

Psychrometry



Dr. Sam C. M. Hui

Department of Mechanical Engineering

The University of Hong Kong

E-mail: cmhui@hku.hk

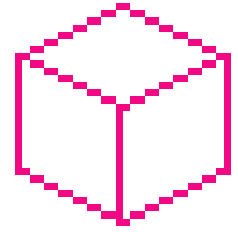
Contents



- Introduction to Psychrometry*
- Psychrometric Processes*
- Psychrometric Software

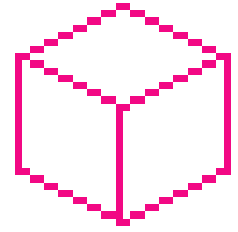
(* Handouts with details can be downloaded from course website for study)

Introduction to Psychrometry



- Basics
 - The atmosphere
 - Water vapour
 - Saturated vapour pressure
- Also, Appendix - Thermodynamic Basics
 - Perfect gas laws
 - 1st law of thermodynamics
 - Conservation of energy

Introduction to Psychrometry



- Psychrometry (測濕學)
 - The measurement or study of the thermodynamic properties of **moist air**
 - The Greek term psuchron (ψυχρόν) meaning "cold" and metron (μέτρον) meaning "means of measurement"
 - Moist air properties:
 - Dalton's law of partial pressures
 - Standard atmospheric pressure = 101.325 kPa
 - Saturated vapour pressure: Max. pressure of water vapour that can occur at any given temperature

Measurement of moist air by sling psychrometer

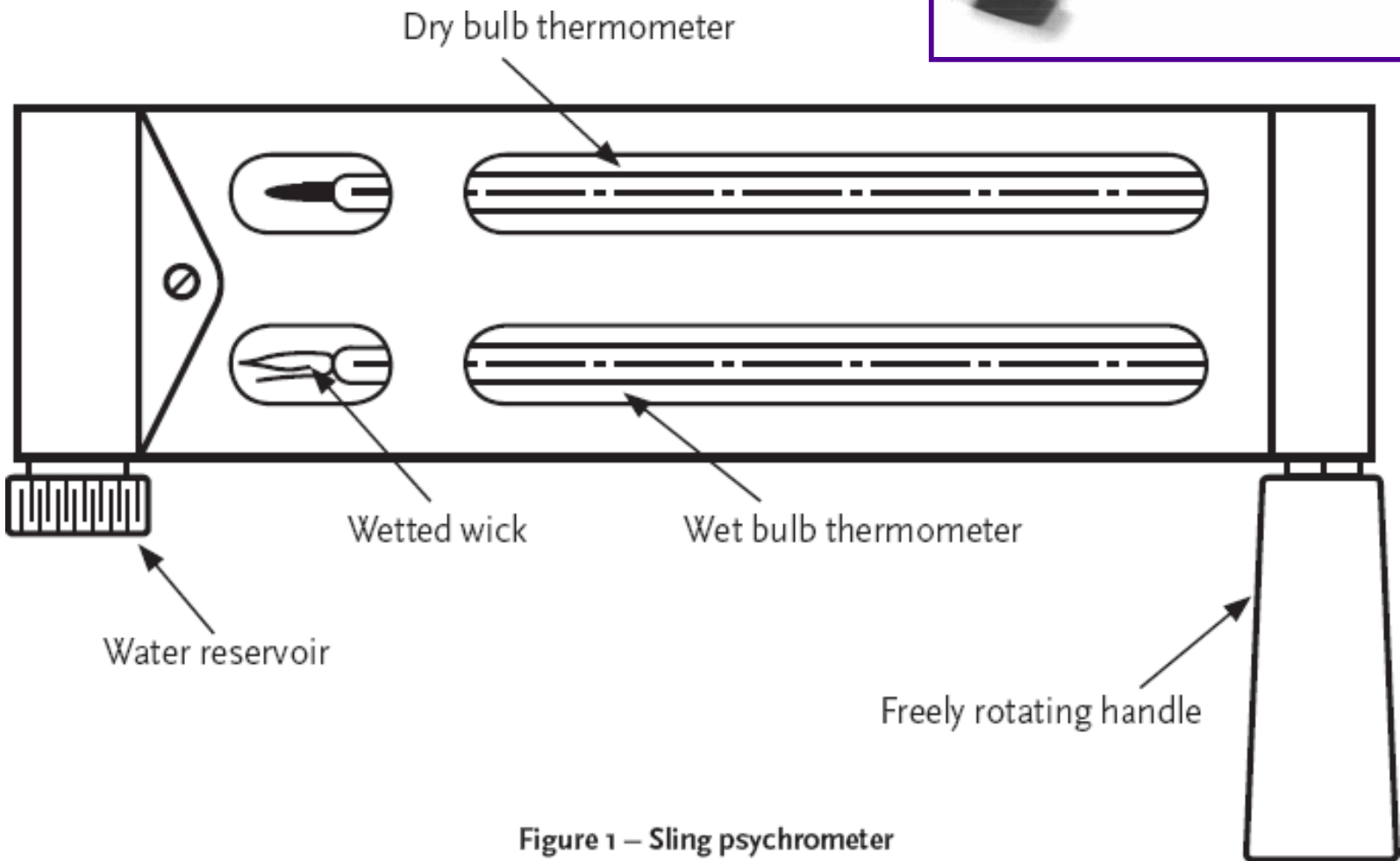
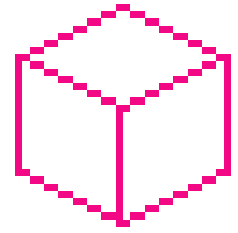


Figure 1 – Sling psychrometer

Introduction to Psychrometry

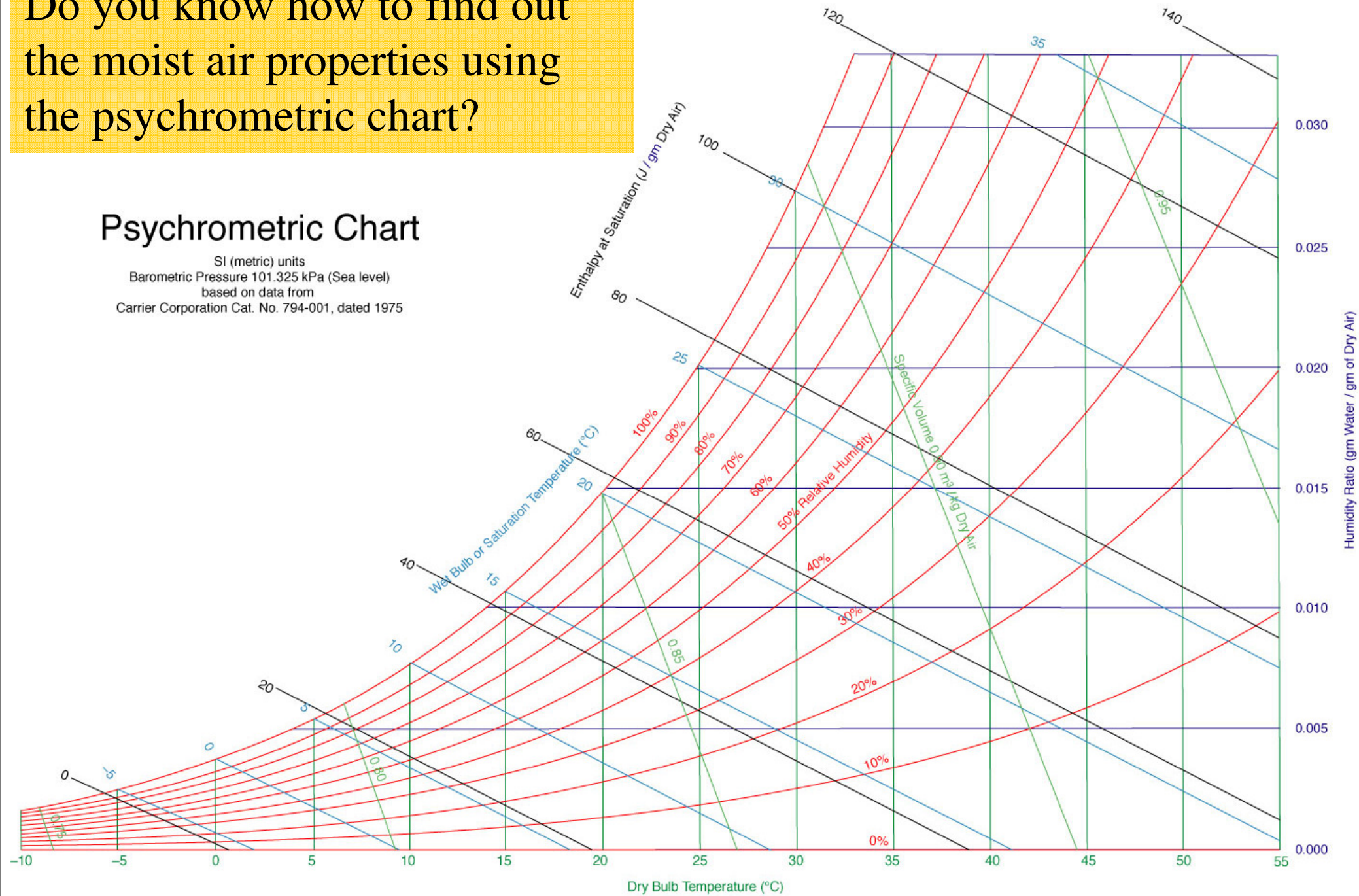


- Psychrometric Chart (Theory)
 - Moisture content (g), or absolute humidity (w)
 - Relative humidity (rh or RH)
 - Percentage saturation (μ)
 - Wet-bulb temperature (t_{wb})
 - Dew-point temperature (t_{dp})
 - Specific enthalpy (h)
 - Specific volume (v)
 - Density (ρ)

Do you know how to find out the moist air properties using the psychrometric chart?

Psychrometric Chart

SI (metric) units
Barometric Pressure 101.325 kPa (Sea level)
based on data from
Carrier Corporation Cat. No. 794-001, dated 1975



Psychrometric Chart

Can you read them from the chart?

Wet-bulb temperature

Enthalpy

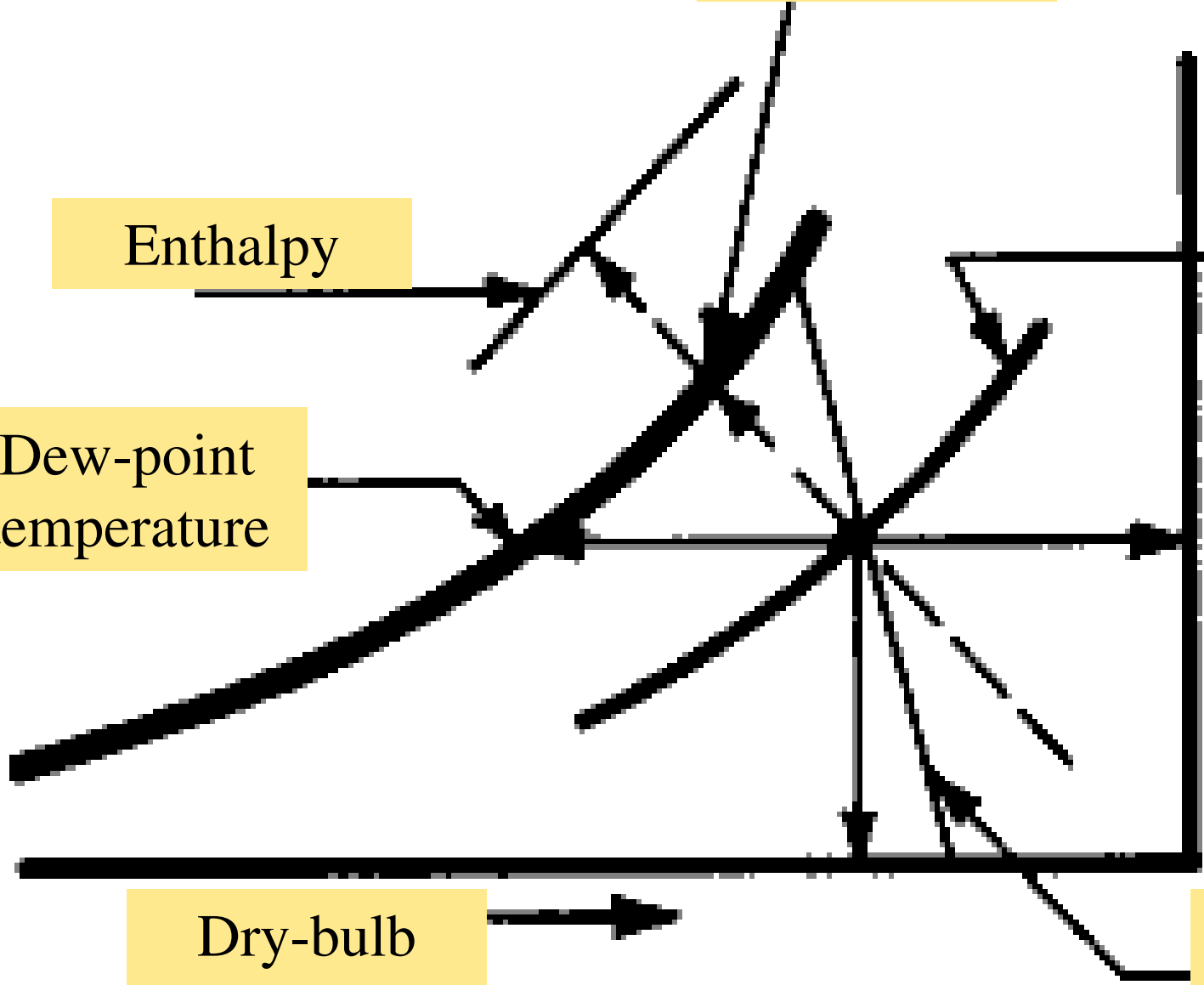
Relative humidity

Dew-point temperature

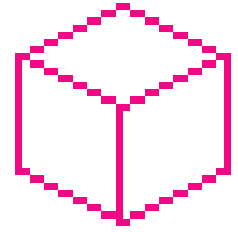
Humidity ratio

Dry-bulb temperature

Specific volume



Introduction to Psychrometry



- Commonly used psychrometric charts
 - ASHRAE psychrometric chart
 - CIBSE psychrometric chart
 - Mollier chart in Mainland China (濕空氣焓濕圖)
- You should learn how to read and use the psychrometric charts for HVAC design



ASHRAE PSYCHROMETRIC CHART NO.1

NORMAL TEMPERATURE

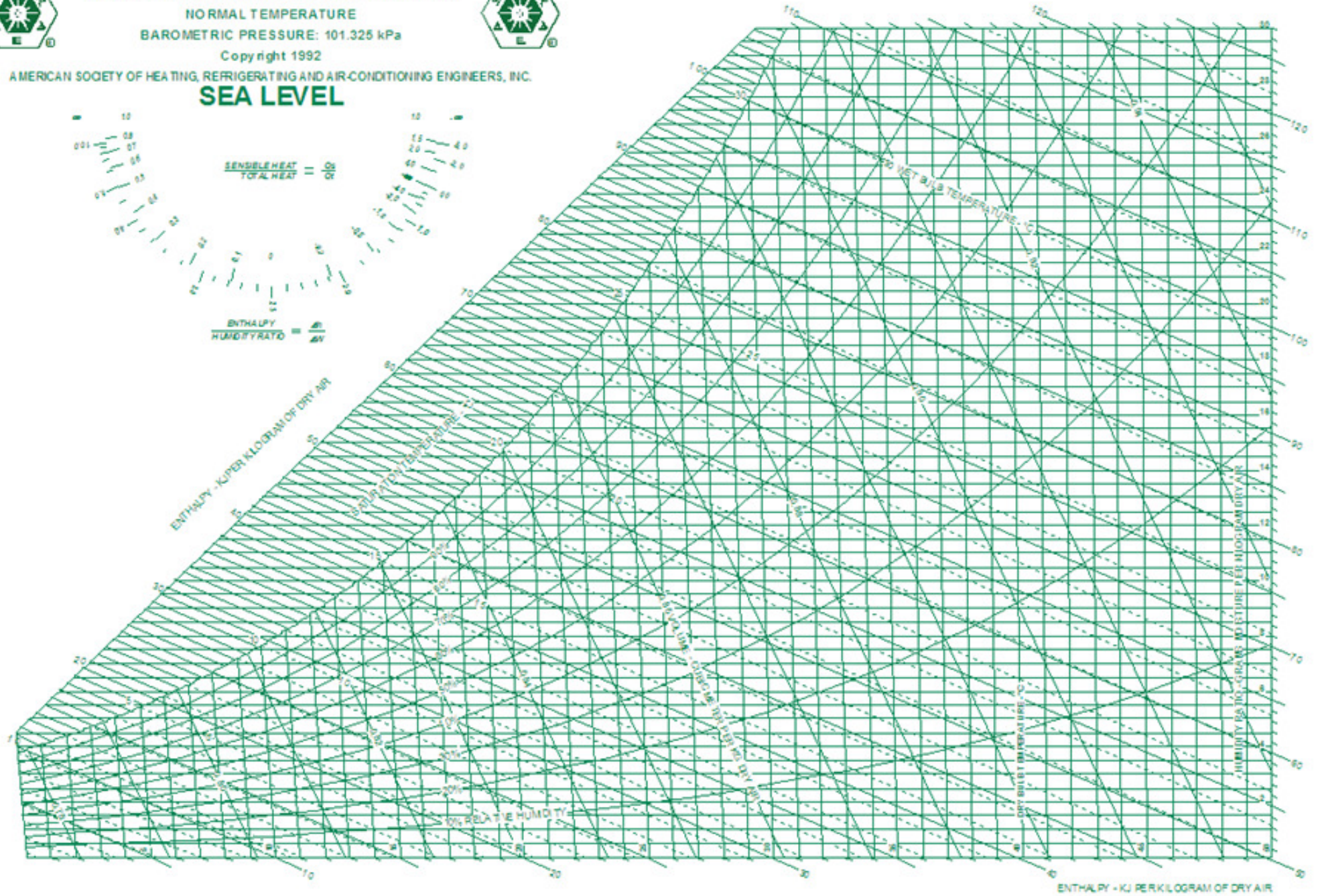
BAROMETRIC PRESSURE: 101.325 kPa

Copyright 1992

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.



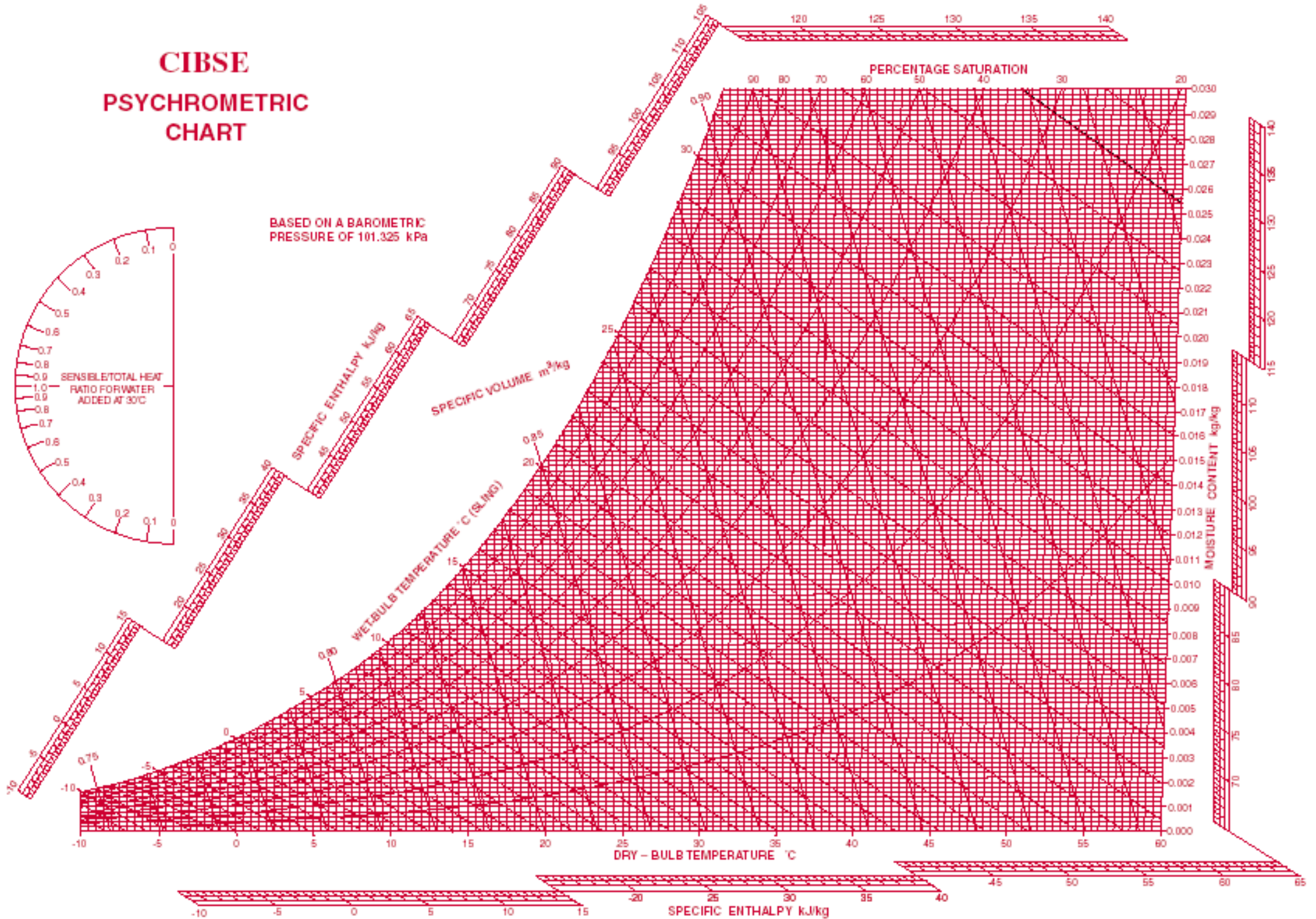
SEA LEVEL

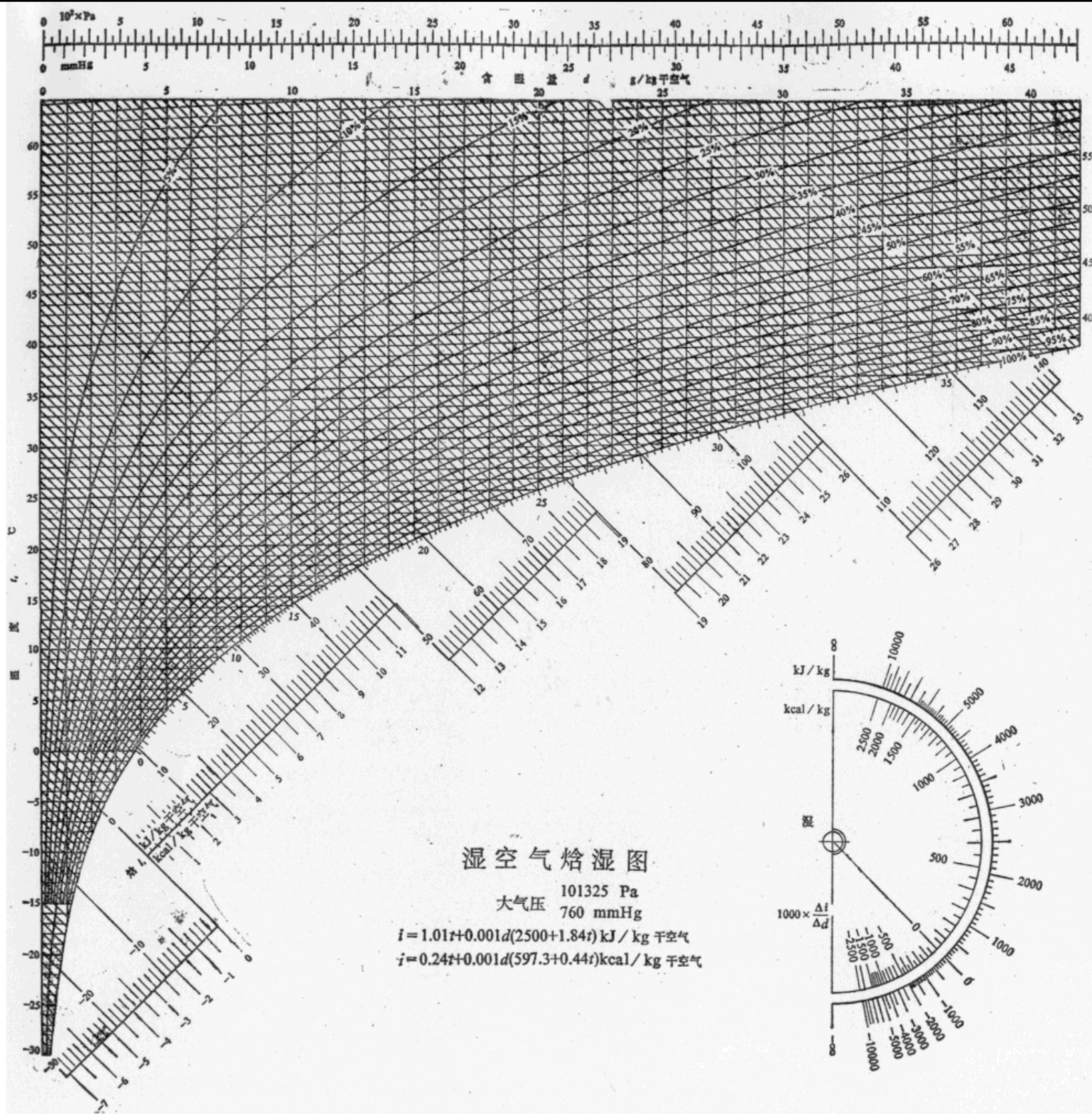


ENTHALPY - KJ PER KILOGRAM OF DRY AIR

CIBSE PSYCHROMETRIC CHART

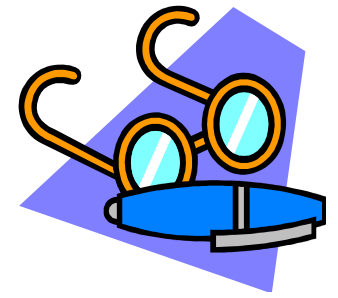
BASED ON A BAROMETRIC
PRESSURE OF 101.325 kPa





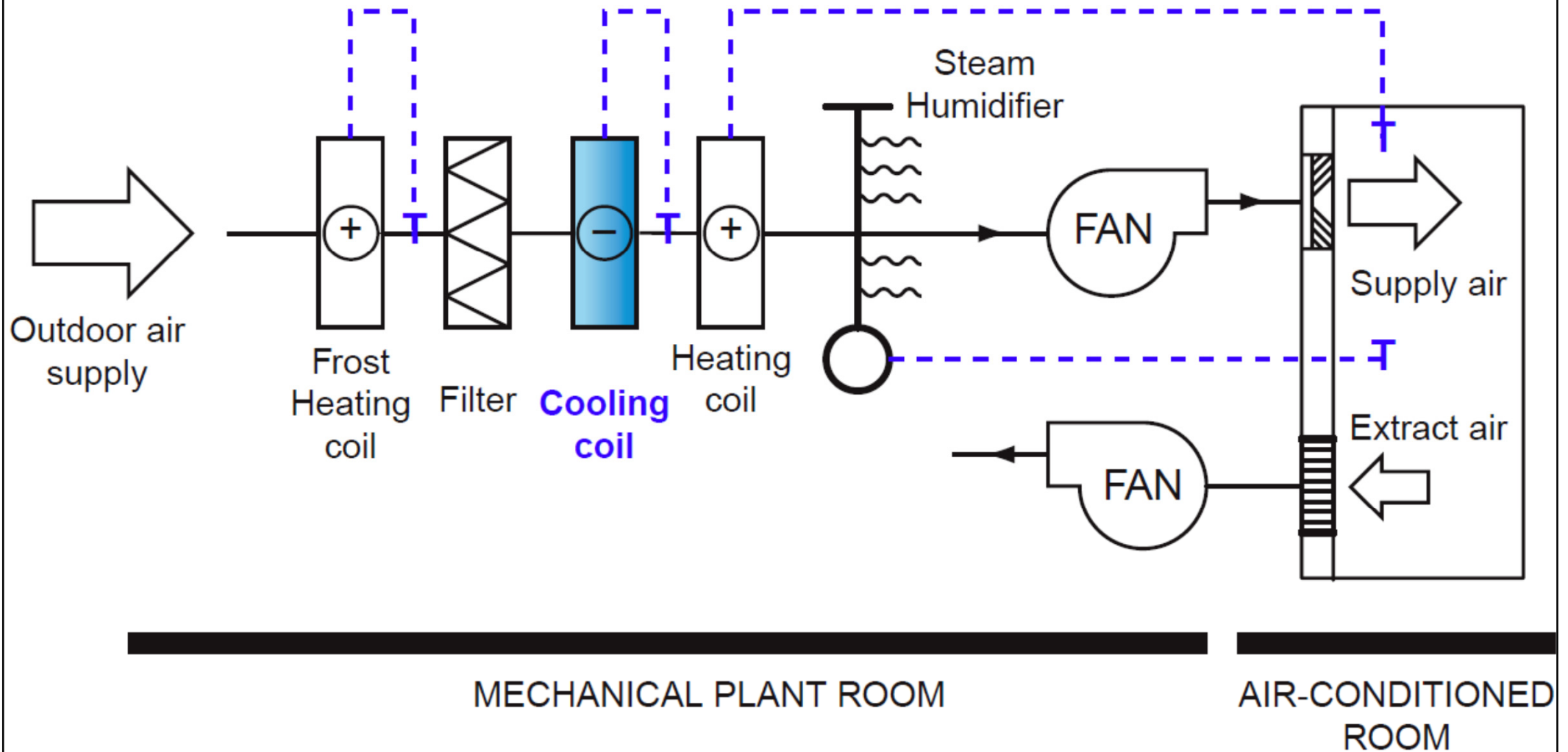
Mollier
chart style

Psychrometric Processes

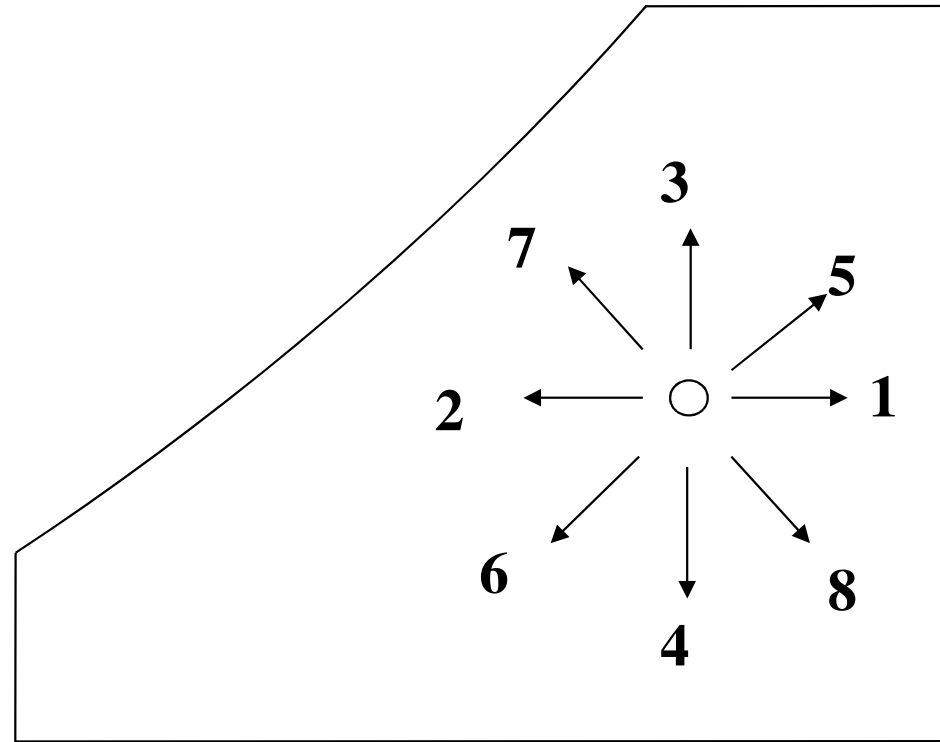


- Common processes:
 - Sensible cooling / sensible heating
 - Cooling and dehumidification / heating and humidification
 - Humidification / dehumidification
 - Evaporative cooling / chemical dehydration
- Typical devices:
 - Cooling/heating coils
 - Humidifiers / dehumidifiers

Schematic representation of all fresh-air, constant volume air conditioning system



Basic psychrometric processes



Process 0-1: Sensible heating

Process 0-2: Sensible cooling

Process 0-3: Humidifying

Process 0-4: Dehumidifying

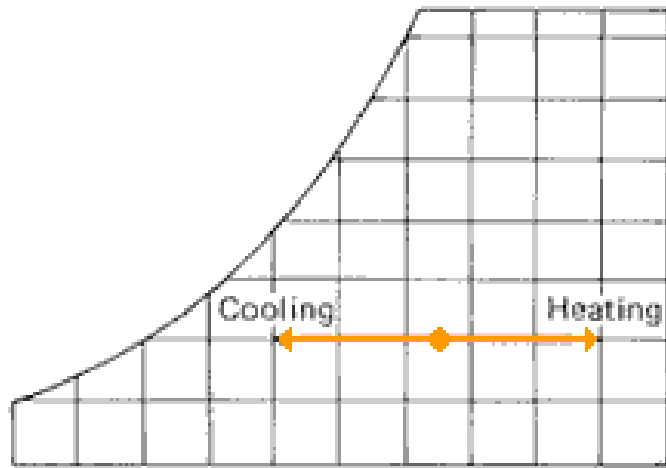
Process 0-5: Heating and humidifying

Process 0-6: Cooling and dehumidifying

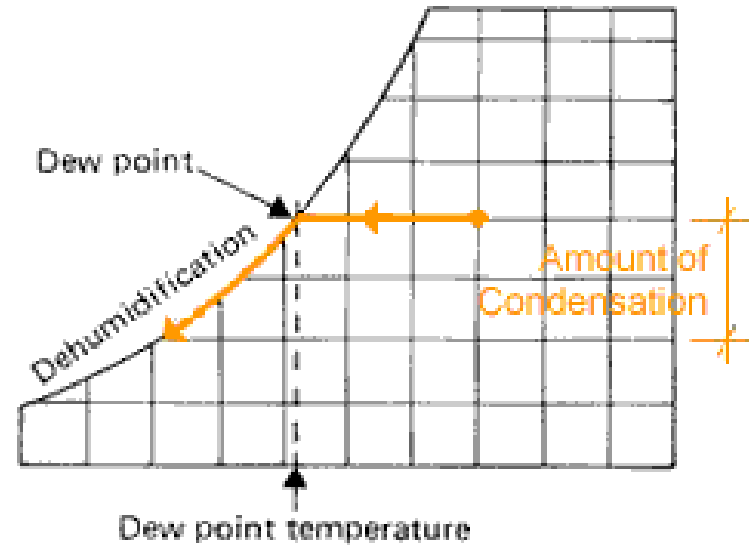
Process 0-7: Cooling and humidifying

Process 0-8: Heating and dehumidifying

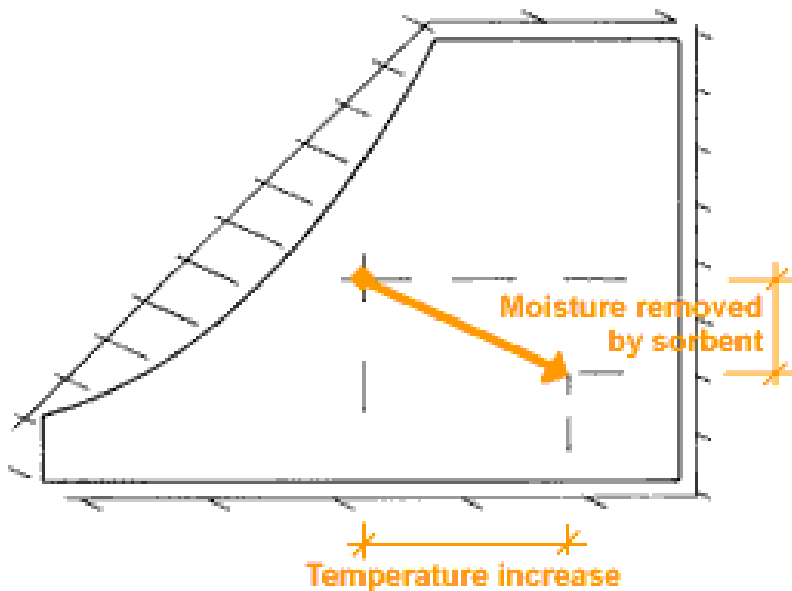
Psychrometric processes



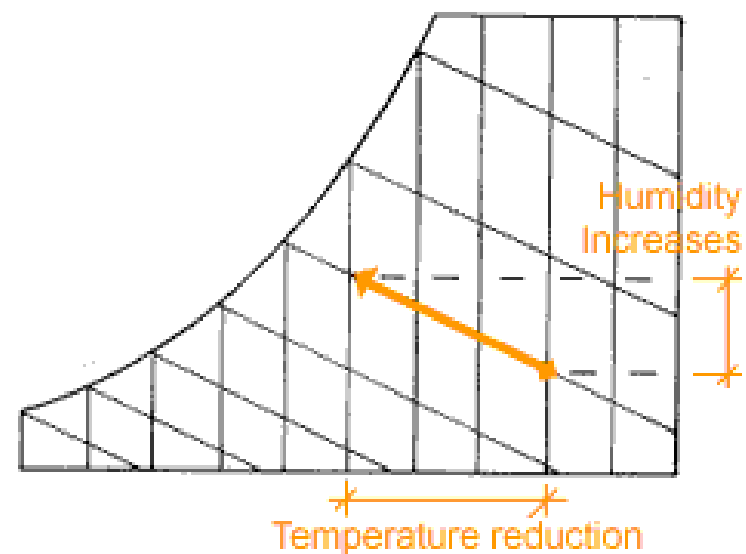
Sensible cooling/heating



Cooling and dehumidification

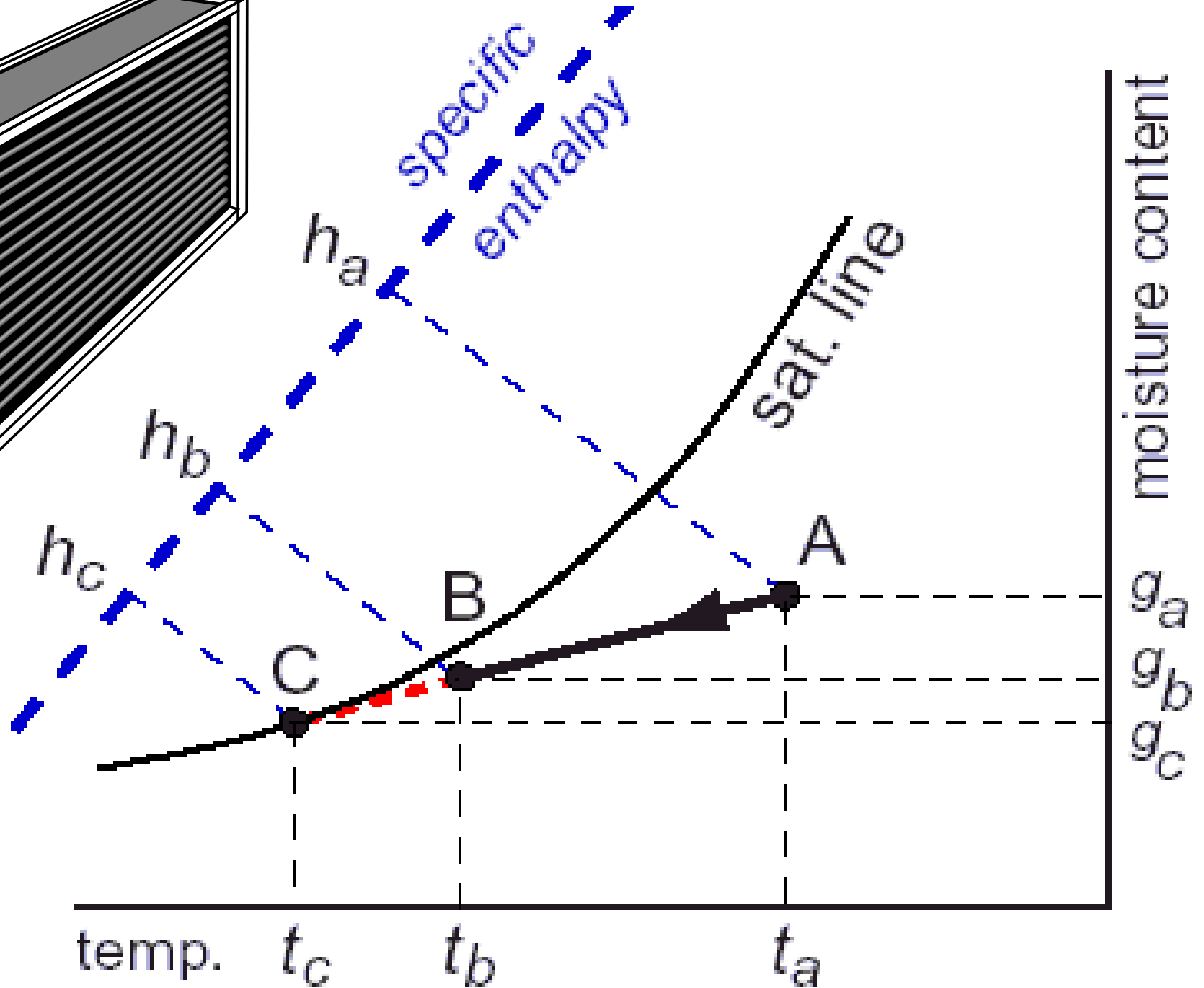
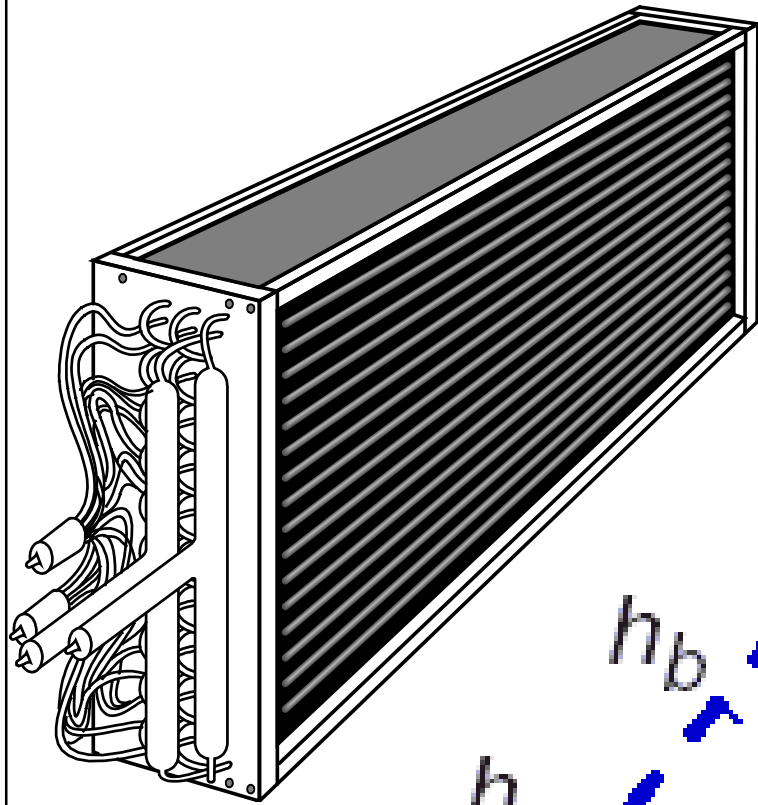


Adiabatic dehumidification

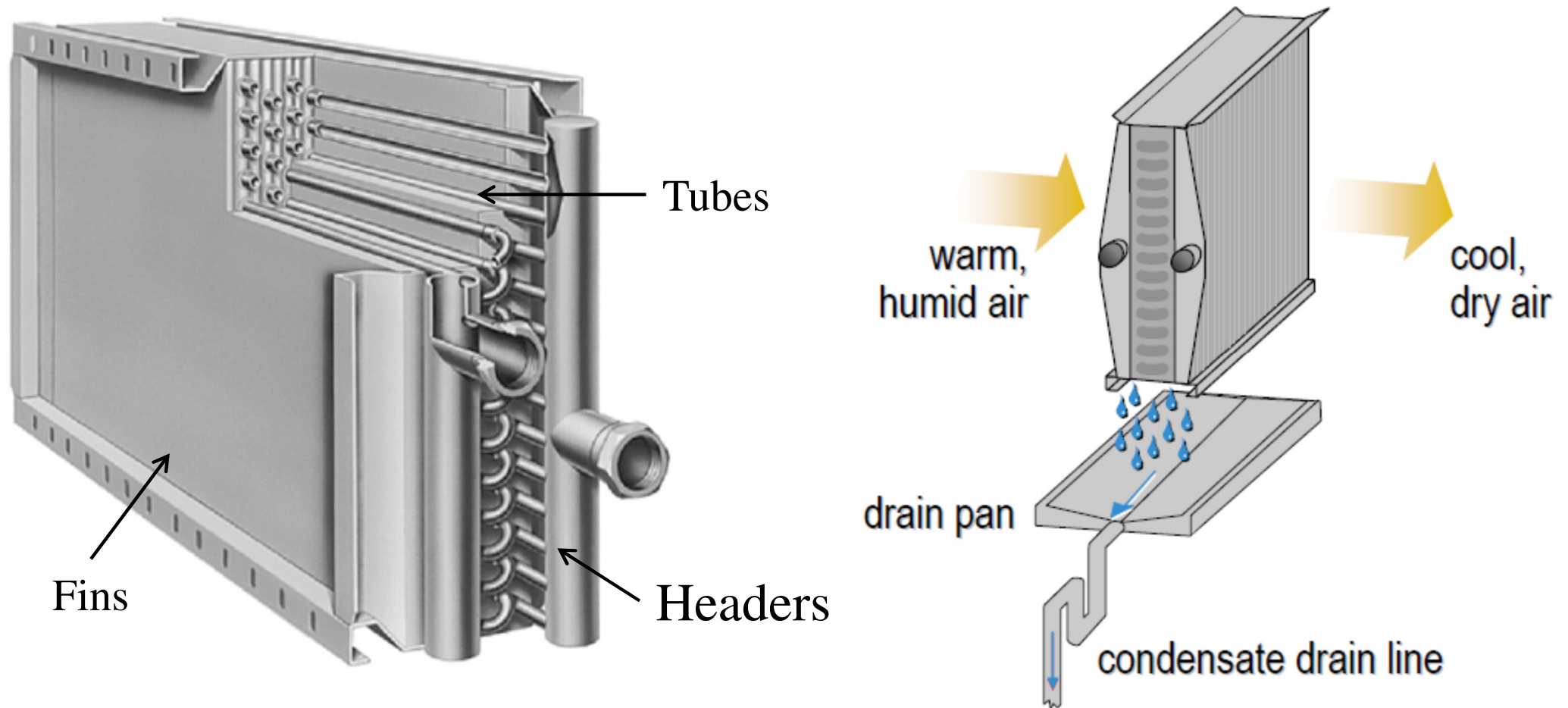


Evaporative cooling

Cooling and dehumidification

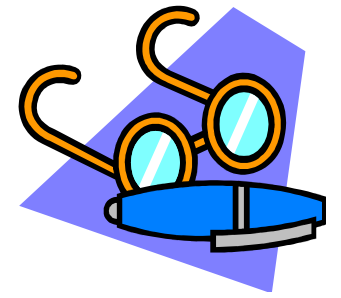


Chilled water cooling coil (a heat exchanger)



Sensible heat exchange: $q_S = m_a \times c_p \times (t_b - t_a)$

Latent heat exchange: $q_L = m_a \times h_{fg}$



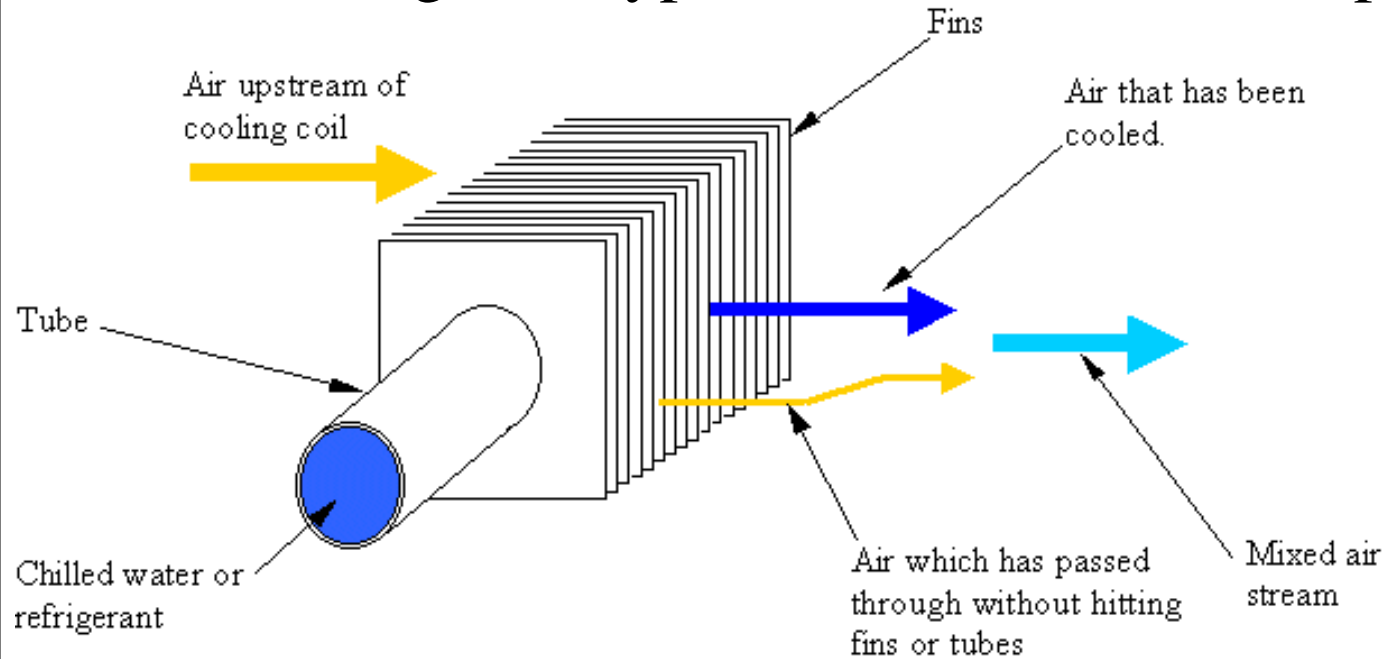
Psychrometric Processes

- Specific enthalpy difference: $q = m \times (h_a - h_b)$
- Sensible heat: $q_S = m_a \times c_p \times (t_b - t_a)$
- Latent heat: $q_L = m_a \times h_{fg}$
- Contact factor (cooling coil):

$$\beta = \frac{g_a - g_b}{g_a - g_c} = \frac{h_a - h_b}{h_a - h_c} = \frac{t_a - t_b}{t_a - t_c}$$

- Bypass factor = 1 – Contact factor

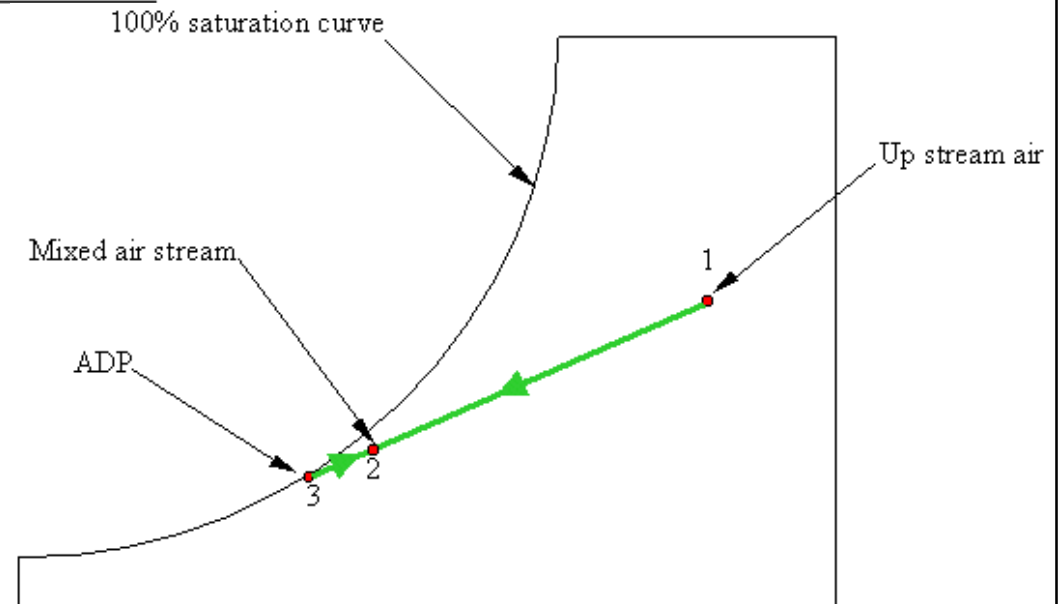
Cooling coil bypass/contact factor and apparatus dew point



The percentage of air that passes through the coil unchanged is called the bypass factor.

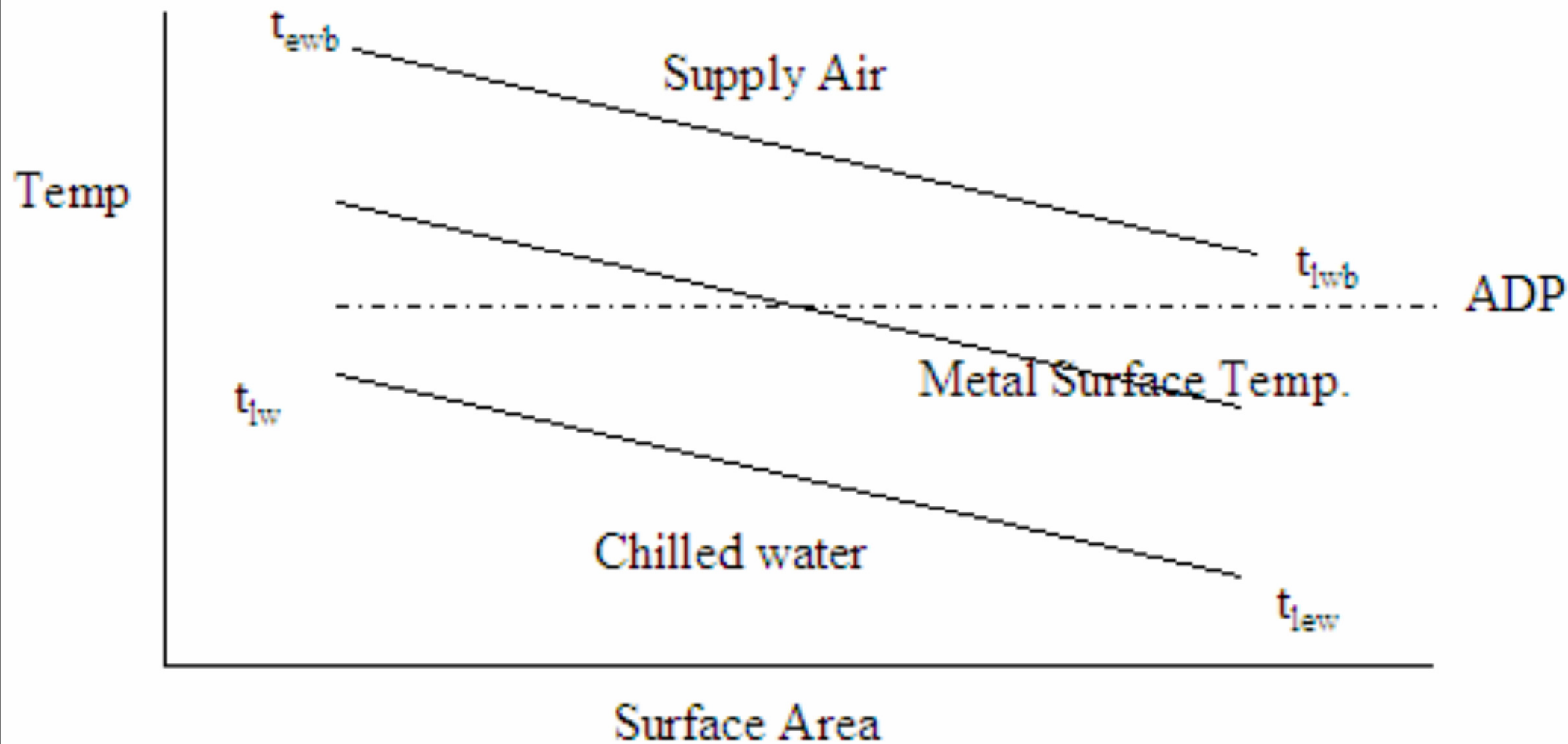
A SECTION OF COOLING COIL SHOWING AIR STREAMS

ADP = apparatus dew point
It is the coil surface dew point temperature required to accomplish a cooling/dehumidifying process.



PSYCHROMETRIC CHART SHOWING COOLING COIL CONTACT FACTOR

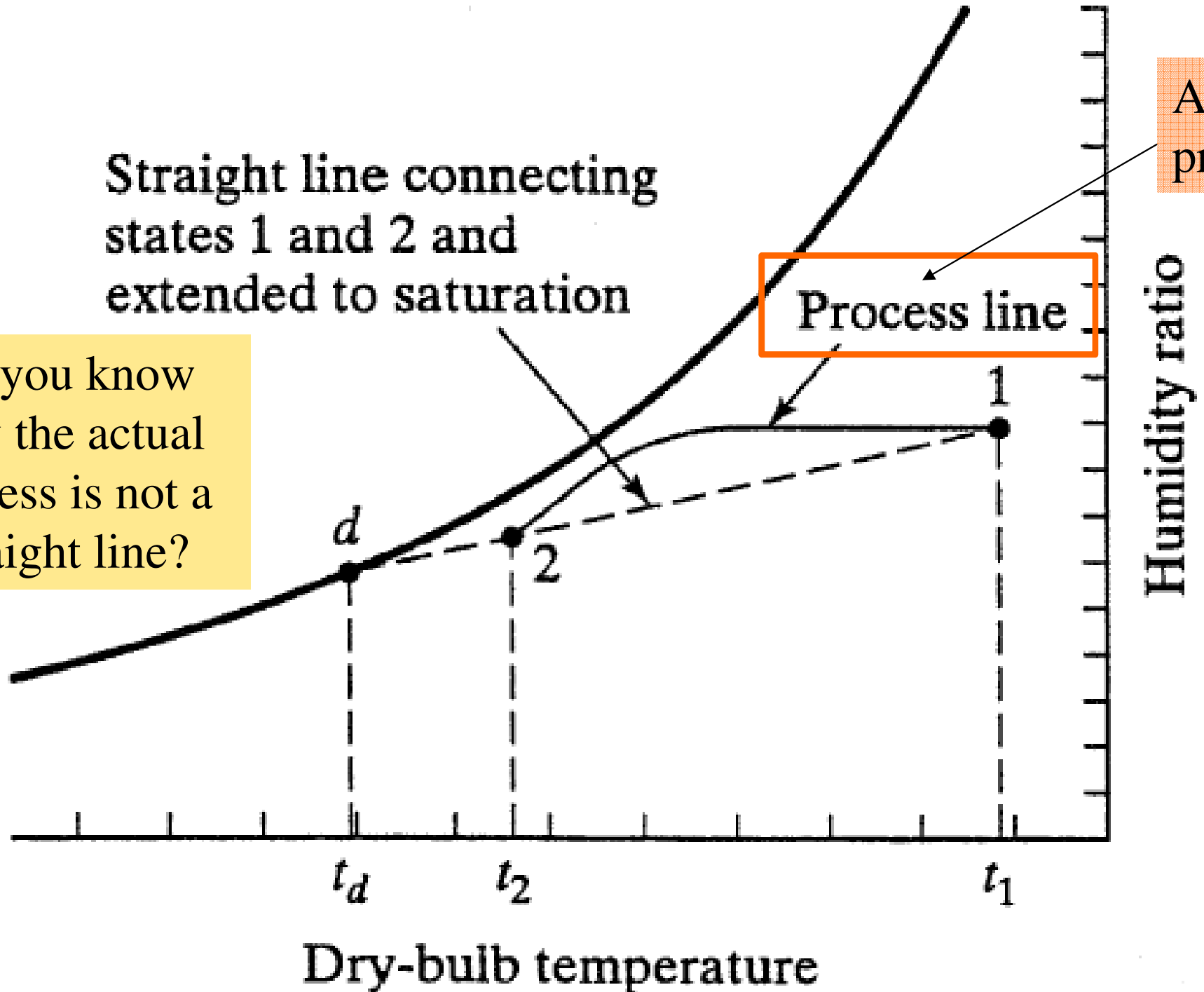
Relationship of apparatus dew point (ADP) to supply air and chilled water temperatures



Cooling and dehumidification

Straight line connecting states 1 and 2 and extended to saturation

Do you know why the actual process is not a straight line?



Actual process

Process line

Humidity ratio

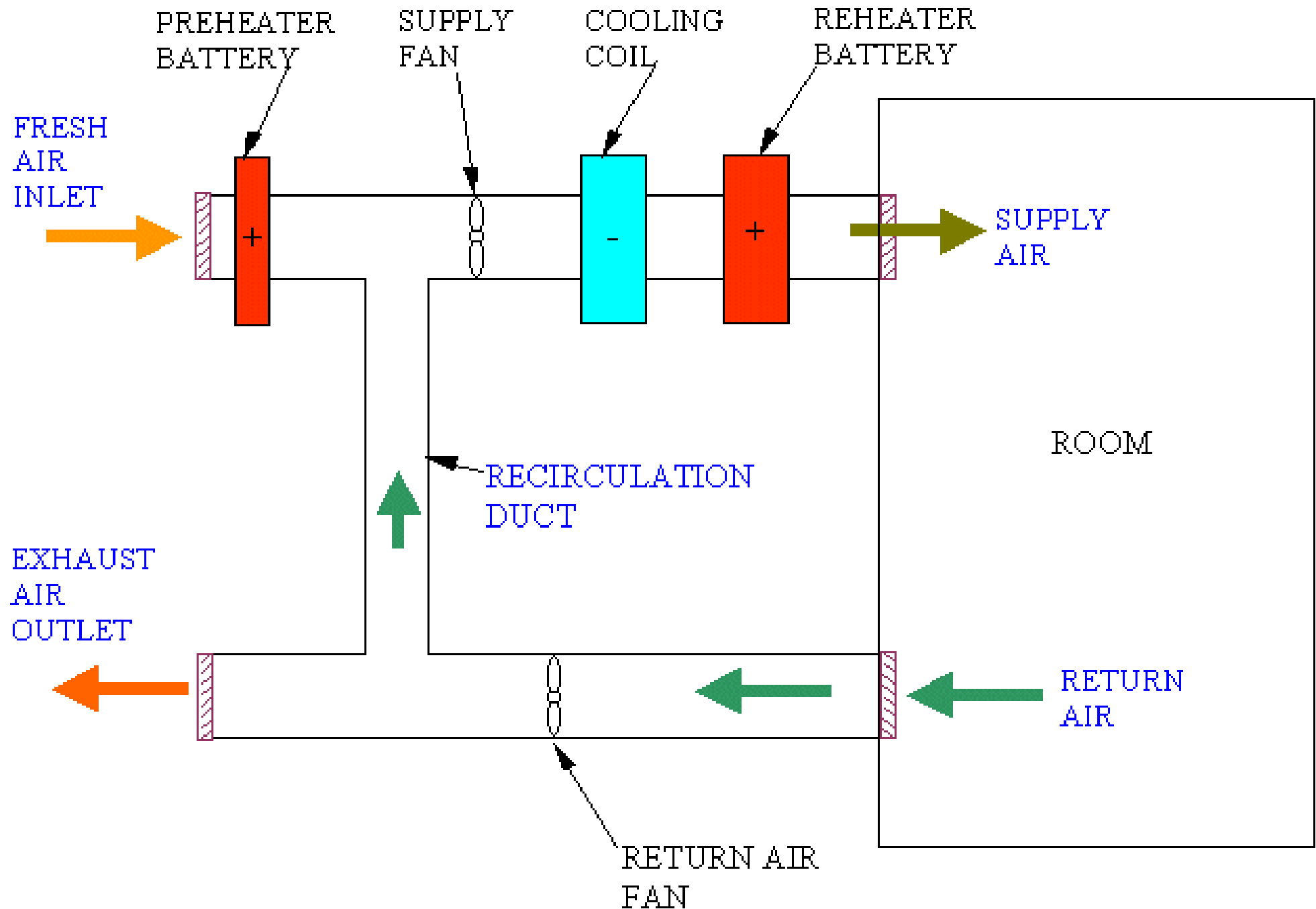
Dry-bulb temperature

t_d

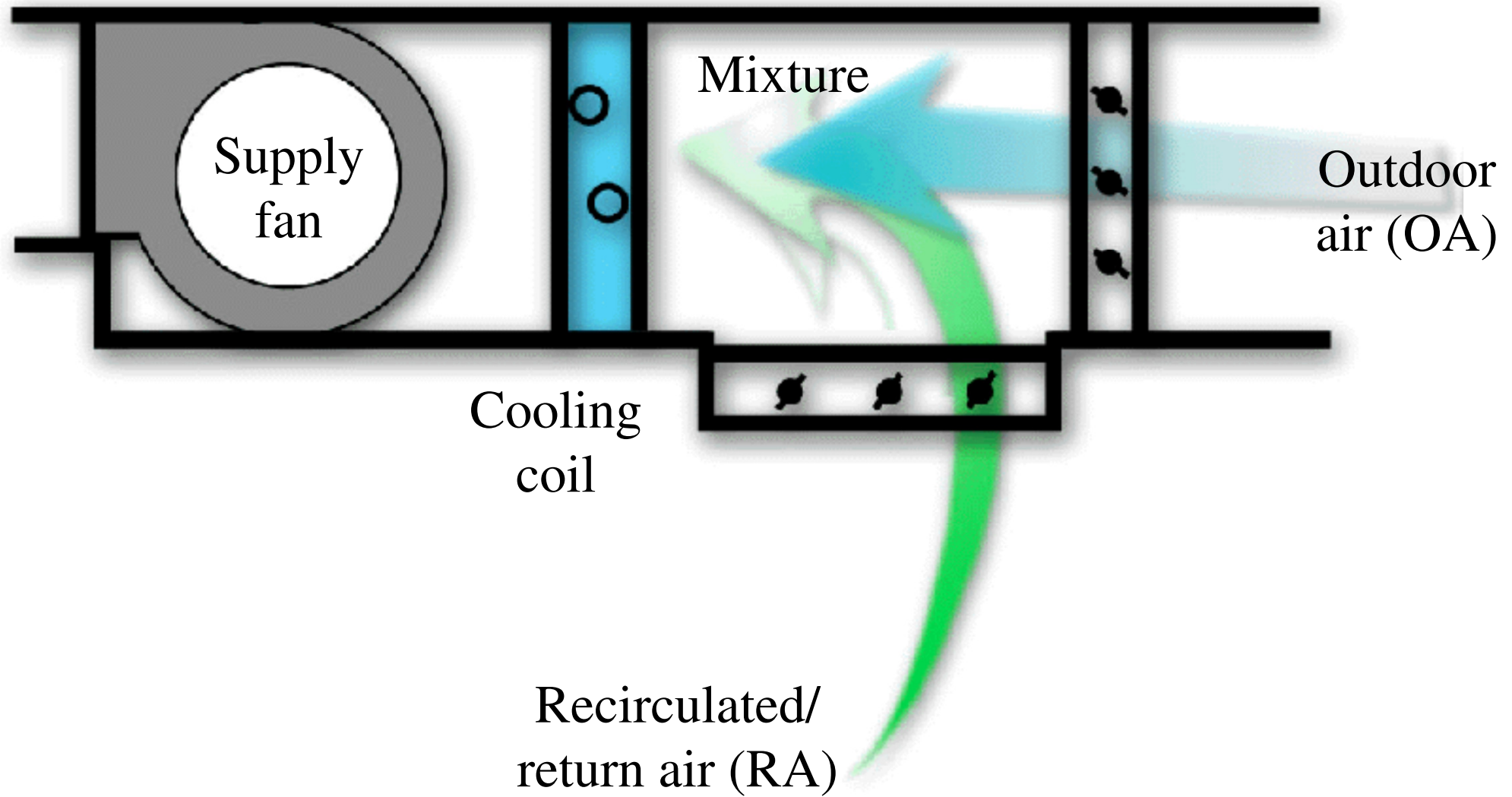
t_2

t_1

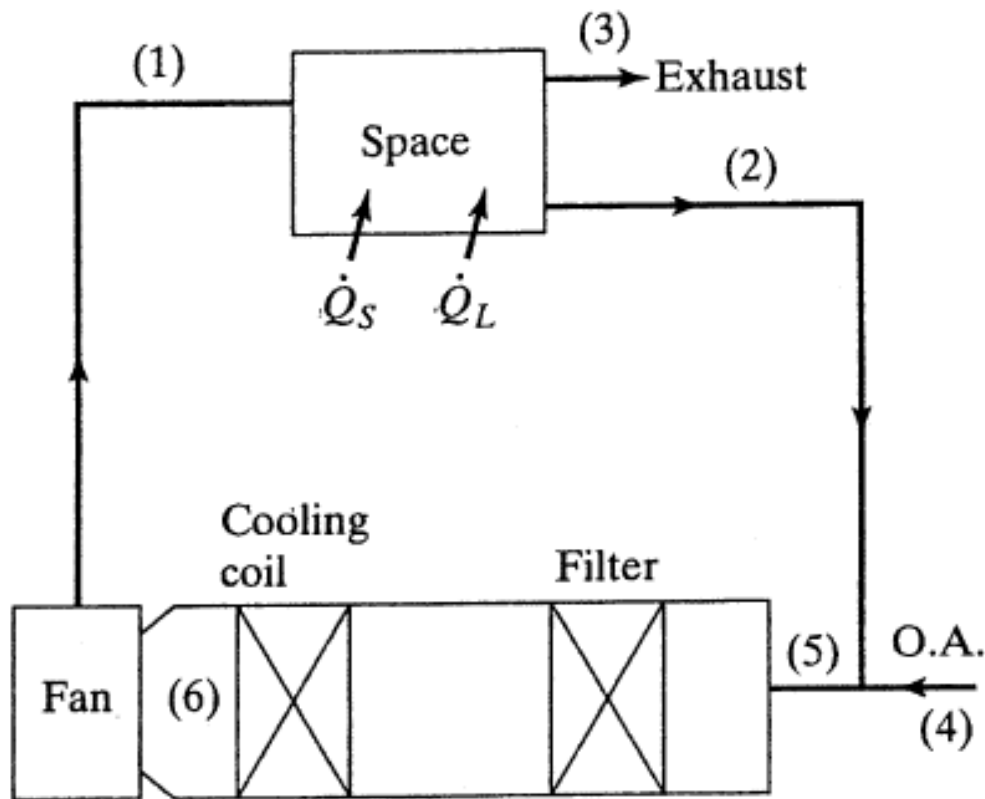
Major components of the HVAC air-side system



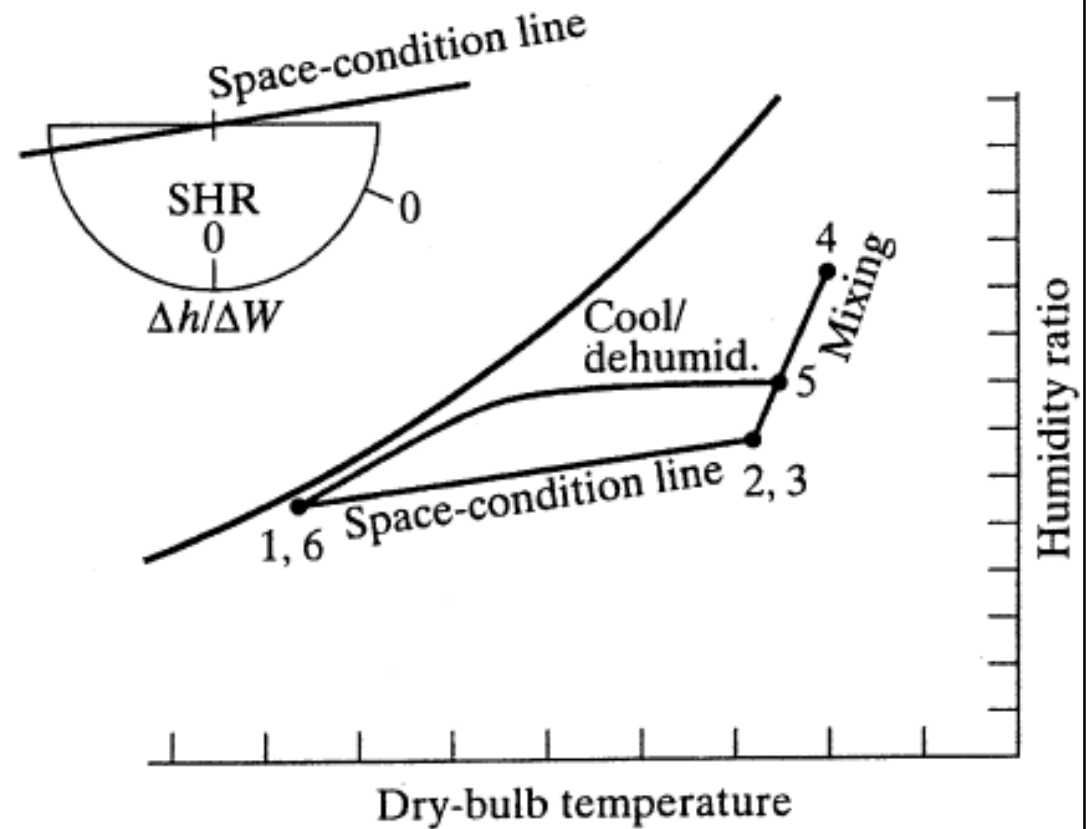
Determining entering air conditions



Simple air conditioning cycle



(a)



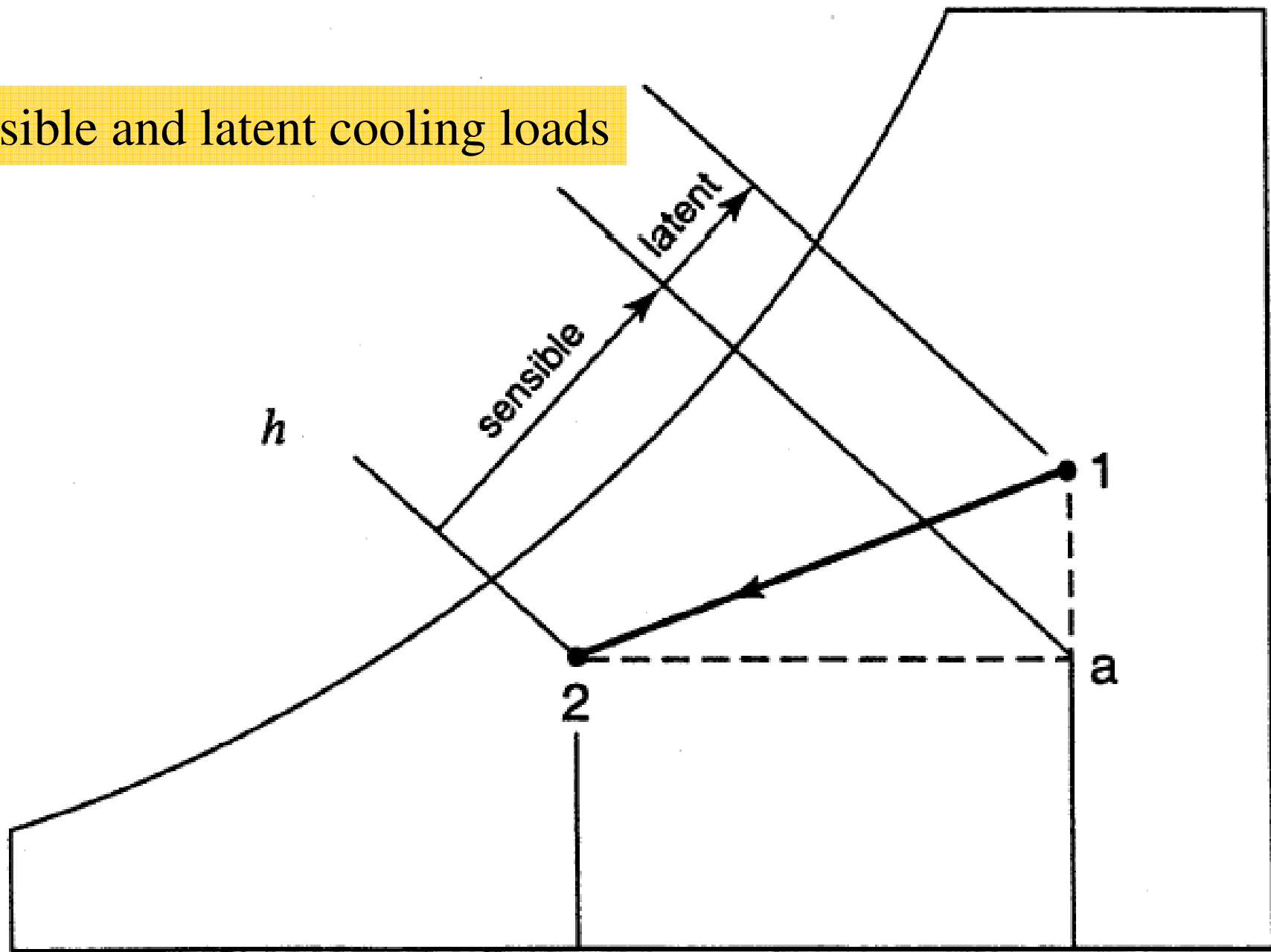
(b)

Can you draw such a cycle for Hong Kong summer conditions?

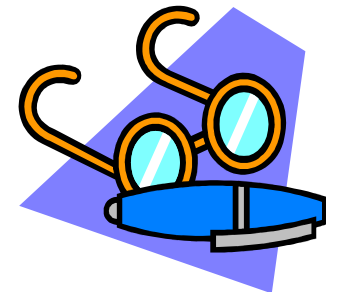
- Outdoor: DBT = 33 °C; WBT = 28 °C; flow = 20% of supply air
- Indoor: DBT = 25 °C; %RH = 50%
- Air leaving cooling coil: DBT = 13 °C; %RH = 95%

Using psychrometric chart to represent different HVAC systems

Sensible and latent cooling loads

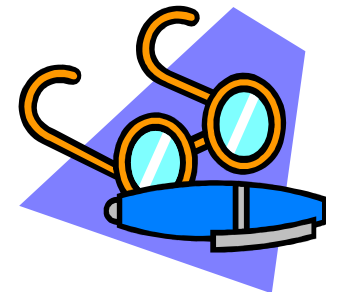


Psychrometric Processes



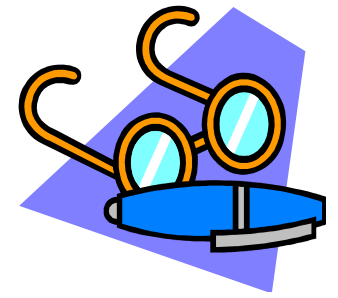
- Demonstration examples of calculations using the psychrometric chart
 - An Example Using the Psychrometric Chart (6:25)
<http://youtu.be/xzT9y0QZz20>
 - Use Psychrometric chart for cooling moist air (9:45) <http://youtu.be/A6PVsARawvs>

Psychrometric Processes



- Sensible heating coils
- Cooling coils
- Humidifiers
- Water spray types
- Steam humidifier
- Room psychrometric process
- Mixing air streams

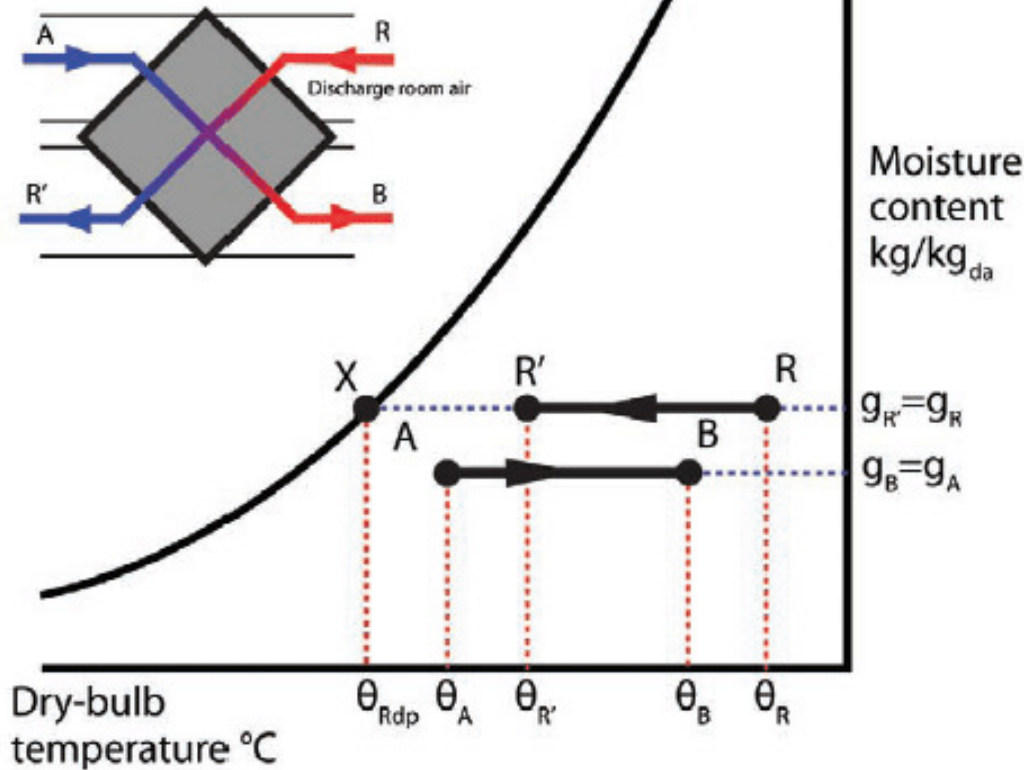
Psychrometric Processes



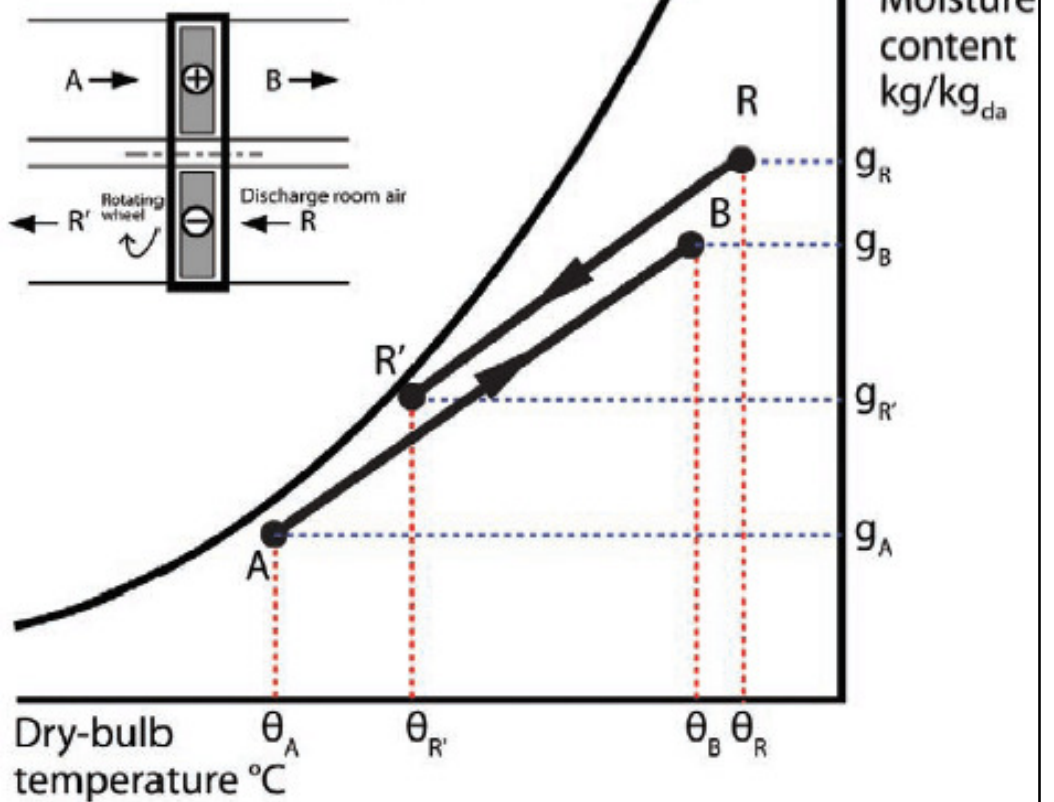
- Calculations:
 - 1. Sensible heat ratio (SHR)
 - SHR is the ratio of sensible heat load to total heat load
 - 2. Space cooling load
 - 3. Cooling coil's load/capacity
 - 4. Humidification capacity
 - 5. Mixing processes
 - Principles of heat balance & conservation of mass

The psychrometrics of HVAC sub-systems

Plate Heat Exchanger (sensible heat recovery)



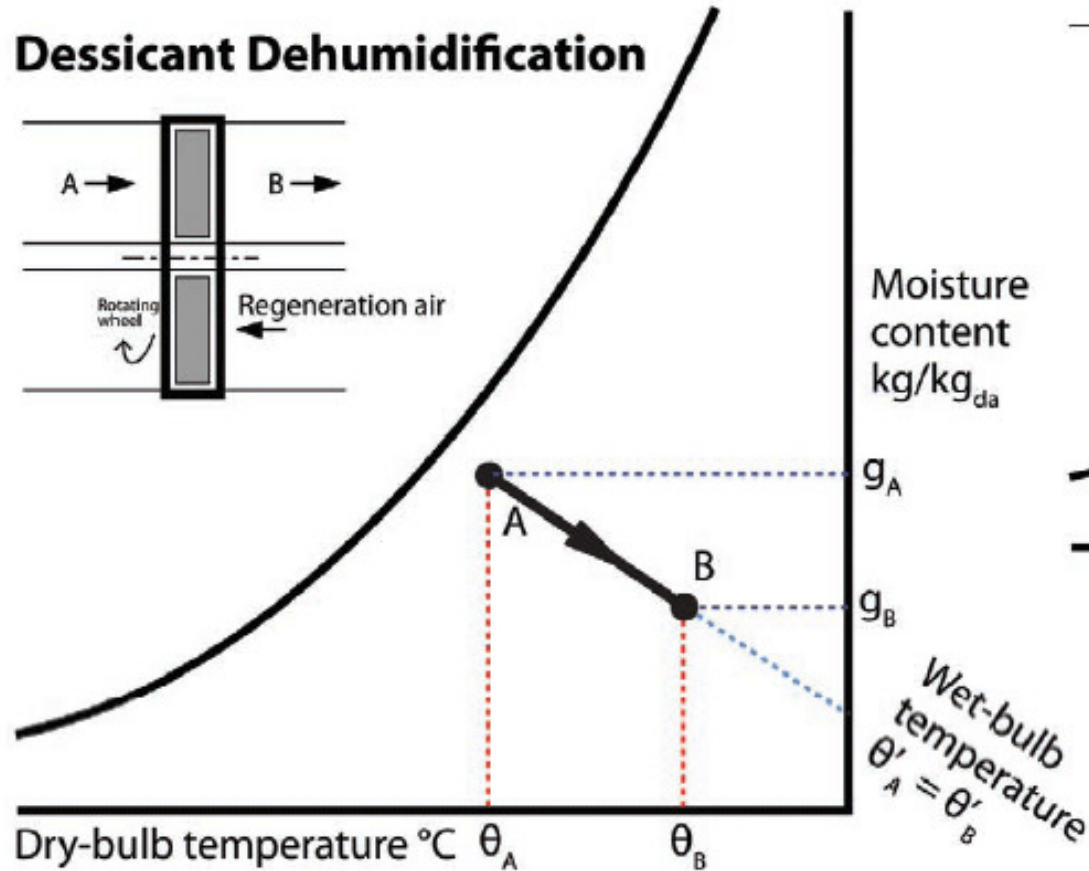
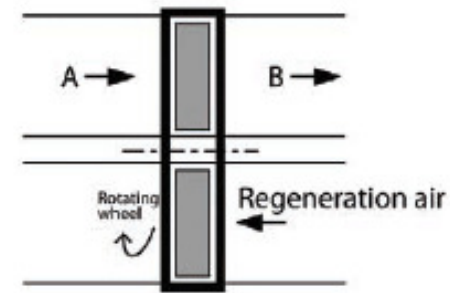
Regenerative Thermal Wheel (sensible + latent heat recovery)



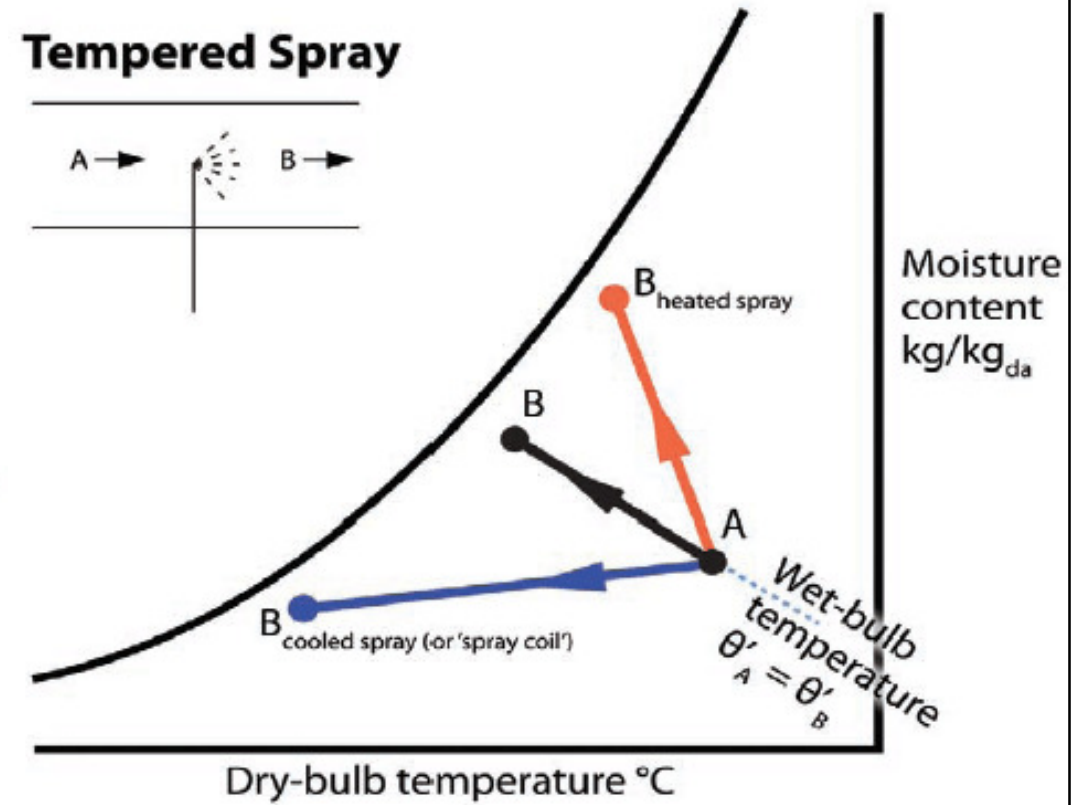
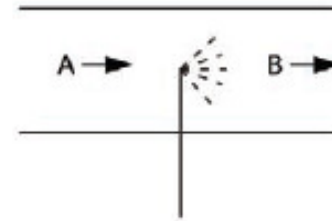
Do you know how to represent the processes of different HVAC sub-systems on the psychrometric chart?

The psychrometrics of HVAC sub-systems (cont'd)

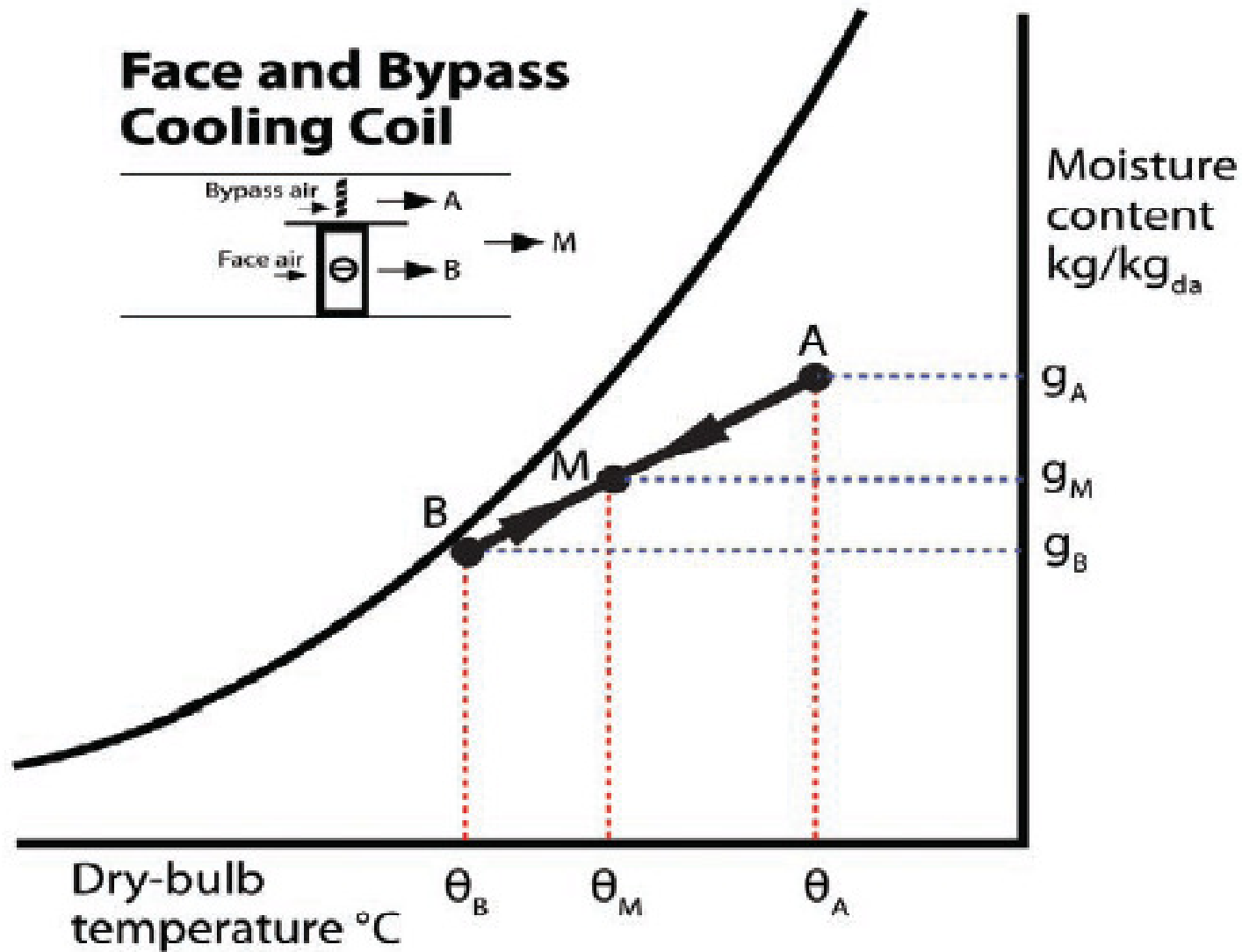
Dessicant Dehumidification



Tempered Spray



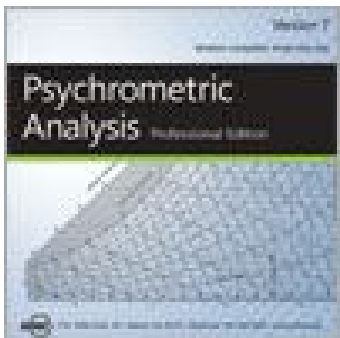
The psychrometrics of HVAC sub-systems (cont'd)



Psychrometric Software



- ASHRAE Psychrometric Analysis CD-ROM (2012, 2007, 2002) [AV 697 P97]
 - The program allows the user to plot typical psychrometric processes and perform the corresponding energy calculations
 - The program produces near-exact replications of the charts and can output a listing of points and processes in a tabular report with calculated properties and energy values for each. It includes a presentation of the ASHRAE climate data presented in the 2009 ASHRAE Handbook - Fundamentals



Psychrometric Software



- Psychrometric analysis software:
 - ArchiSci Software - PSYCHWIN
 - <http://arch.hku.hk/teaching/archisci/archisci.zip>
 - Psychrometric Chart (PSY) software
 - <http://www.vector.co.jp/soft/win95/business/se288946.html>
 - Daikin's Psychrometrics tool
 - http://me.hku.hk/bse/MEBS6006/Psychrometric_diagram_viewer_V210_tcm24-133157.zip
- Free Online Psychrometric Chart
 - <http://www.flycarpet.net/en/PsyOnline>

Free Online Psychrometric Chart <http://www.flycarpet.net/en/PsyOnline>

www.flycarpet.net/en/PsyOnline

Home About Projects Contact

Free Online Psychrometric Chart World's first online, and only! A convenient, precise and powerful psychrometric chart & calculator tool for HVAC engineers.

Basic Process Cycle 1 Cycle 2 Setting Display 简体中文

Click on chart for air properties

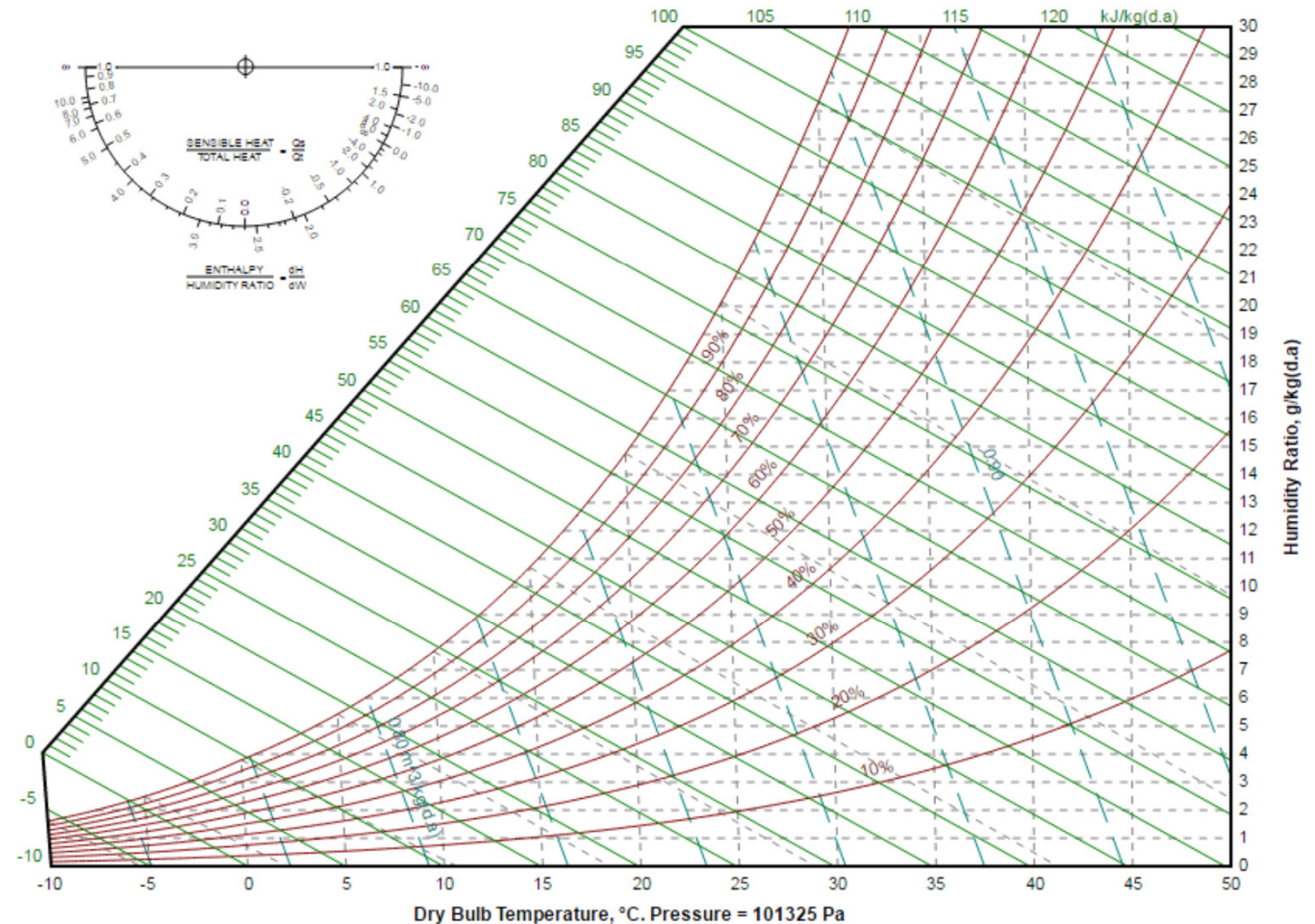
Or input data for air properties

T.Dry, °C 25

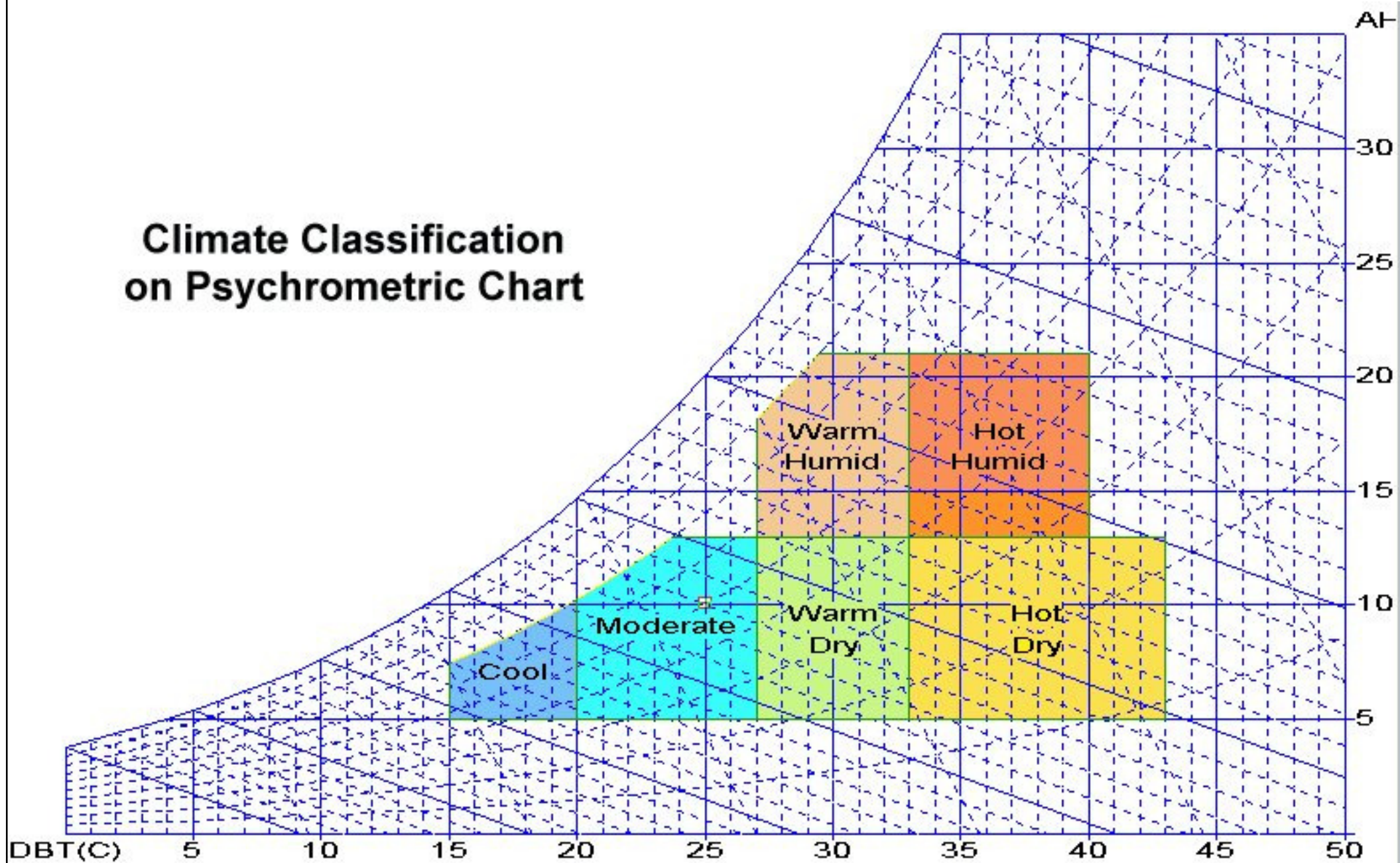
Rel.Humid, % 50

Quantity	Value	Units
P.Ambient		Pa
T.Dry.Bulb		°C
Humid.Ratio		g/kg(d.a)
Rel.Humid		%
T.Wet.Bulb		°C
T.Dew		°C
T.Saturation		°C
Enthalpy		kJ/kg(d.a)
P.Vapour		Pa
P.Sat.Vapour		Pa
Spec.Heat		kJ/(kg.K)

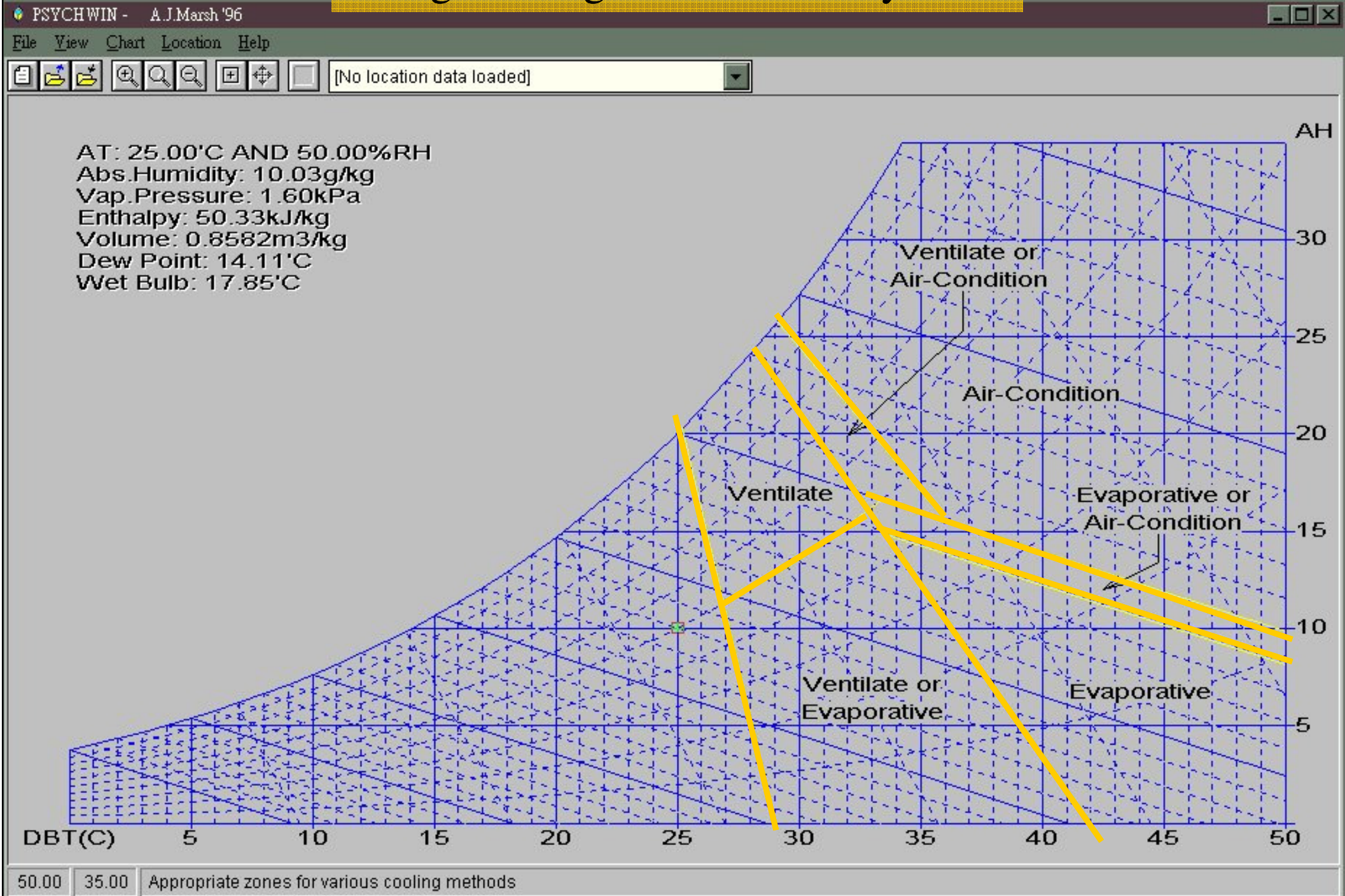
Stop and Play. We have a free small game for you: Survive Broken. Click to start play.



Climate Classification on Psychrometric Chart

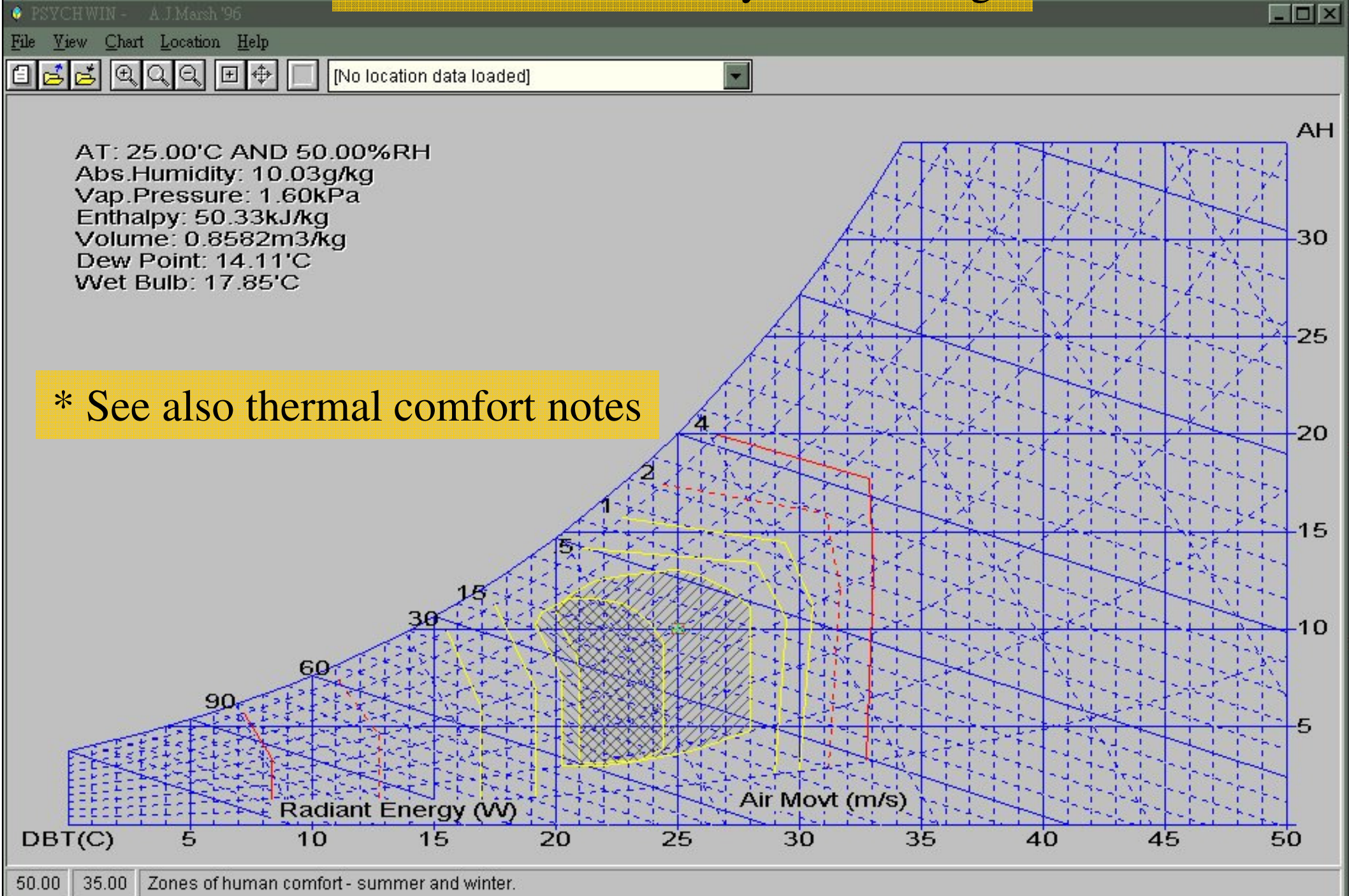


Design strategies for HVAC systems

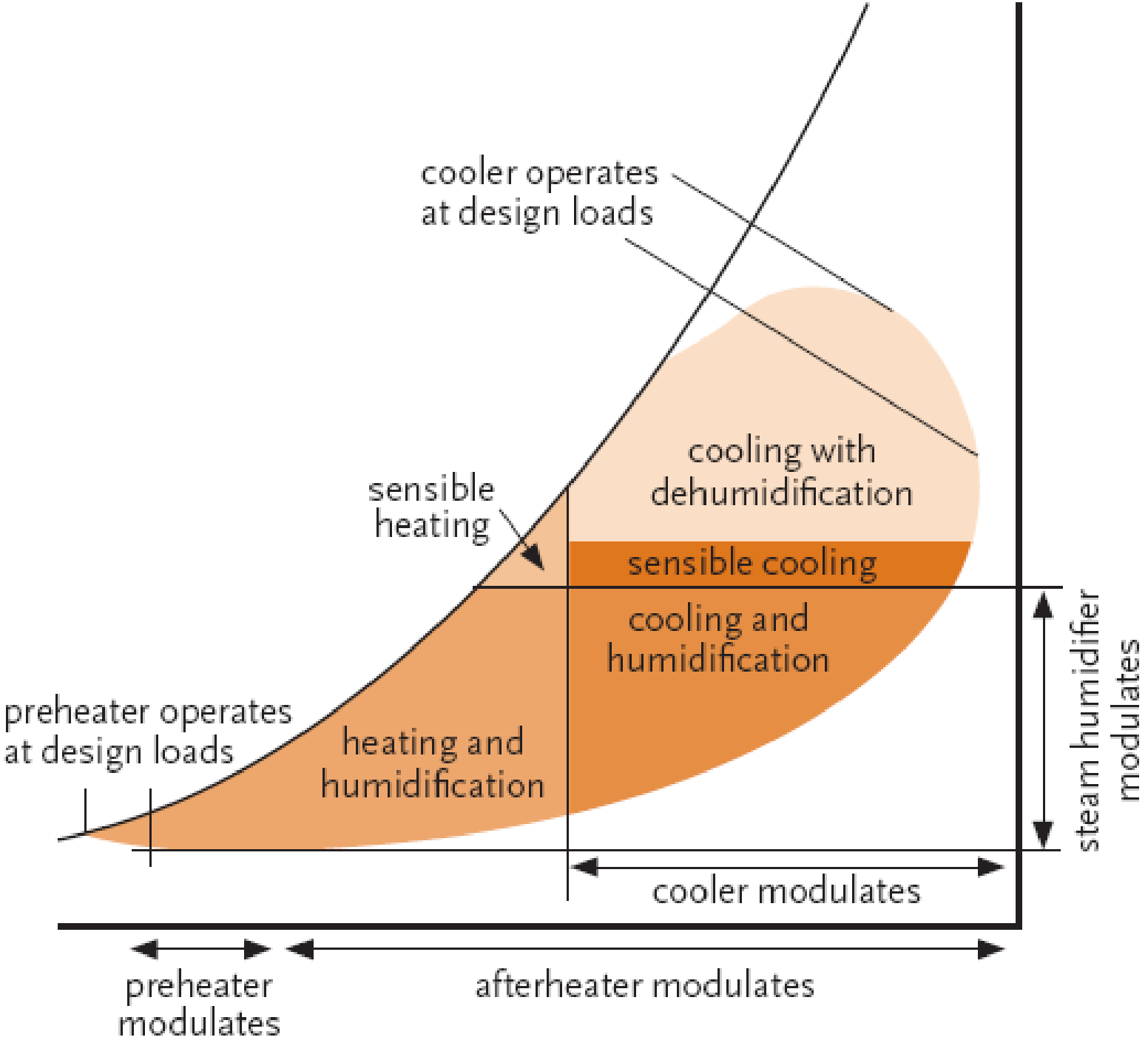


(Source: ArchiSci Software - PSYCHWIN)

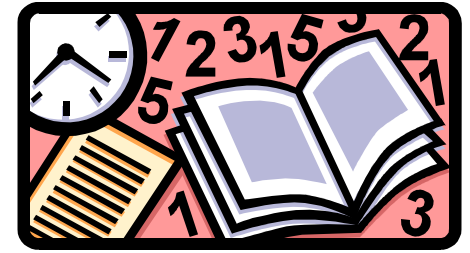
Thermal comfort analysis and design



All-year-round operating regime based on outdoor conditions

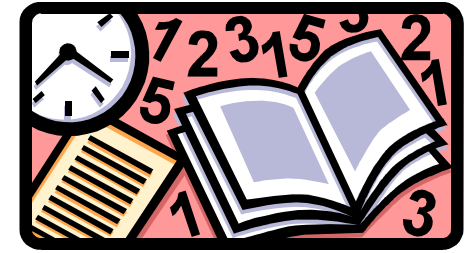


(Source: CIBSE Journal CPD Programme: The psychrometrics of air conditioning systems (Mar 2010) <http://www.cibsejournal.com/cpd/2010-03/>)



Further Reading

- Air Conditioning: Psychrometrics
 - http://www.arca53.dsl.pipex.com/index_files/psy1.htm
- CIBSE Journal CPD Programme:
 - <http://www.cibsejournal.com/cpd/>
 - The properties of air (Apr 2009)
 - Applying the psychrometric relationships (Aug 2009)
 - The Basic Psychrometric Processes (Oct 2009)
 - The psychrometrics of HVAC sub-systems (Dec 2009)
 - The psychrometrics of air conditioning systems (Mar 2010)
 - Travelling into time with psychrometry (Dec 2010)



References

- ASHRAE Psychrometrics Tools
 - www.ashrae.org/resources--publications/bookstore/psychrometrics
 - Psychrometric Chart App (on iPad)
 - ASHRAE HVAC Psychrometric Chart App (8:11)
<http://www.youtube.com/watch?v=VFFqkBHDqPk>
 - Psychrometric Analysis CD, Version 7 (2012)
 - Understanding Psychrometrics, 3rd ed. (2013)

