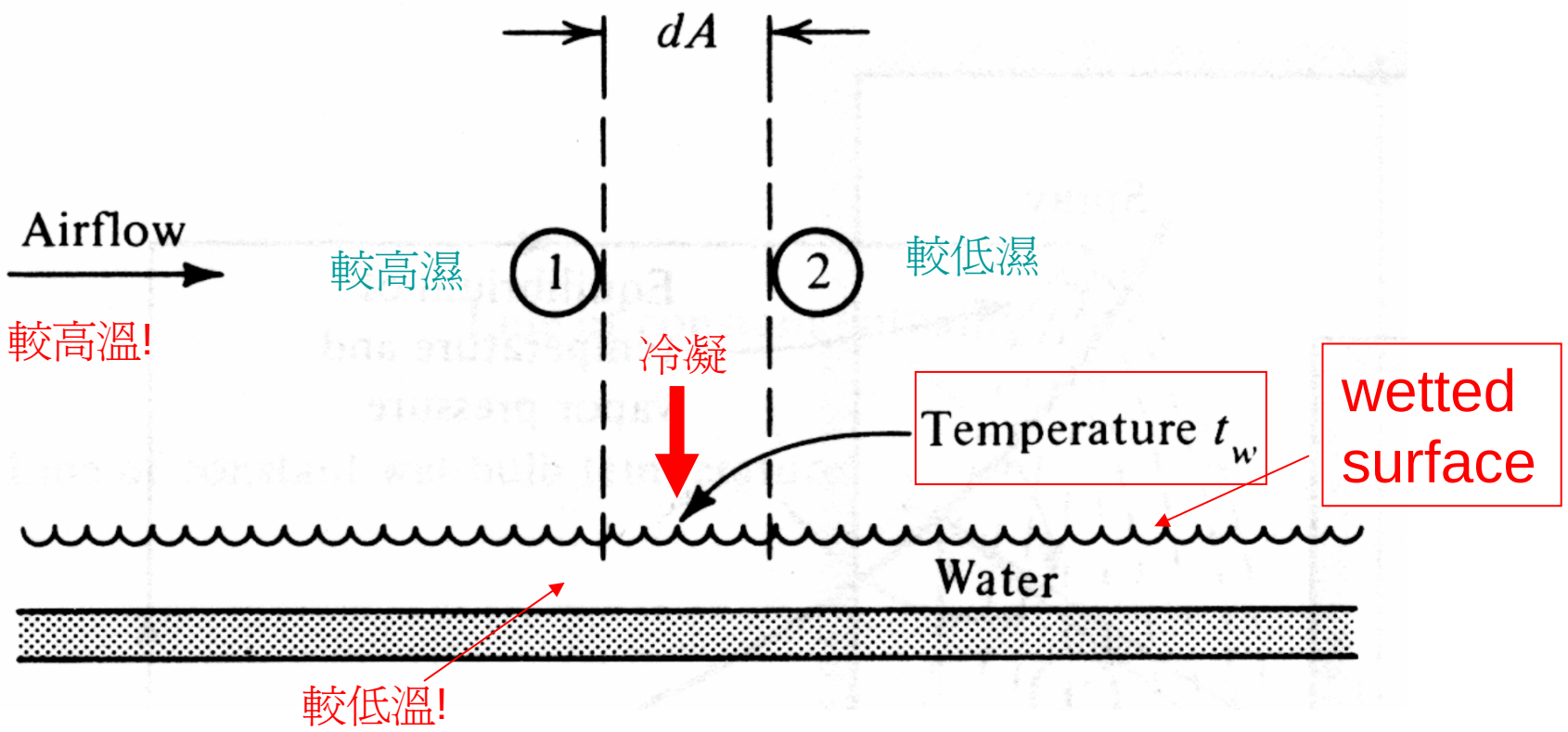
濕球溫度(Wet-Bulb Temperature)與露點溫度(Dew-Point Temperature)兩者不同



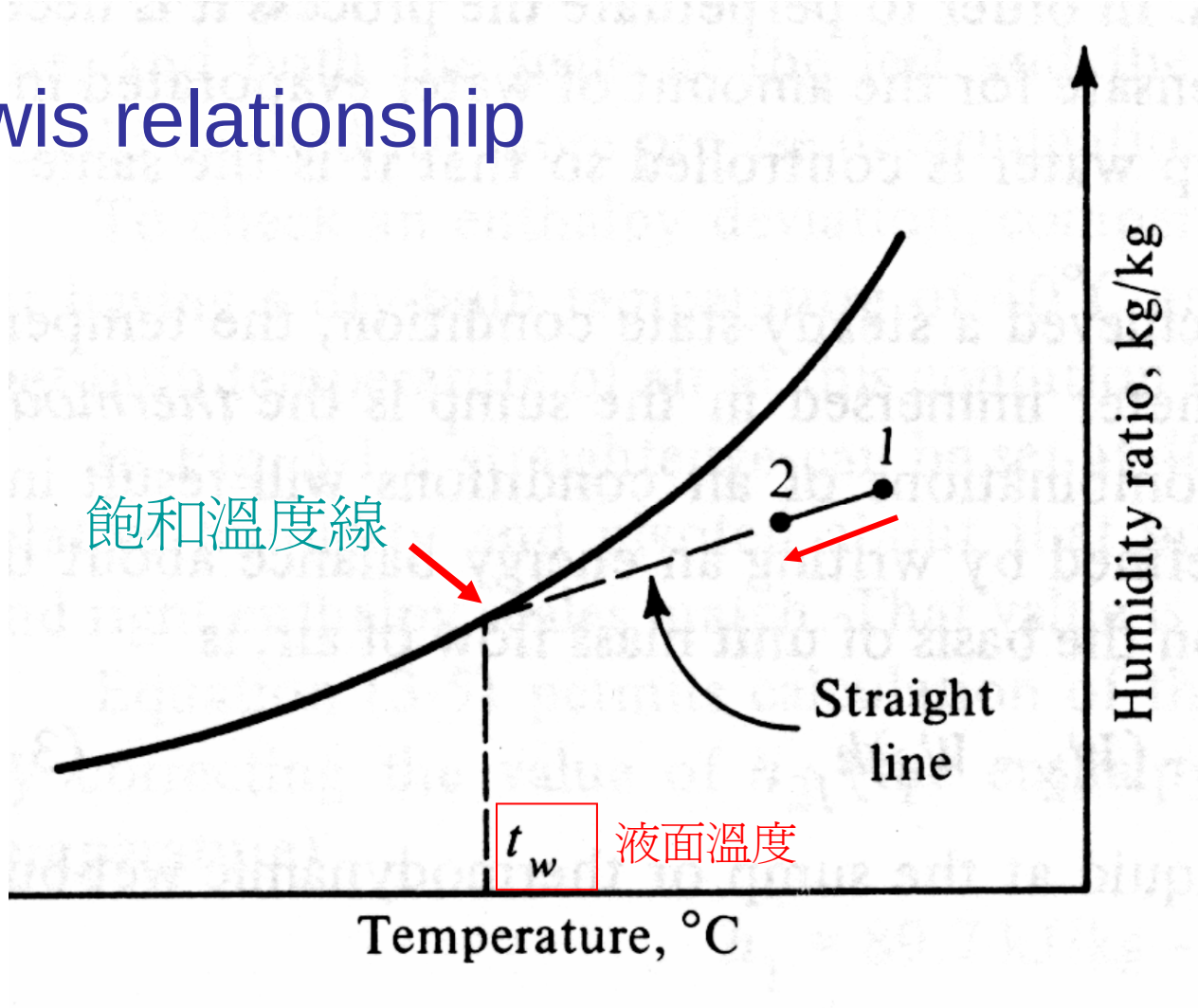
相對之露點溫度=24°C　相對之濕球溫度=27°C

Straight-Line Law – 直線定律

When air is transferring heat and mass (water) to or from a wetted surface, the condition of the air shown on a psy-chrometric chart drives toward the saturation line at the temperature of the wetted surface.



Lewis relationship



Note: 若通過之距離相當長，最終濕空氣之溫度與液面相同，同時濕度亦達到飽合之狀態

Wet-Bulb Thermometer (濕球溫度計)

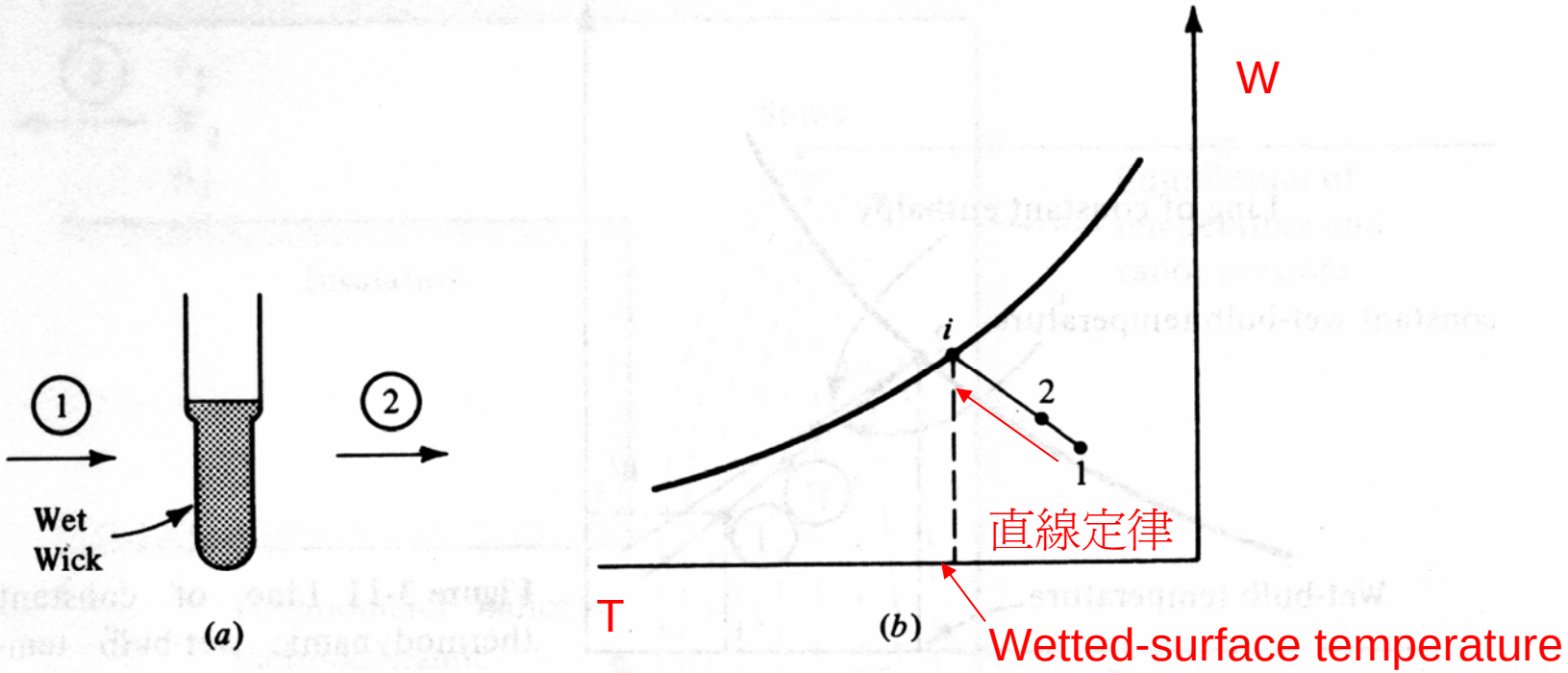


Figure 3-12 (a) The wet-bulb temperature, and (b) the process on a psychrometric chart.

能量平衡: $h_2 = h_1 + h_f(W_2 - W_1)$

上式符合 wet-bulb temperature 之公式 !

wetted-surface temperature 亦即 wet-bulb temperature !

乾球溫度計

濕球溫度計

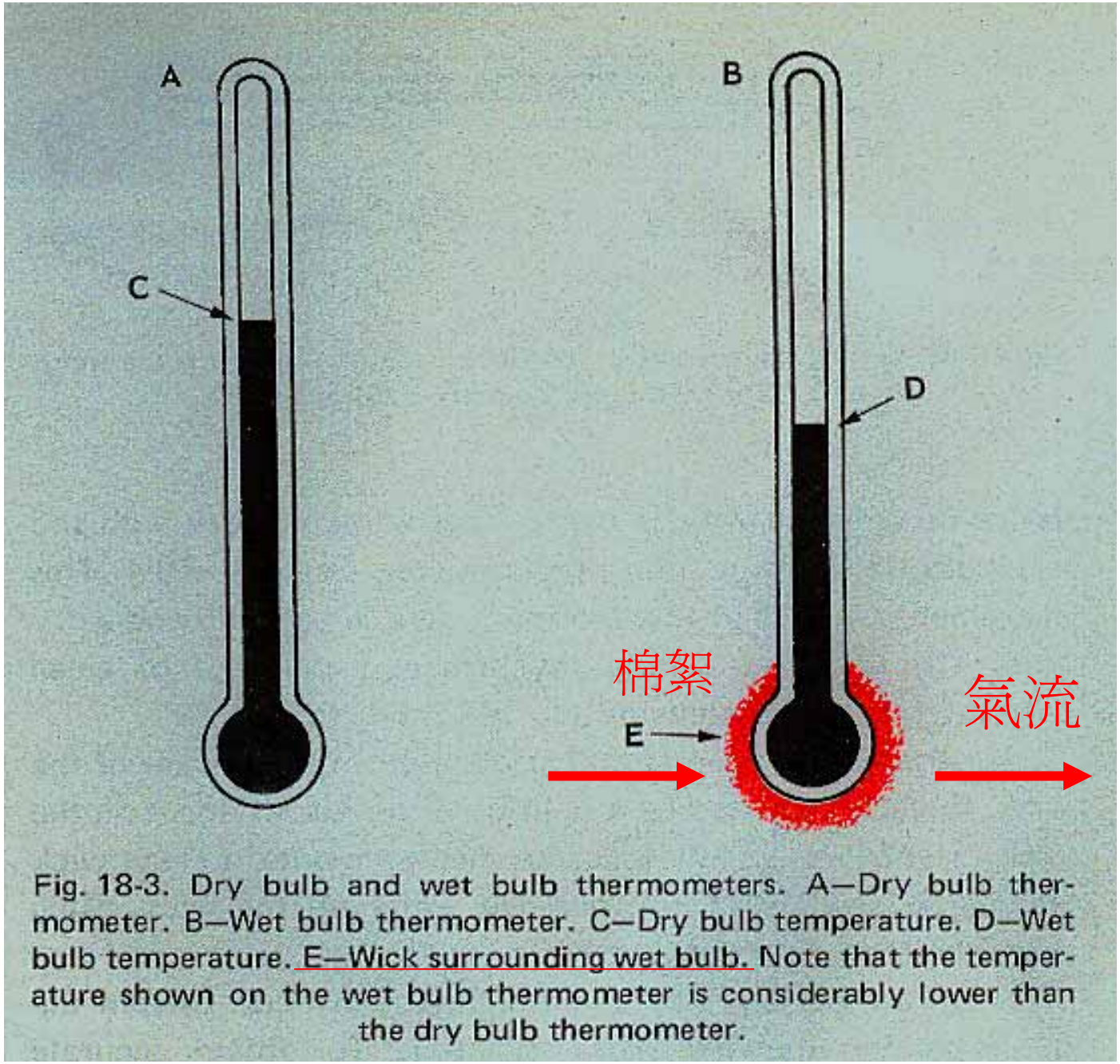


Fig. 18-3. Dry bulb and wet bulb thermometers. A—Dry bulb thermometer. B—Wet bulb thermometer. C—Dry bulb temperature. D—Wet bulb temperature. E—Wick surrounding wet bulb. Note that the temperature shown on the wet bulb thermometer is considerably lower than the dry bulb thermometer.

並非達到飽和

“等焓線”與”等濕球溫度線”之差異

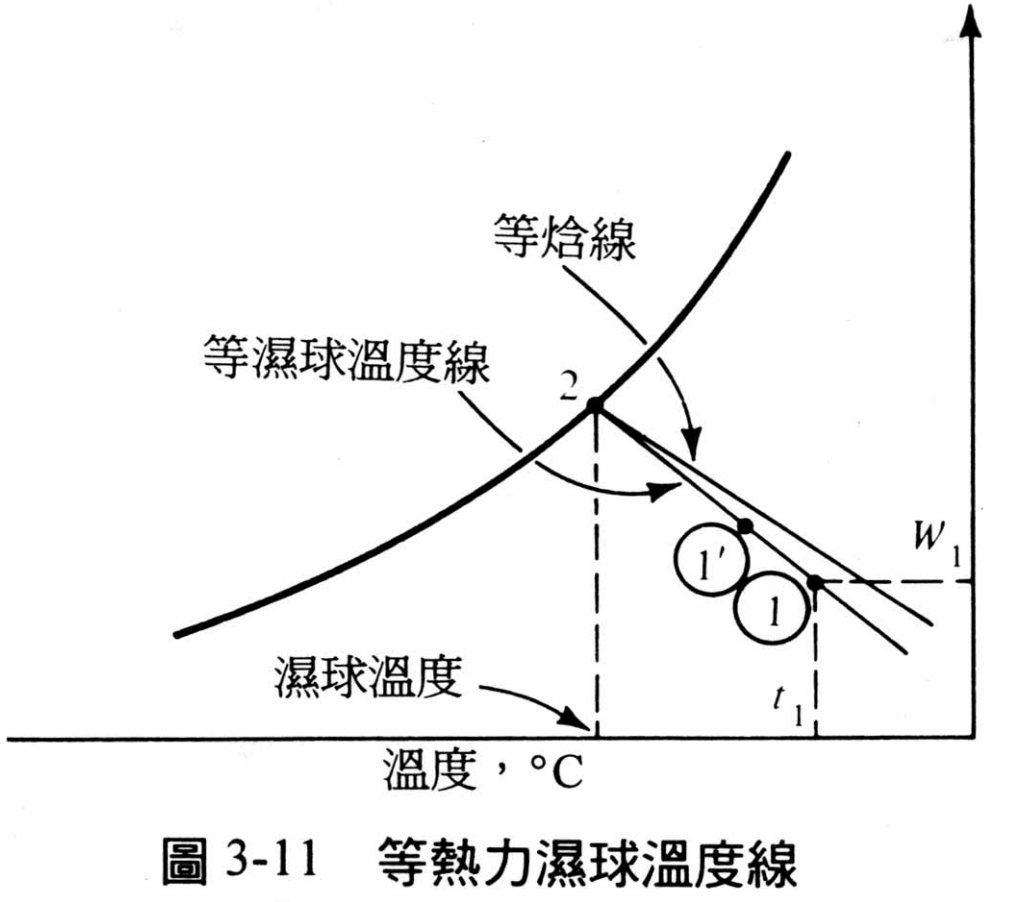


圖 3-11　等熱力濕球溫度線

查焓值:

at T = 40°C, ϕ = 41%

Approach I: 查圖3.1(等焓線)

h_1 = 89 (kJ/kg)

at 28°C; Table A-1

Approach II: 若由等濕球溫度線計算

$h_1 = h_2 - h_f (W_2 - W_1) = 89.7 – (117.3)(0.0241-0.019)$

$= 89.1$ (kJ/kg)

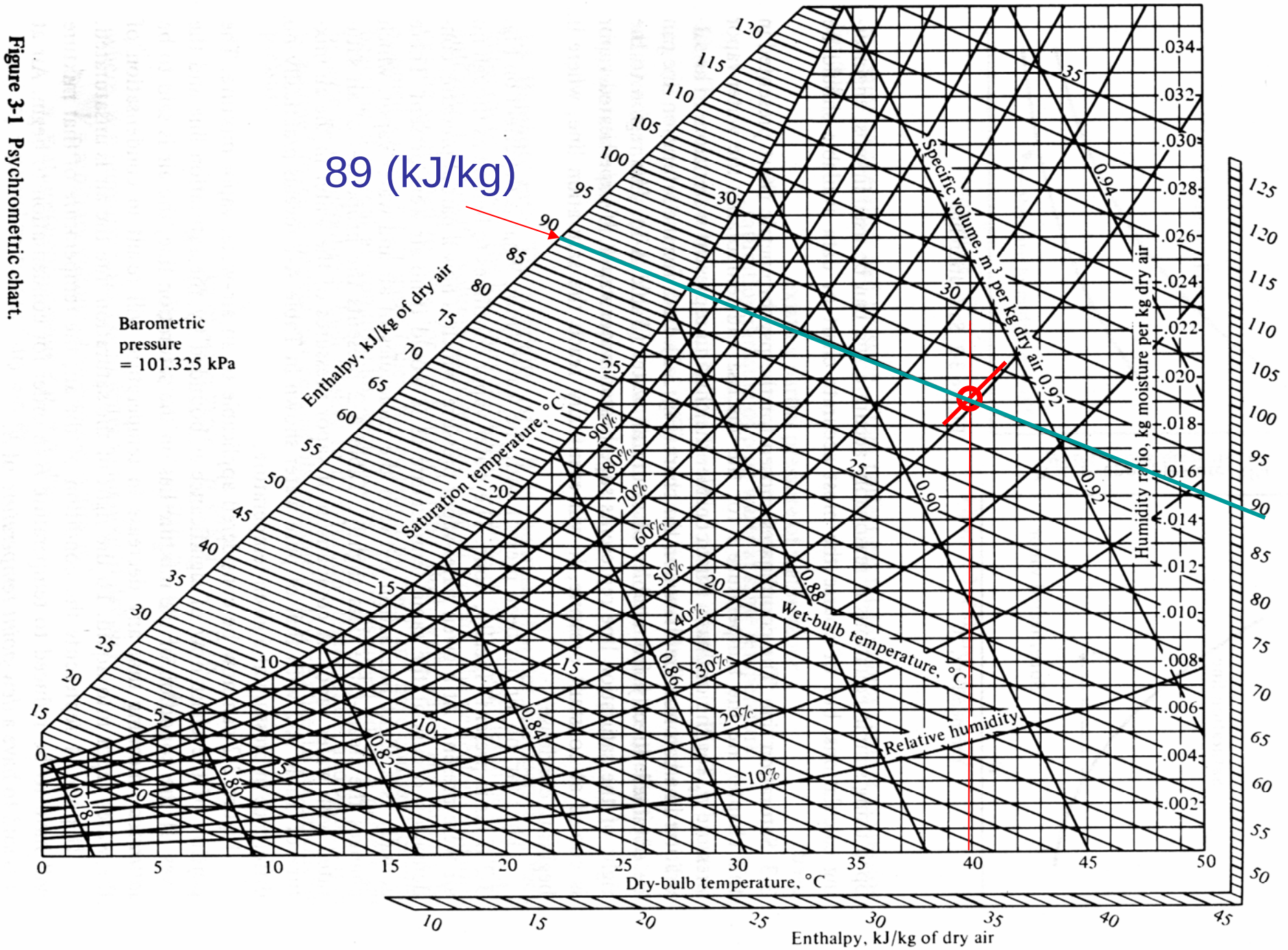


Figure 3-1 Psychrometric chart.

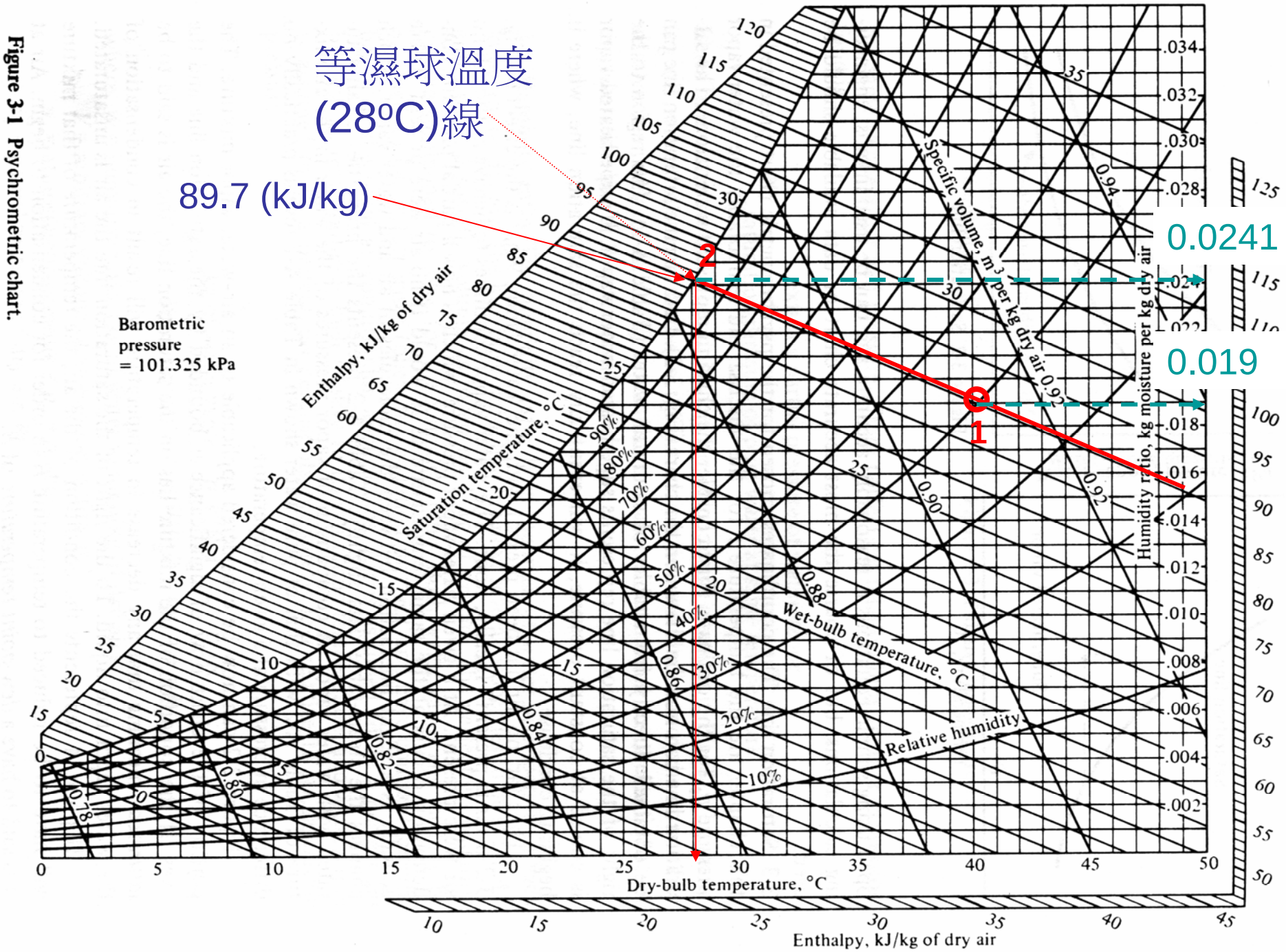


Figure 3-1 Psychrometric chart.

Processes – Sensible Heating or Cooling
(顯熱加熱與顯熱冷卻)

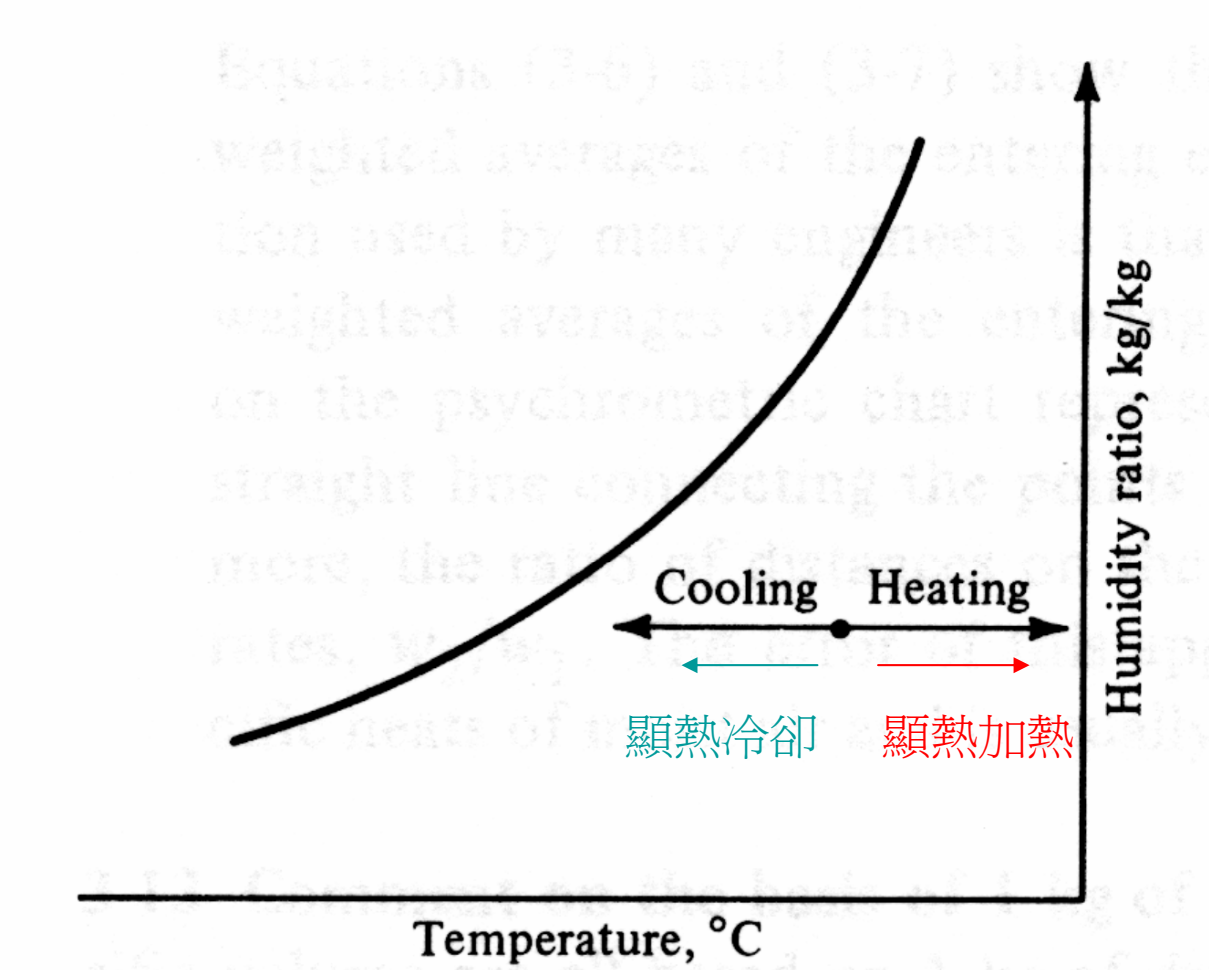
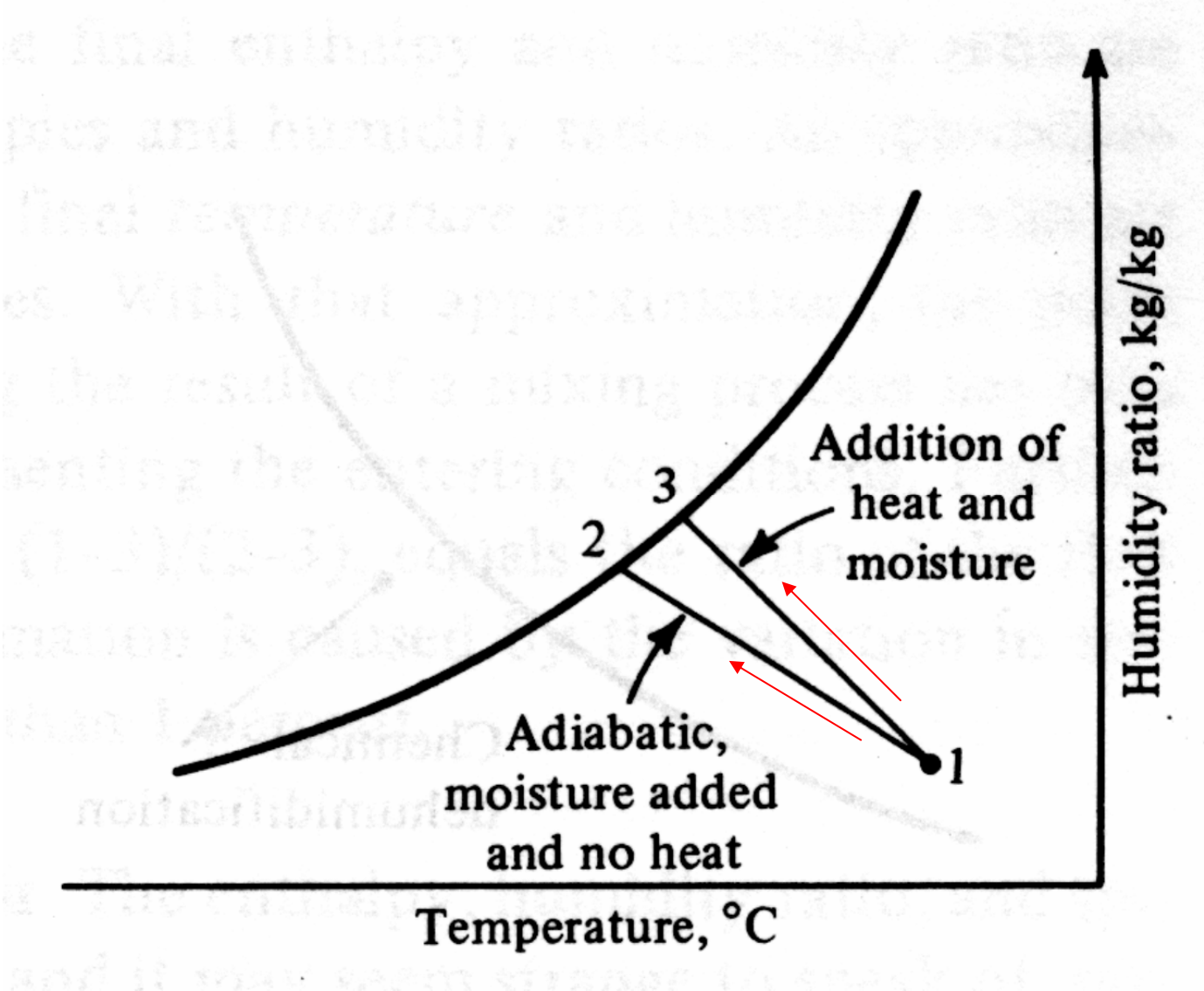
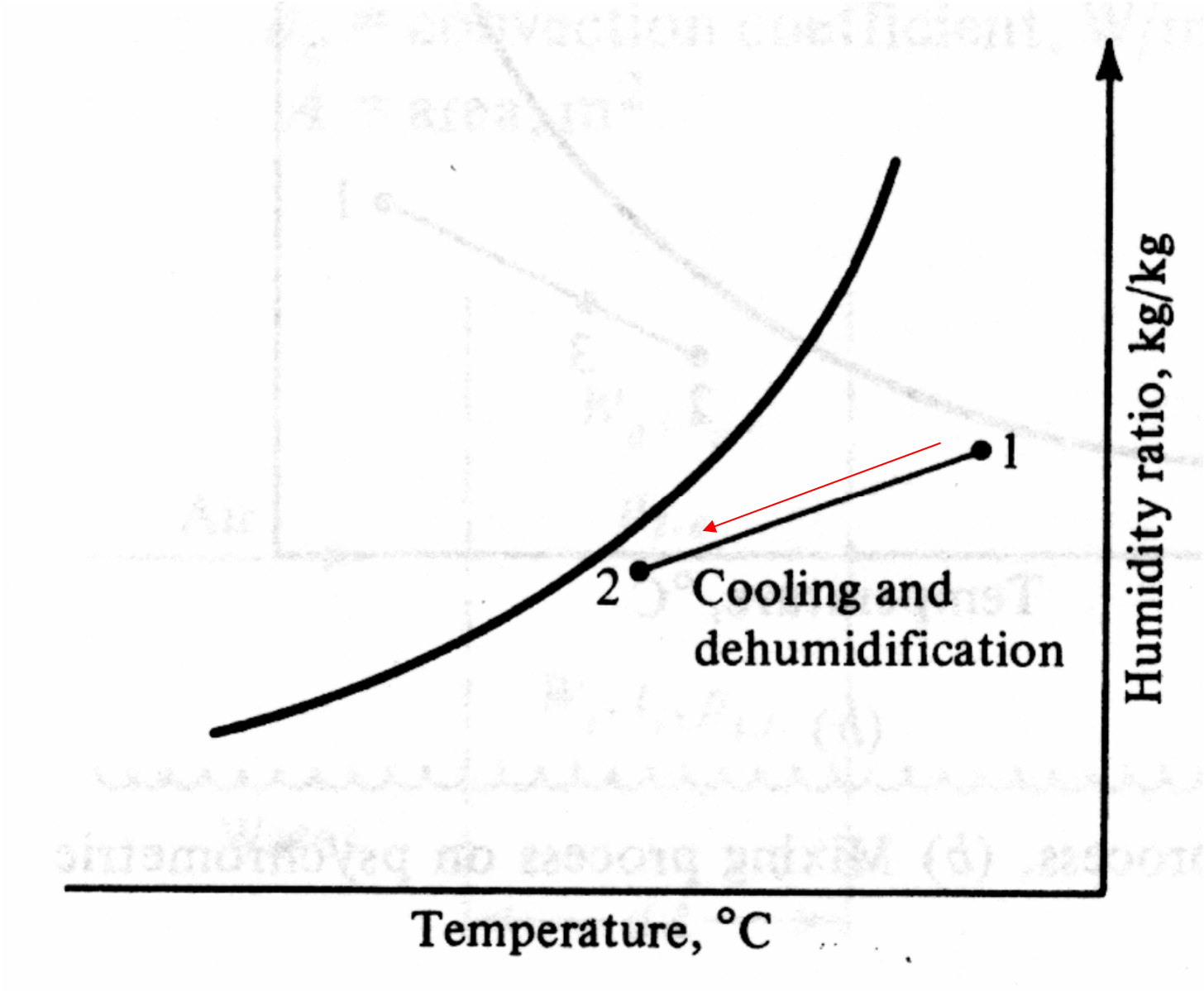


Figure 3-13 Sensible heating or cooling.

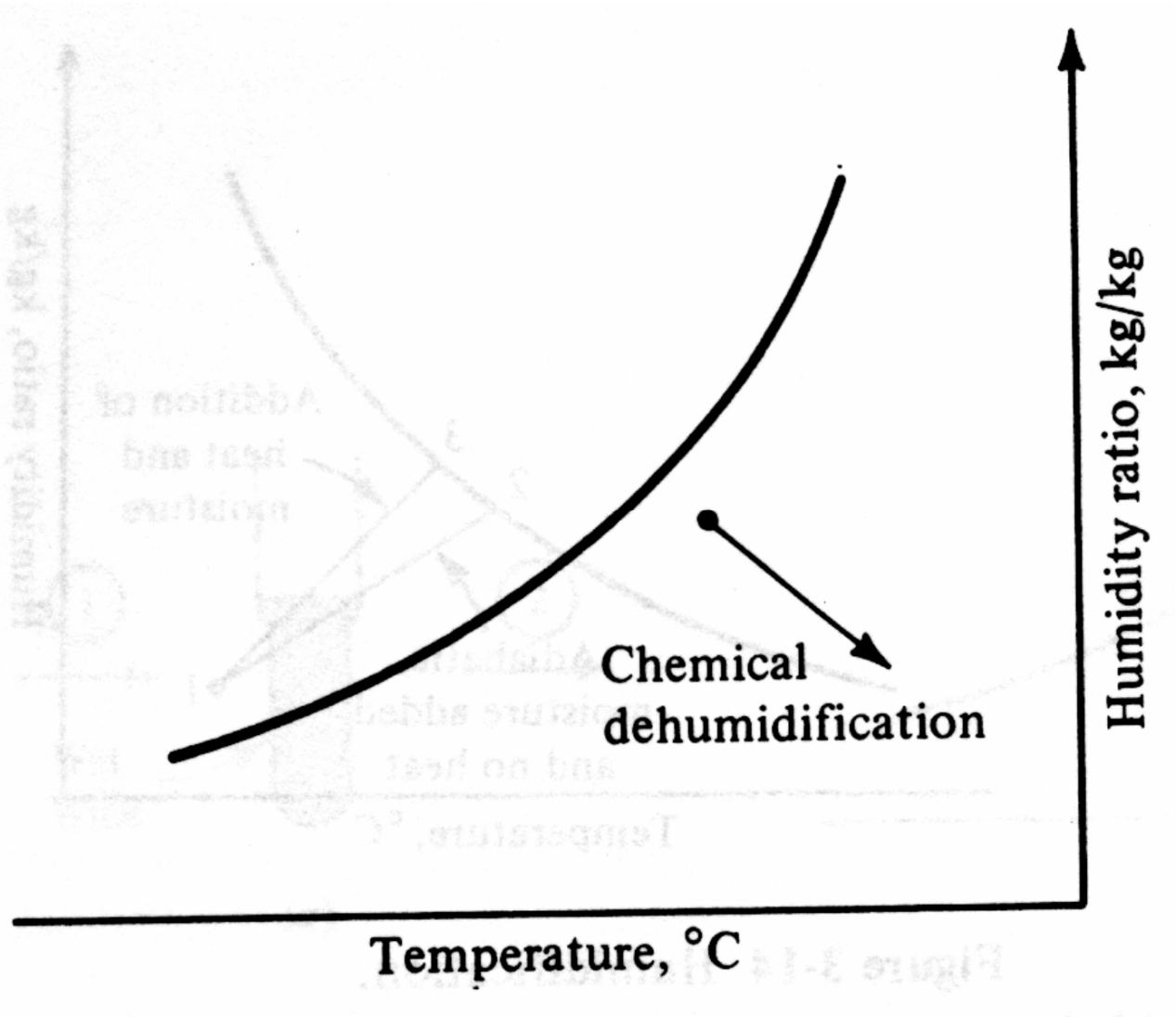
Processes – Humidification (加濕)



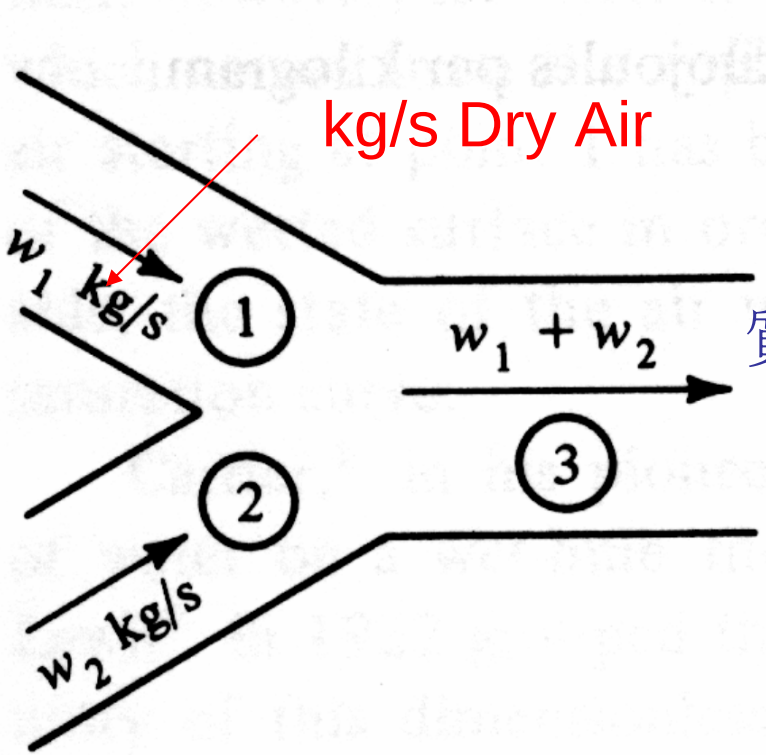
Processes – Cooling and Dehumidification



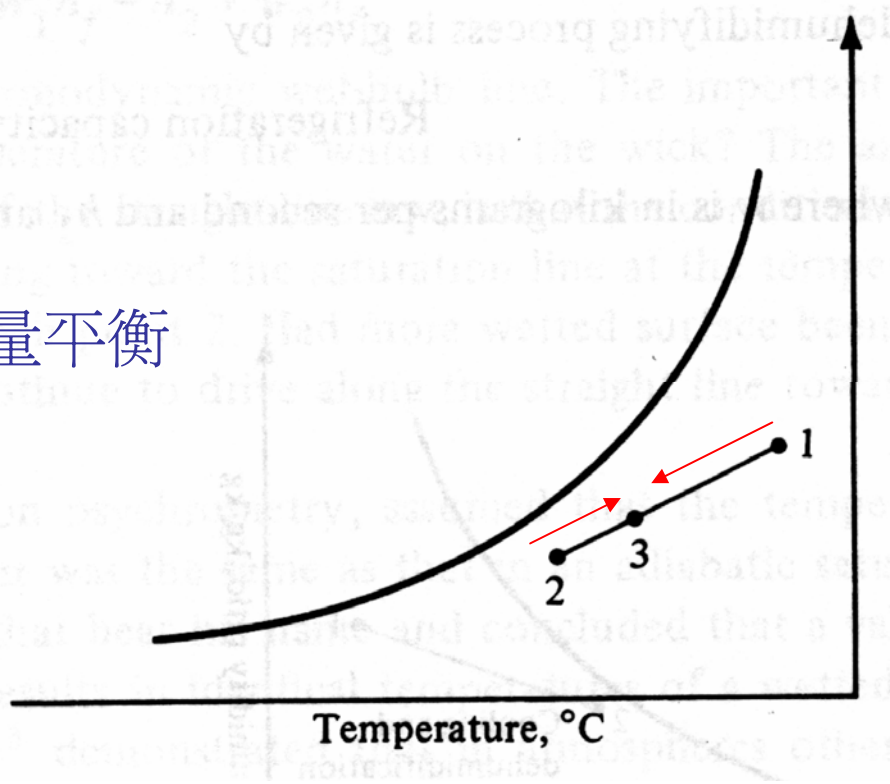
Processes – Chemical Dehumidification (吸附除濕)



Processes – Mixing (混合)



質量平衡



能量平衡:

濕空氣: $w_1 h_1 + w_2 h_2 = (w_2 + w_1)\, h_3$

質量平衡:

水蒸氣: $w_1 W_1 + w_2 W_2 = (w_2 + w_1)\, W_3$

Homework 2
(作業2)

教科書

- 3-4
- 3-6
- 3-8