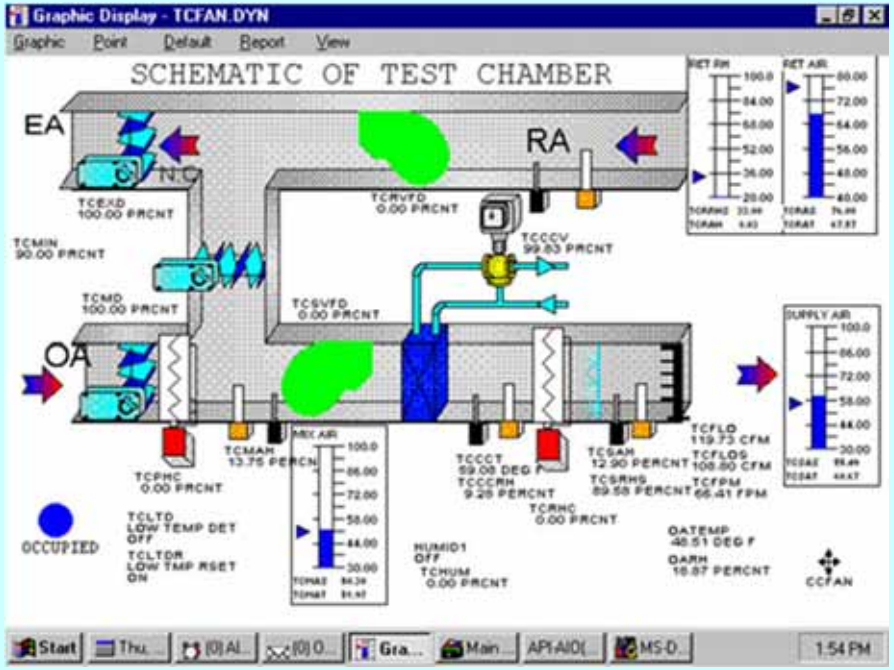
MEBS6006 Environmental Services I

http://me.hku.hk/bse/MEBS6006/



Introduction

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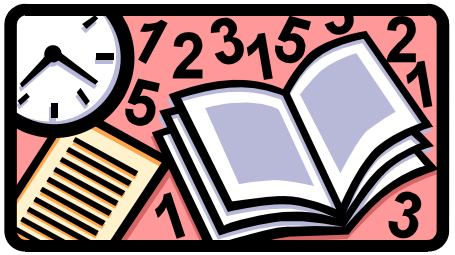
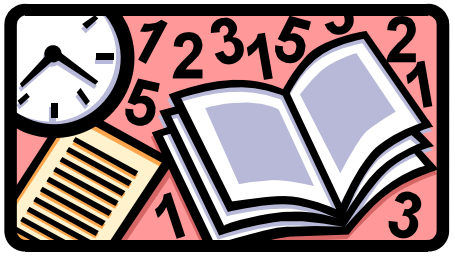
Course Background



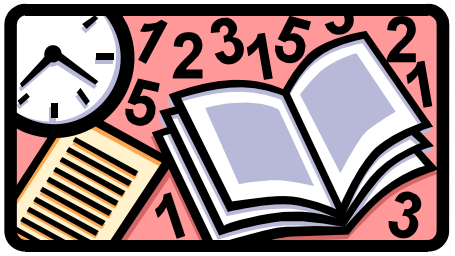
- MEBS6006 Environmental Services I
  - Educational Objectives
    - To enable students to understand the basic principles of design and operation of heating, ventilating, air-conditioning and refrigerating (HVAC&R) systems for environmental control of buildings
    - To enable students to design and select proper HVAC&R systems to serve the desired purpose

Course Background

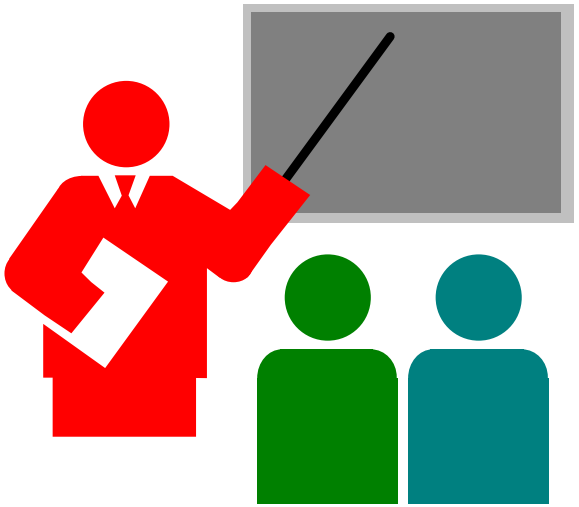


- MEBS6006 Environmental Services I
  - Learning Outcomes:
    - To explain the fundamental principles of HVAC&R systems for environmental control of buildings.
    - To develop skills for design and selection of HVAC&R systems.
  - Assessment:
    - 80% by written examination (2 hours)
    - 20% by continuous assessment

Course Background



- These two courses are related
  - MEBS6006 Environmental services I
    - Basic principles of HVACR
    - Practical design skills
  - MEBS6008 Environmental services II
    - System characteristics and operation
    - Analysis and design strategies



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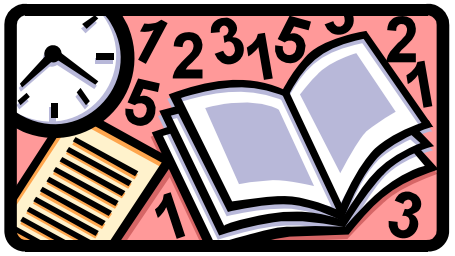


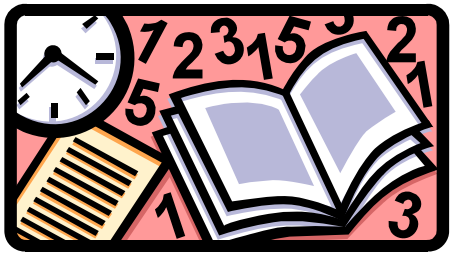
- Study topics of MEBS6006:
  - Introduction
  - Advanced psychrometry
  - Thermal comfort
  - Load estimation
  - Energy calculations

Dr. Sam C M Hui

  - Cooling system
  - Heating and ventilation system
  - Air side system
  - Water side system
  - Refrigeration

Dr. Benjamin P L Ho

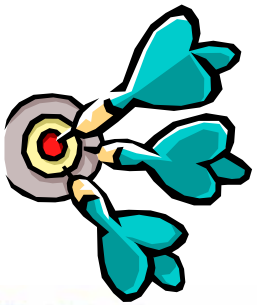
Course Background



- Assumptions
  - You have basic knowledge of thermodynamics and fluid mechanics
  - You are interested in developing your knowledge and skills in HVAC
- Focus of this course
  - From basic principles to intermittent level of HVAC design skills
  - Main focus on cooling design and air conditioning

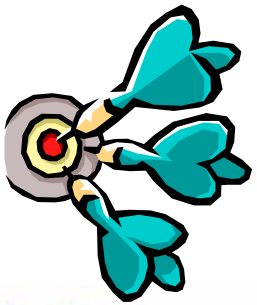
What is Environmental Services?

Environmental Services



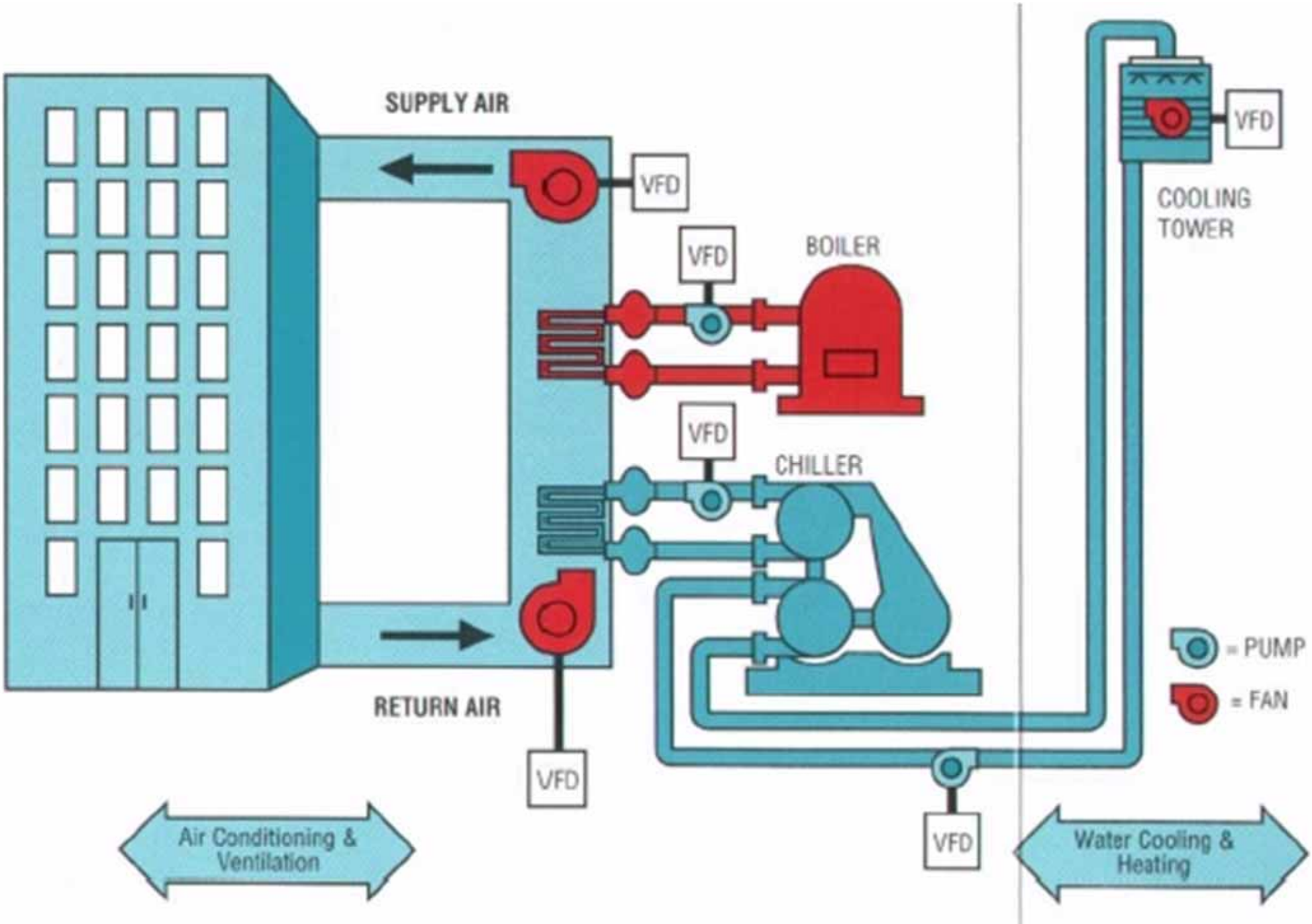
- They are the engineering systems that help to control and maintain the conditions of indoor built environment
- Also known as:
  - Environmental control systems (ECS)
  - Heating, ventilating, air-conditioning and refrigerating (HVAC&R) systems
  - Heating, ventilating and air-conditioning (HVAC)
  - Mechanical ventilating and air-conditioning (MVAC)
  - Air conditioning and refrigeration (AC&R)

Environmental Services



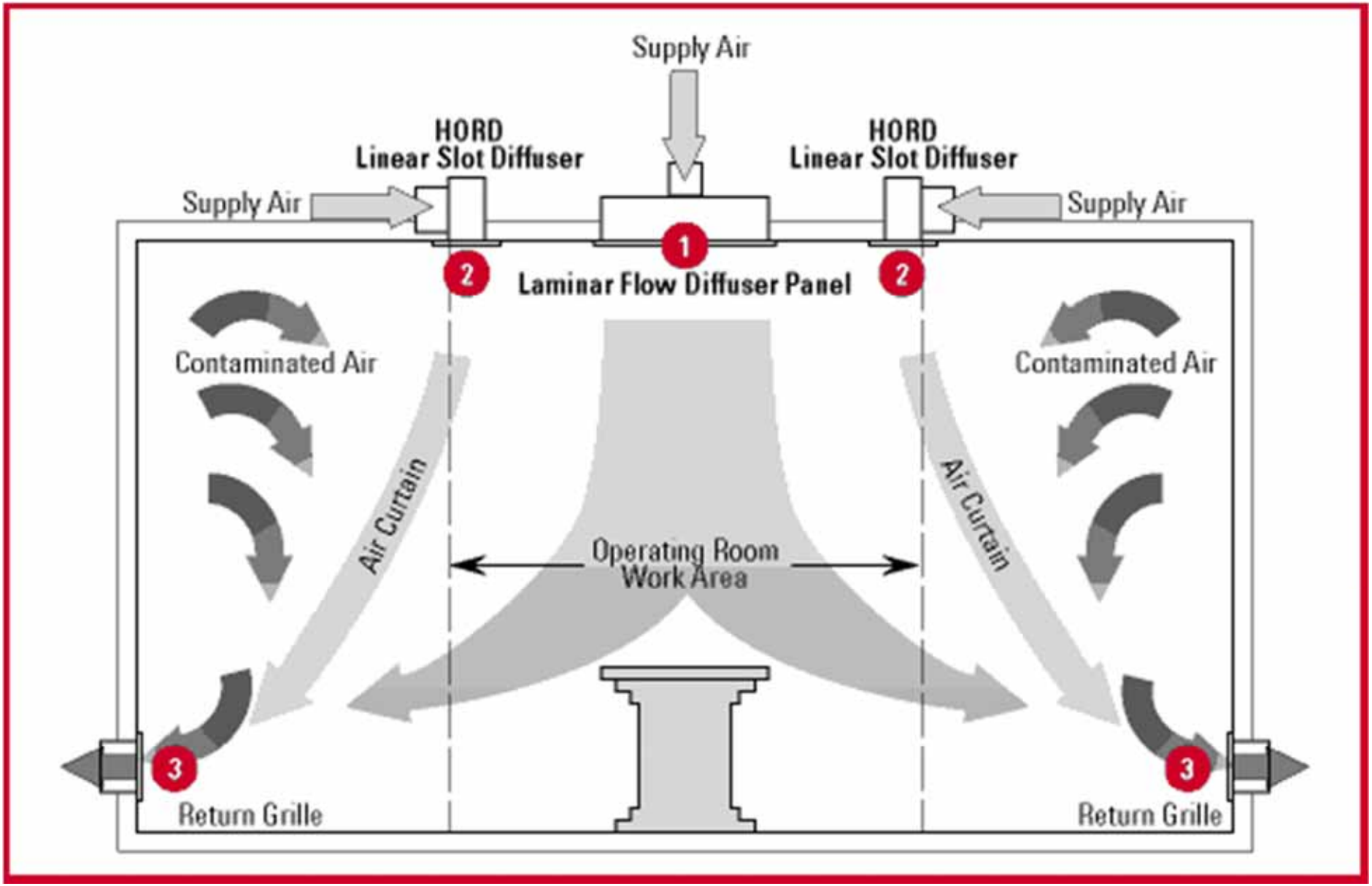
- Importance of HVAC for environmental control in buildings
  - Affect occupant satisfaction, productivity, health and safety
  - Contribute to effective building performance
  - Often form a major part of building construction costs and running costs
  - Affect energy consumption & environmental performance of a building

A centralised HVAC system



(Source: http://www.allhvacinfo.com/)

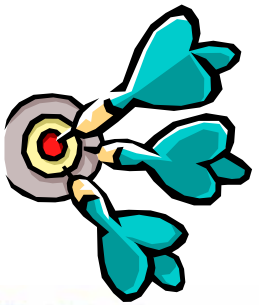
HVAC is critical for hospitals



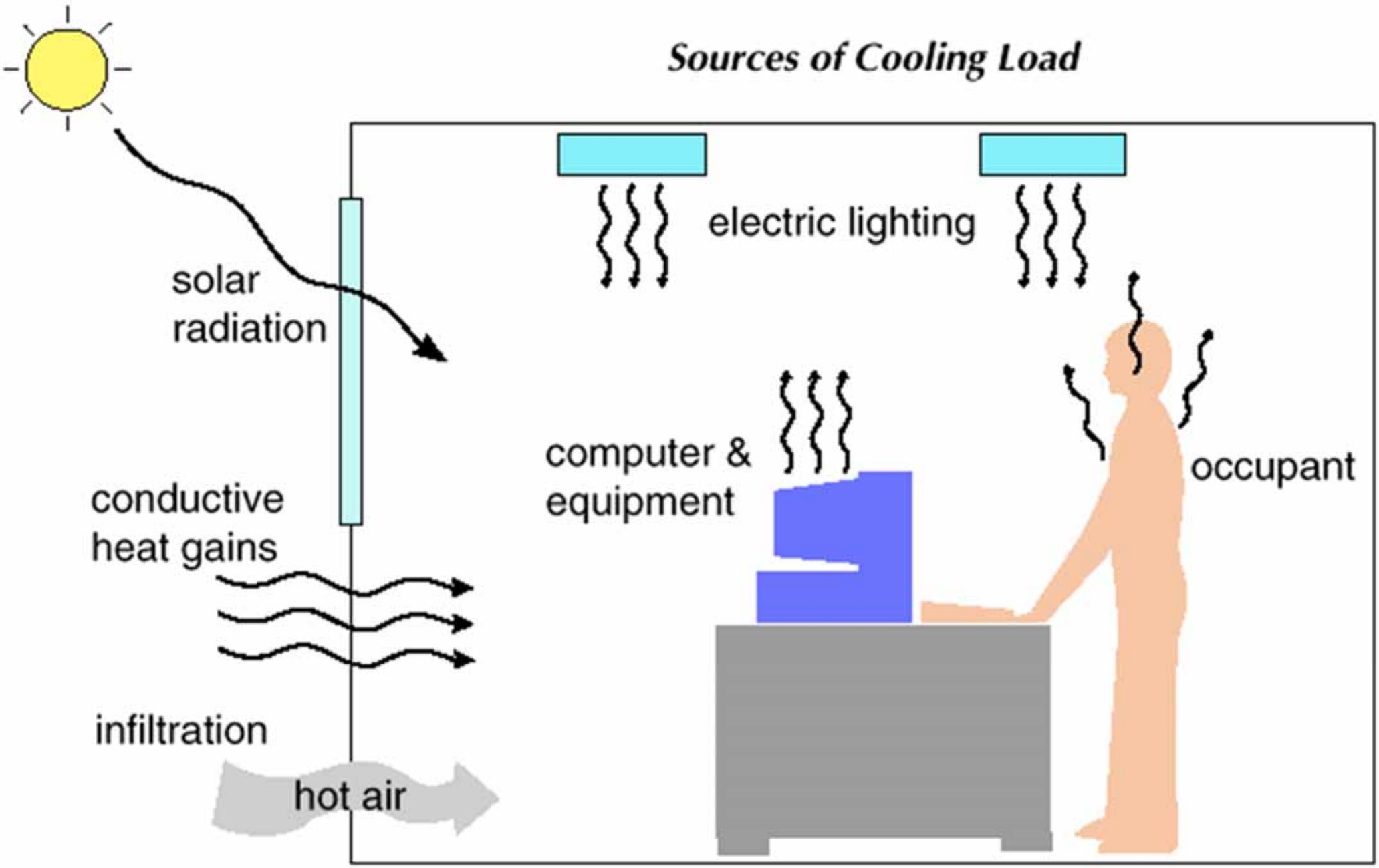
Hospital operating theatre (laminar flow with air curtains)

(Source: http://www.price-hvac.com)

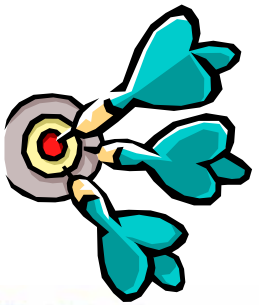
Environmental Services



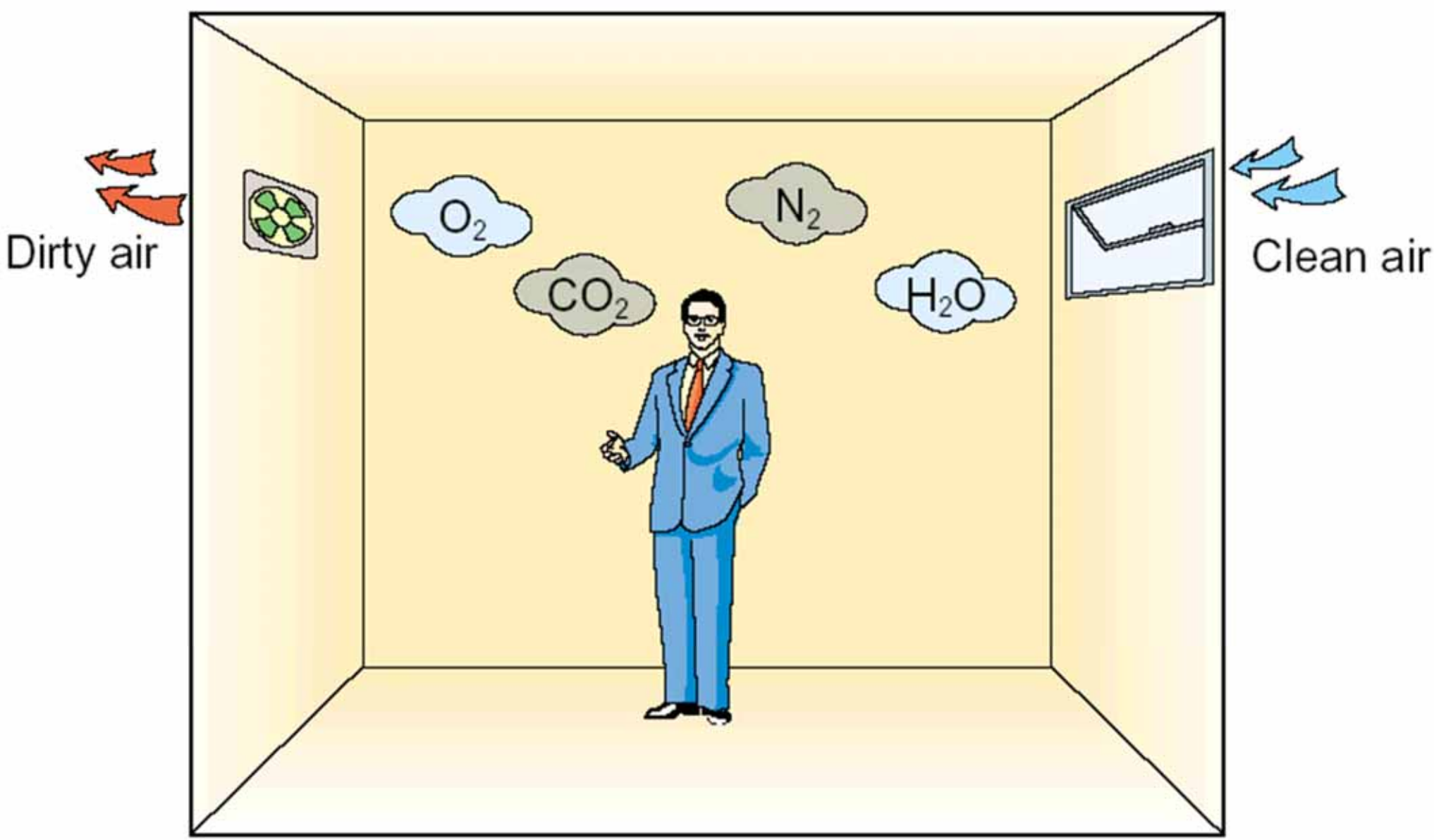
- Interactions affecting HVAC
  - Building fabric (architectural design)
    - Site orientation & conditions
    - Built form, shading, window performance, thermal mass
    - Thermal insulation, reducing infiltration/air leakage
  - Building services elements, e.g.
    - Lighting system & daylighting
    - Small power or equipment loads
  - Occupants' behaviour (human factors)
    - How users behave and react


Sources of Cooling Load
electric lighting
solar
radiation
computer &
equipment
occupant
conductive
heat gains
infiltration
hot air

Environmental Services

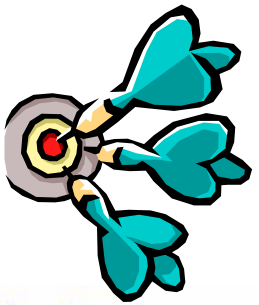


- Understand the purpose of the HVAC design
  - To provide adequate indoor air quality by removing and/or diluting indoor pollutants
  - To provide adequate ventilation for processes
  - To remove heat & maintain thermal comfort
  - To control humidity & prevent condensation
- Understand the climate
  - Summer: cooling design & dehumidification
  - Winter: heating design

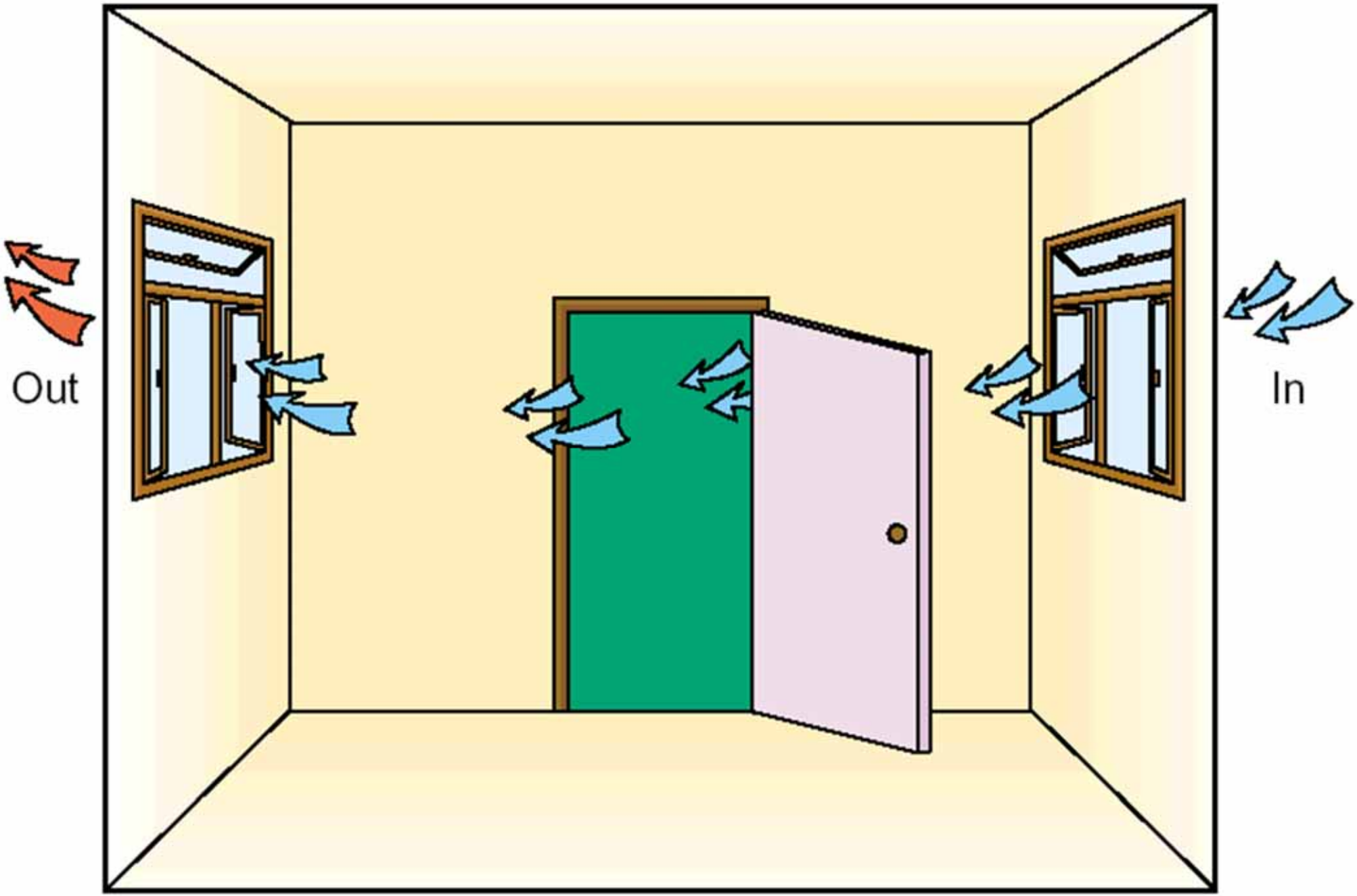


(Source: www.iaq.hk)

Environmental Services



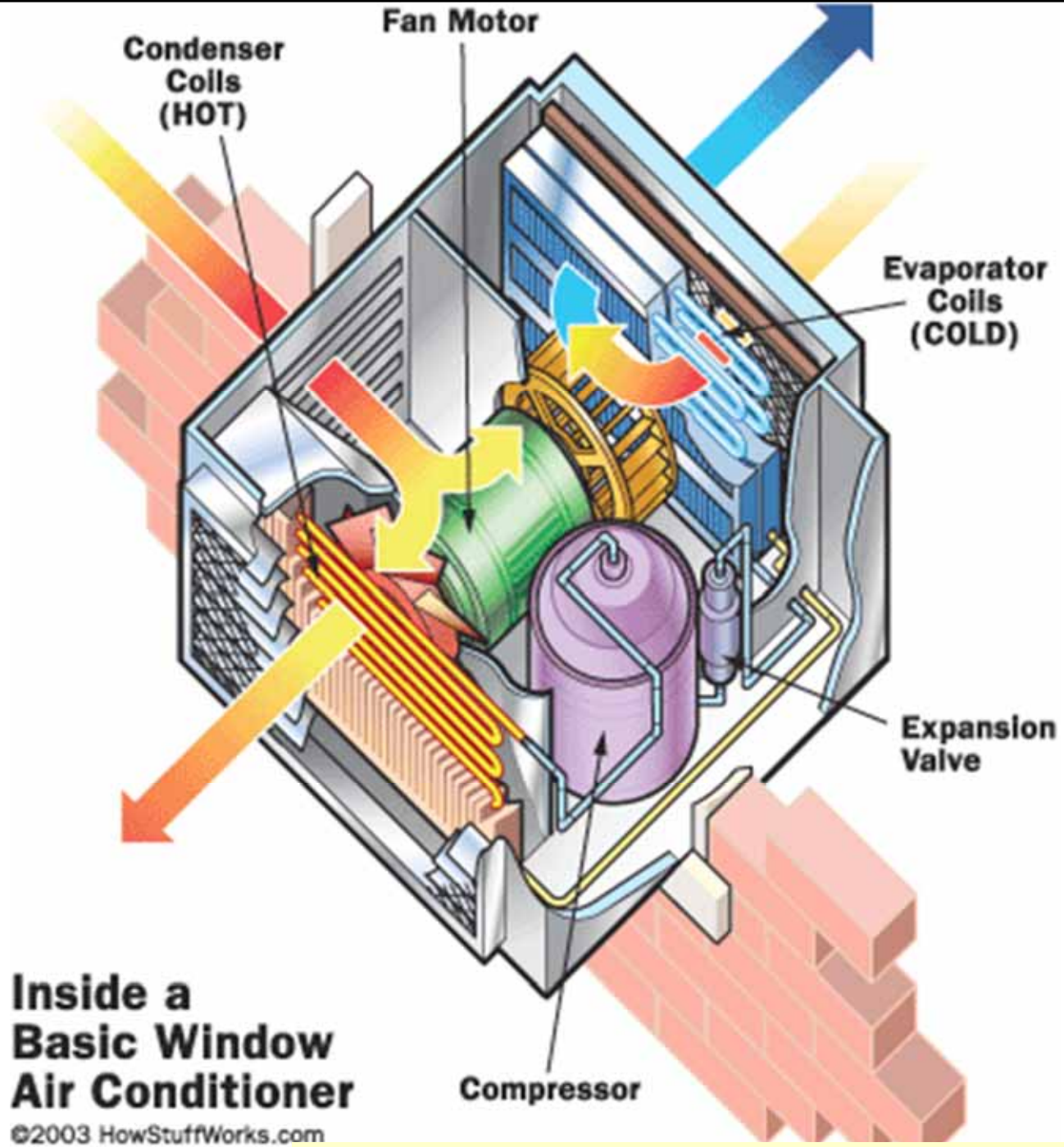
- Common ventilation strategies
  - Natural ventilation
  - Mechanical ventilation
  - Comfort cooling
  - Air conditioning (full control of temp./humidity)
  - Mixed mode or hybrid systems
- If internal heat gains are sufficiently low and the external environment is suitable, natural ventilation can provide a low energy solution



Cross ventilation

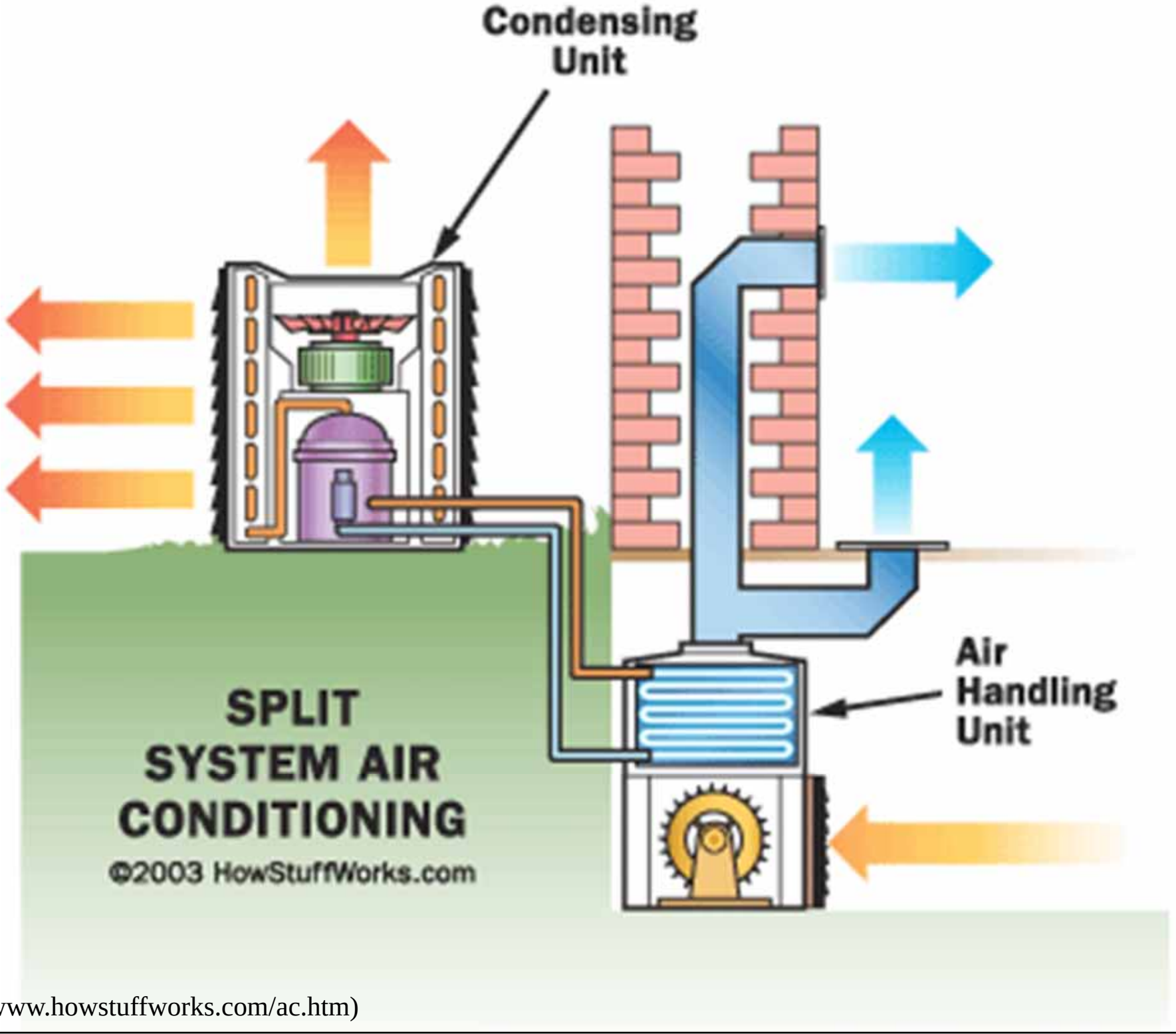
(Source: www.iaq.hk)

(Source: www.iaq.hk)



See also: “How Air Conditioners Work” (1:07)
http://youtu.be/nKZ2DPvvua8

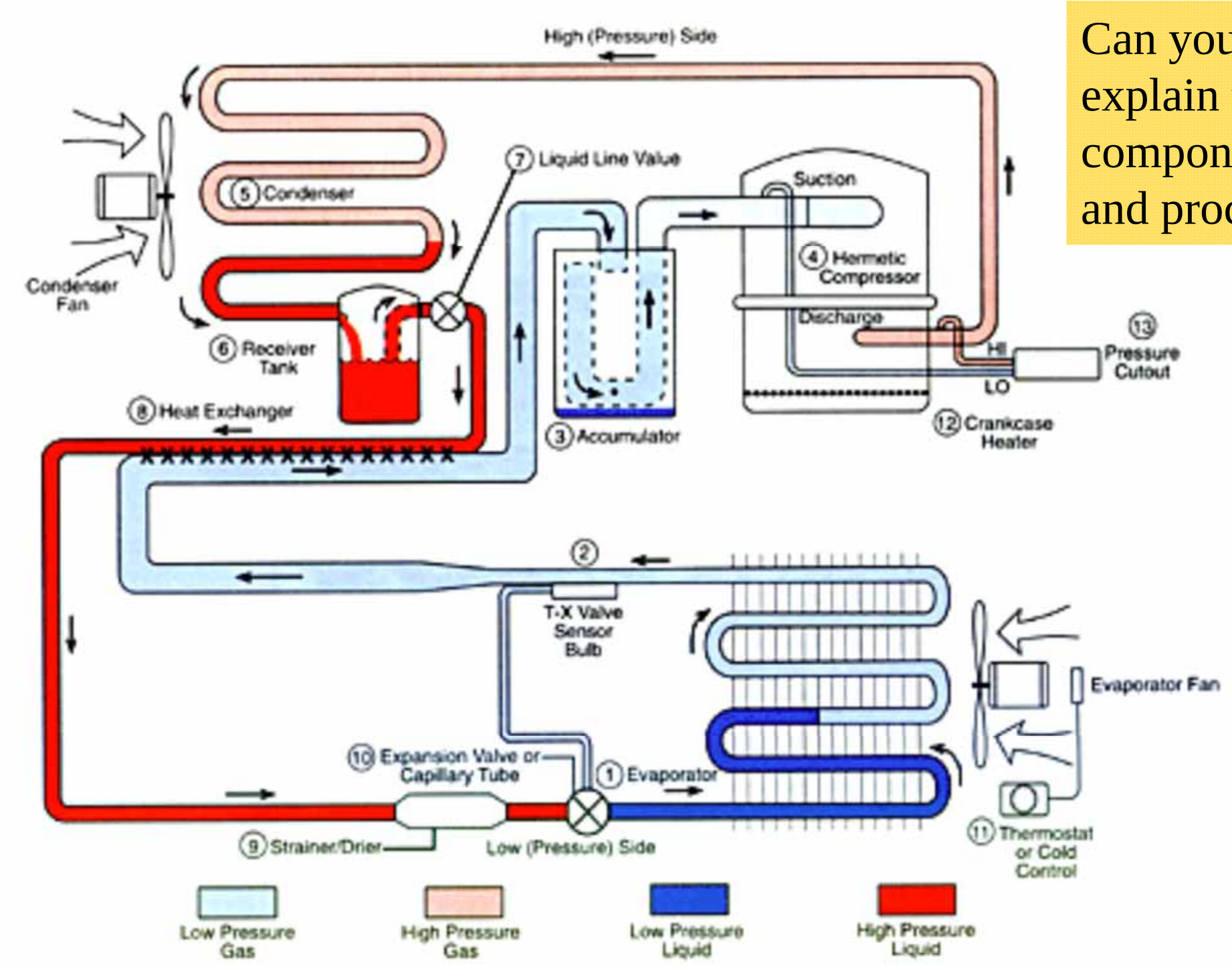
(Source: www.howstuffworks.com/ac.htm)



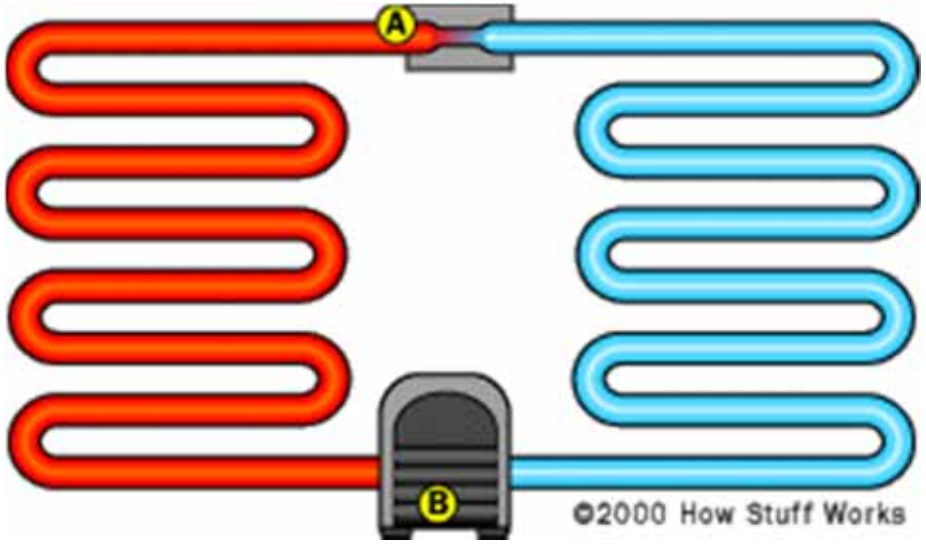
(Source: www.howstuffworks.com/ac.htm)

Basic refrigeration cycle

Can you explain the components and process?

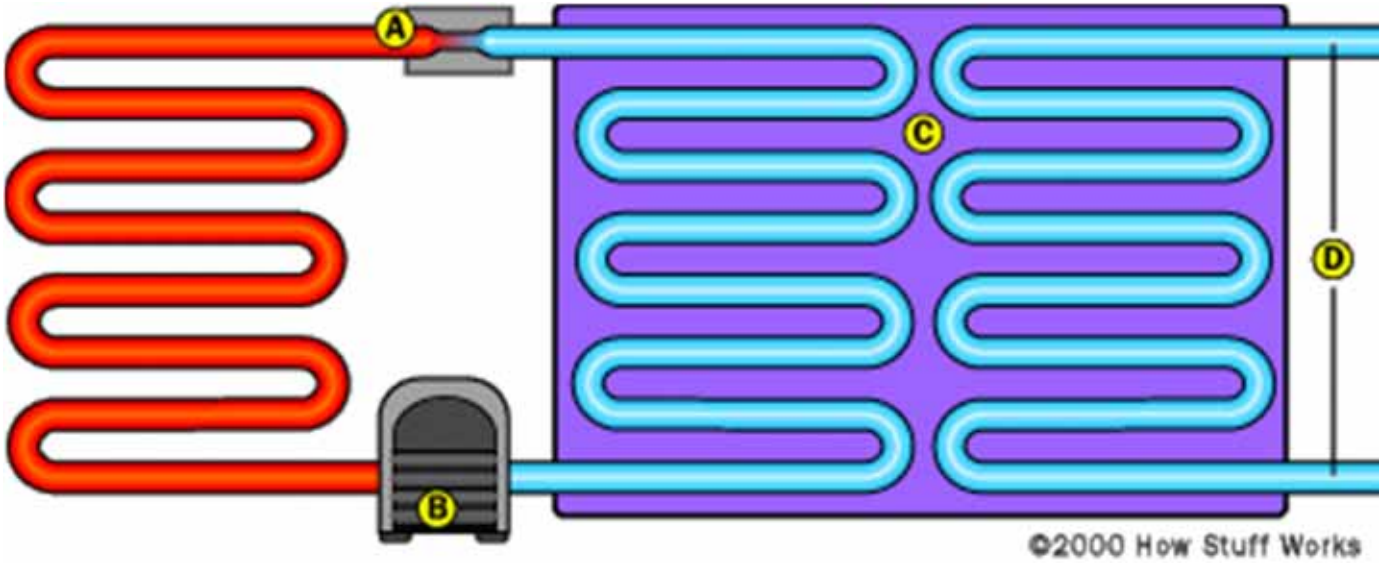


Refrigerant cycle



What are the major components?

A typical air conditioner

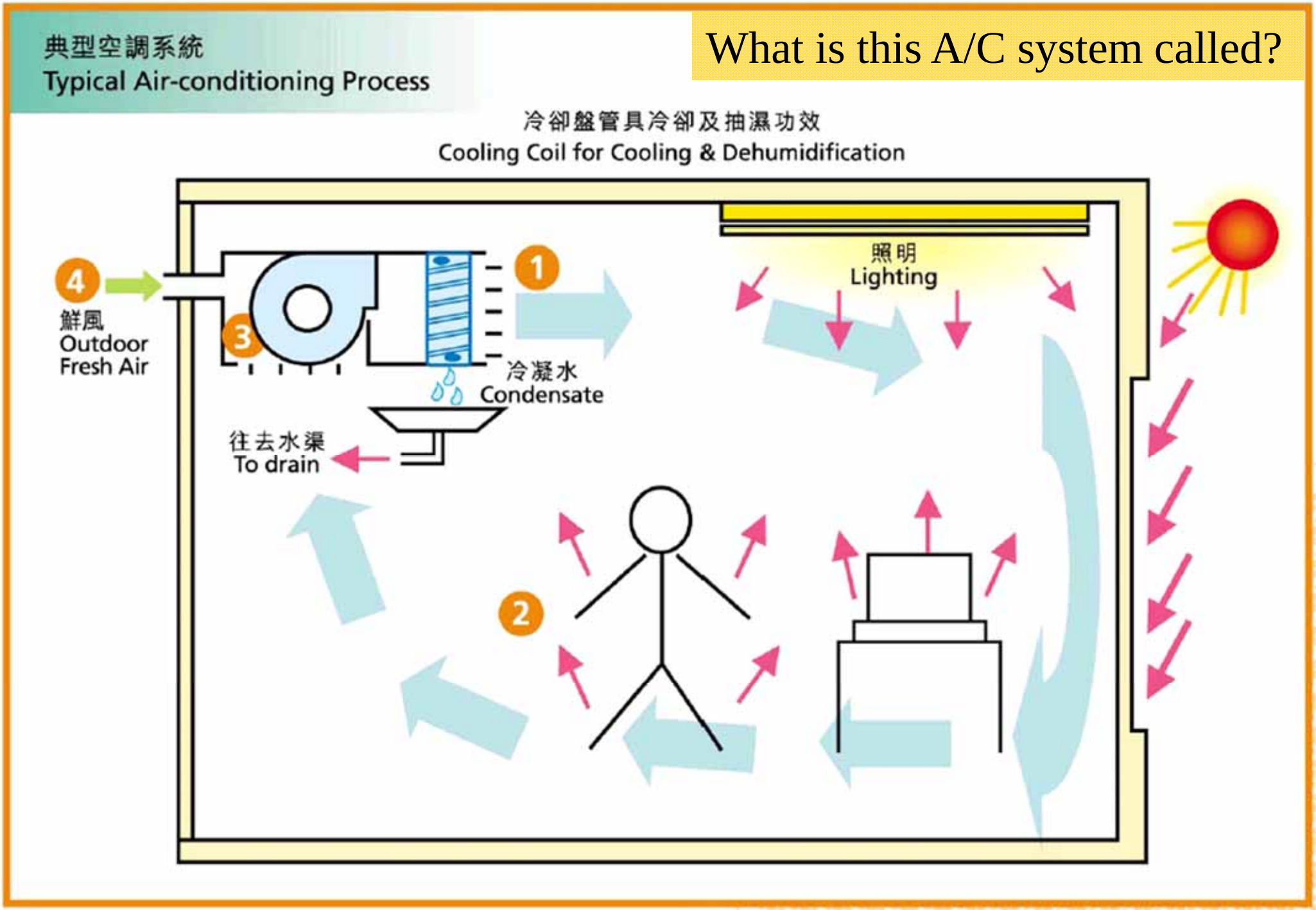


Chilled water system

Air conditioning with a chilled water system

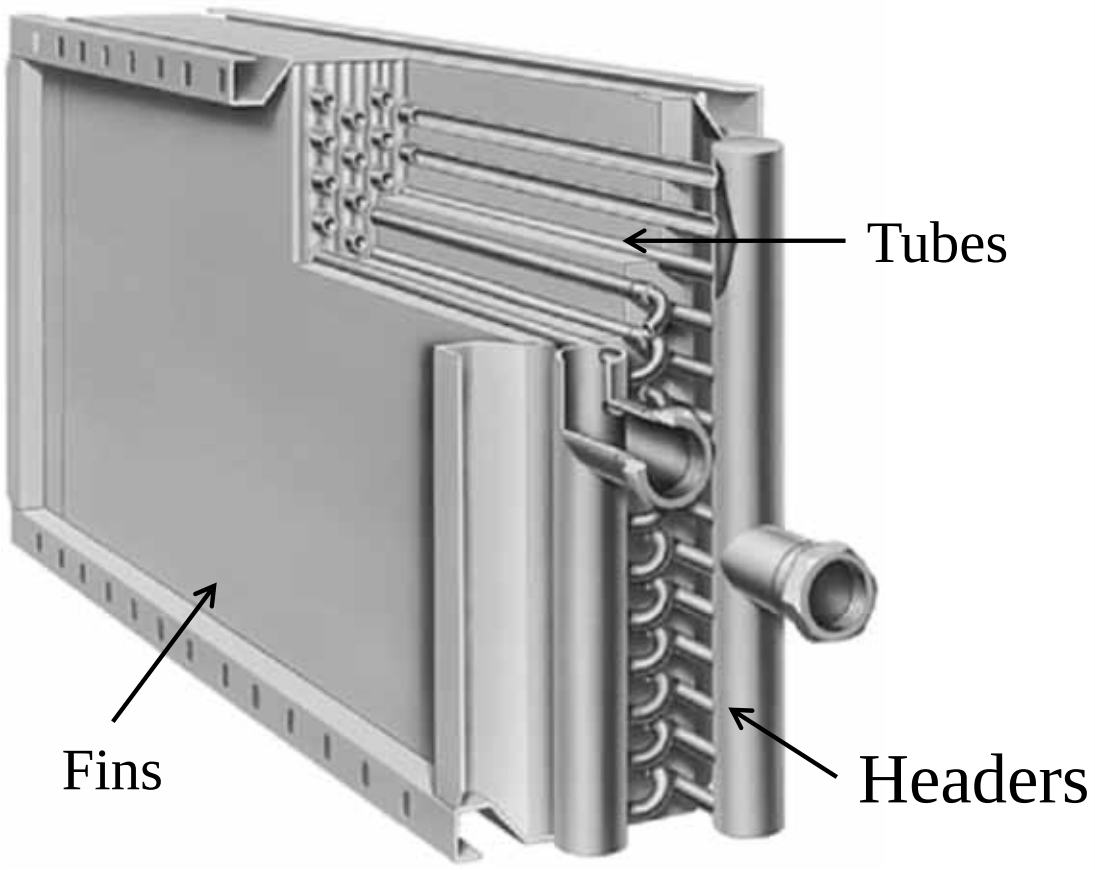
(Source: www.howstuffworks.com/ac.htm)

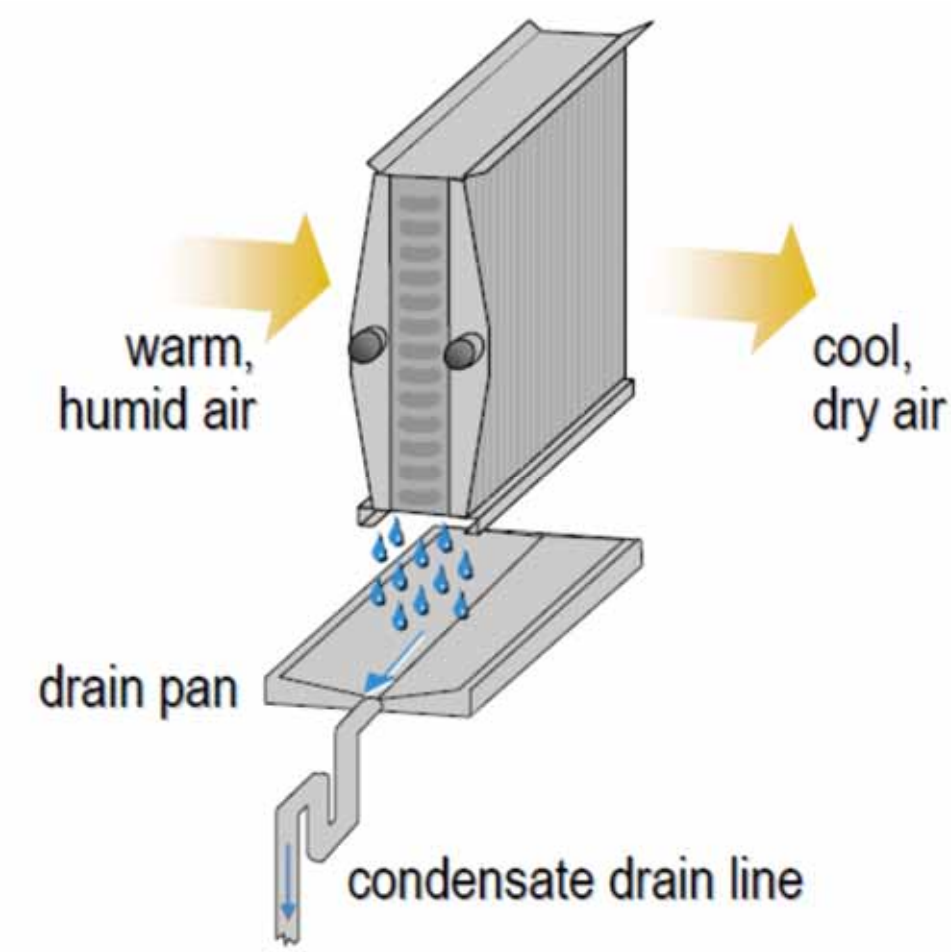
What is this A/C system called?



(Source: EnergyWitts newsletter, EMSD)

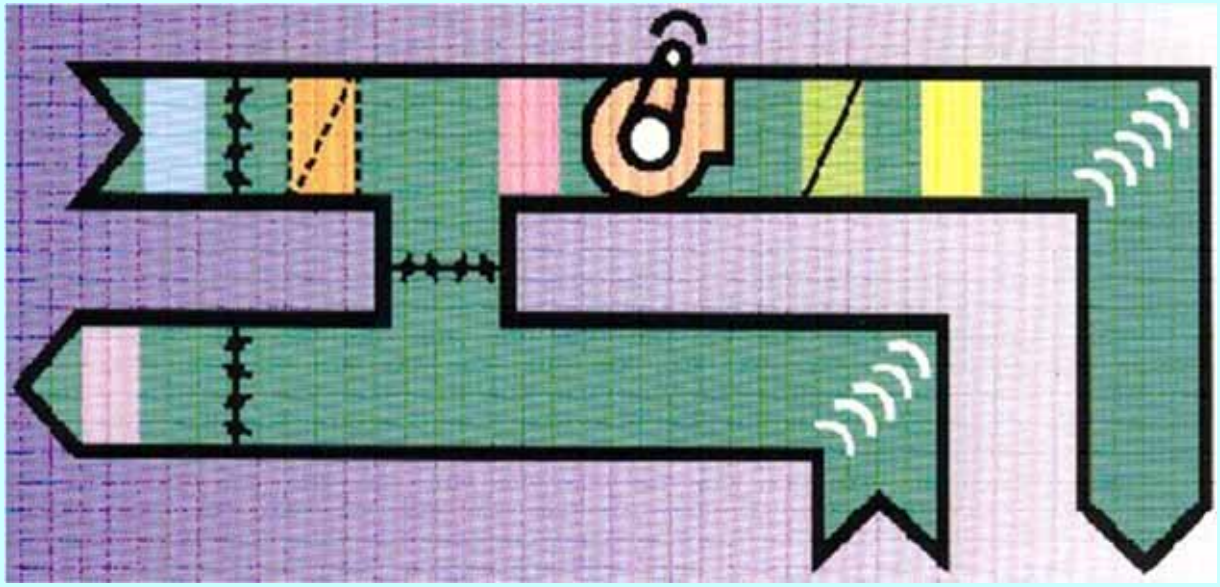
Chilled water cooling coil

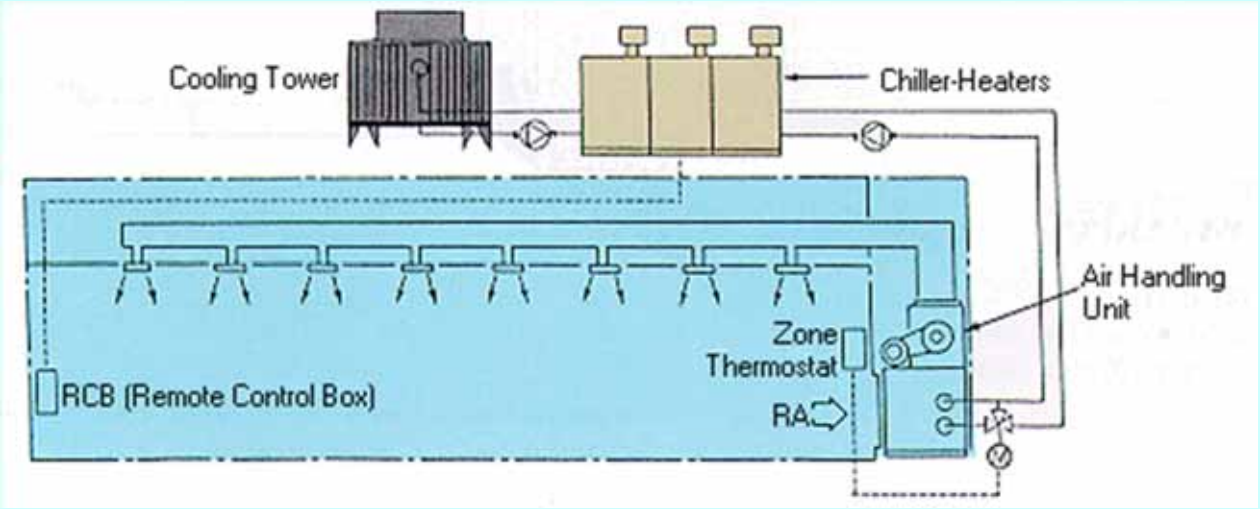




(Source: Trane)

Air Conditioning





Air Conditioning

- Definition (from ASHRAE*)
  - Air conditioning is the process of treating air so as to control simultaneously its temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space.
    - Basic processes: Cooling and Heating
- Comfort air conditioning
  - To meet comfort requirements of occupants

(*ASHRAE = American Society of Heating, Refrigerating & Air-conditioning Engineers, Inc.)

Air Conditioning

- Applications of air conditioning:
  - Industrial air conditioning
    - e.g. textile mills, electronics, pharmaceutical
  - Air conditioning of commercial buildings
    - e.g. offices, hotels, retails
  - Residential air conditioning
  - Air conditioning of vehicles (buses, cars, trains, aircrafts, etc.)

Air Conditioning

- Air Conditioning and Refrigeration
  - No. 10 on the list of the [Greatest Engineering Achievements of the 20th Century]
  - http://www.greatachievements.org
    - These cooling technologies have altered some of our most fundamental patterns of living
    - Buildings are climate-controlled & comfortable
    - Fresh foods & milk are kept in refrigerators/freezers
    - Building designs are changed completely
    - Environment for industrial processes are controlled

Air Conditioning

- The History of Air Conditioning
  - http://www.air-conditioners-and-heaters.com/air_conditioning_history.html
    - 1830: Dr. John Gorrie (ice for cooling hospital rooms)
    - 1881: James Garfield (device w/ melted ice water)
    - Late 19th century: “manufactured air” (controlling humidity in textile mills)
    - Early 1900s’: Willis Carrier (designed modern A/C systems for offices, apartments, hotels, hospitals)
    - 1917-1930: movie theatres were kept cool by A/C

A history of comfort cooling using ice

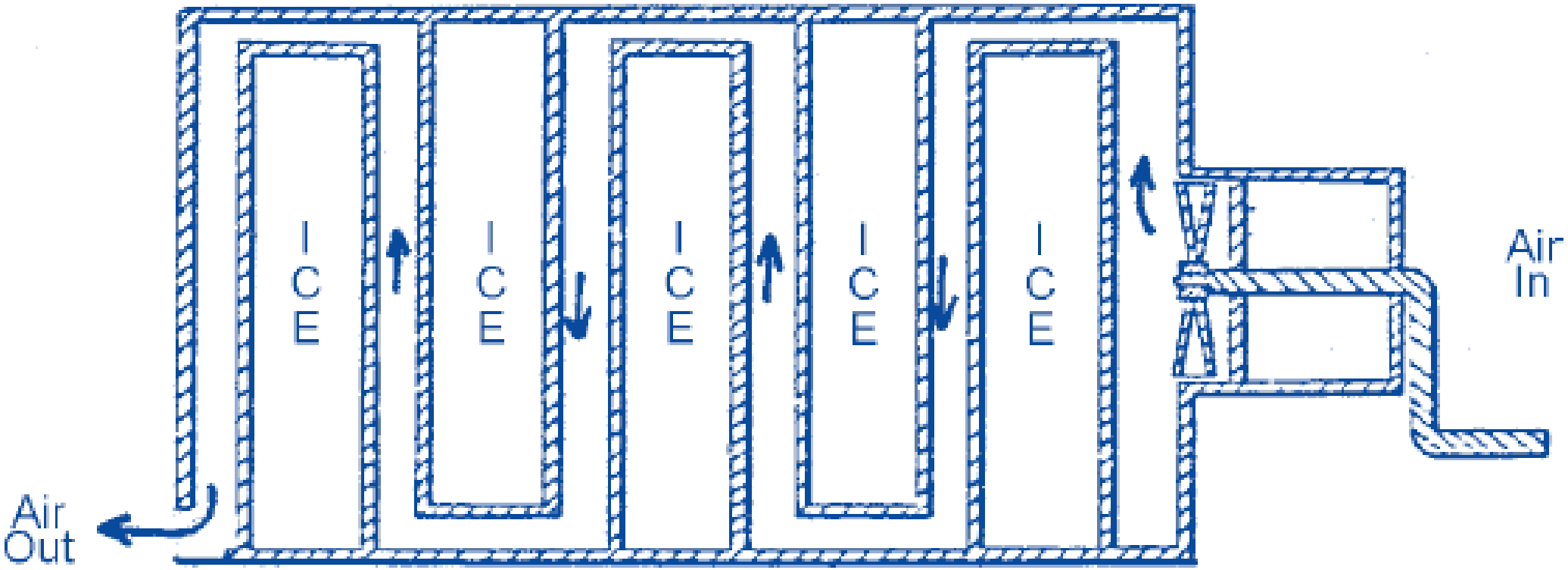


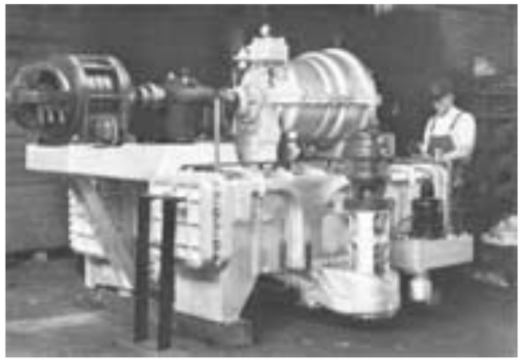
Figure 1: Shaler's patented cooler for ventilating air, 1865.

(Source: ASHRAE Journal, Feb 1999)

Air Conditioning

- The Father of Modern Air Conditioning
  - Dr. Willis Haviland Carrier (1875-1950)

  - Formed Carrier Air Conditioning Company (1907)
  - Published a paper on rational psychrometric formulae in 1911
  - Invented and patented many HVAC equipment
  - Wrote a well-known air conditioning textbook



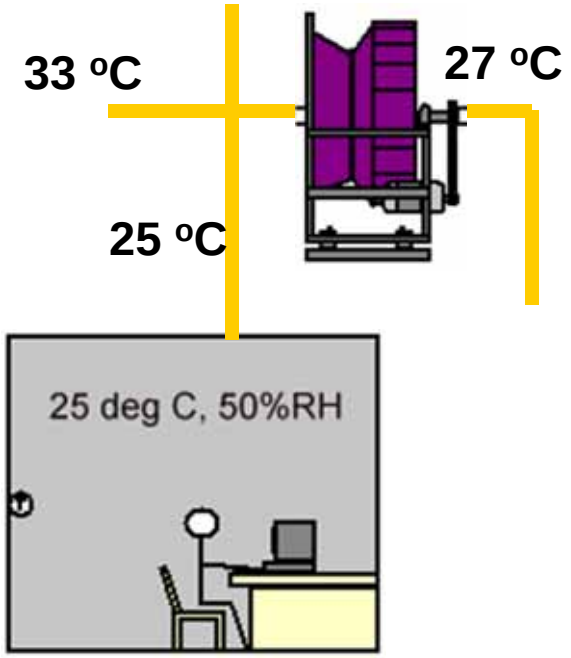
Air Conditioning

- Importance of air conditioning for buildings
  - Change building designs & human adaptation
  - Affect occupant satisfaction, productivity, health and safety
  - Contribute to effective building performance
  - Often form a major part of building construction costs and running costs
  - Affect energy consumption & environmental performance of a building

Air Conditioning

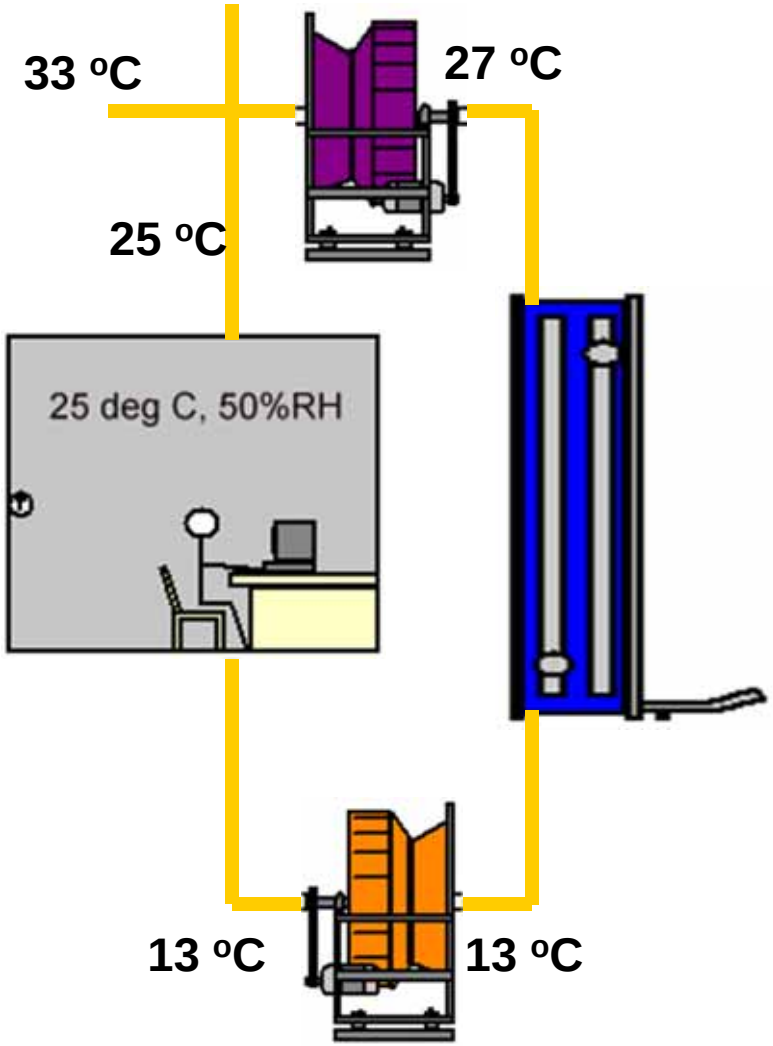
- To understand better, air conditioning system can be divided into five subsystems or loops:
  - Air-side
  - Chilled water
  - Refrigeration equipment
  - Heat rejection
  - Controls

33 °C, 28 °C



Conditioned space

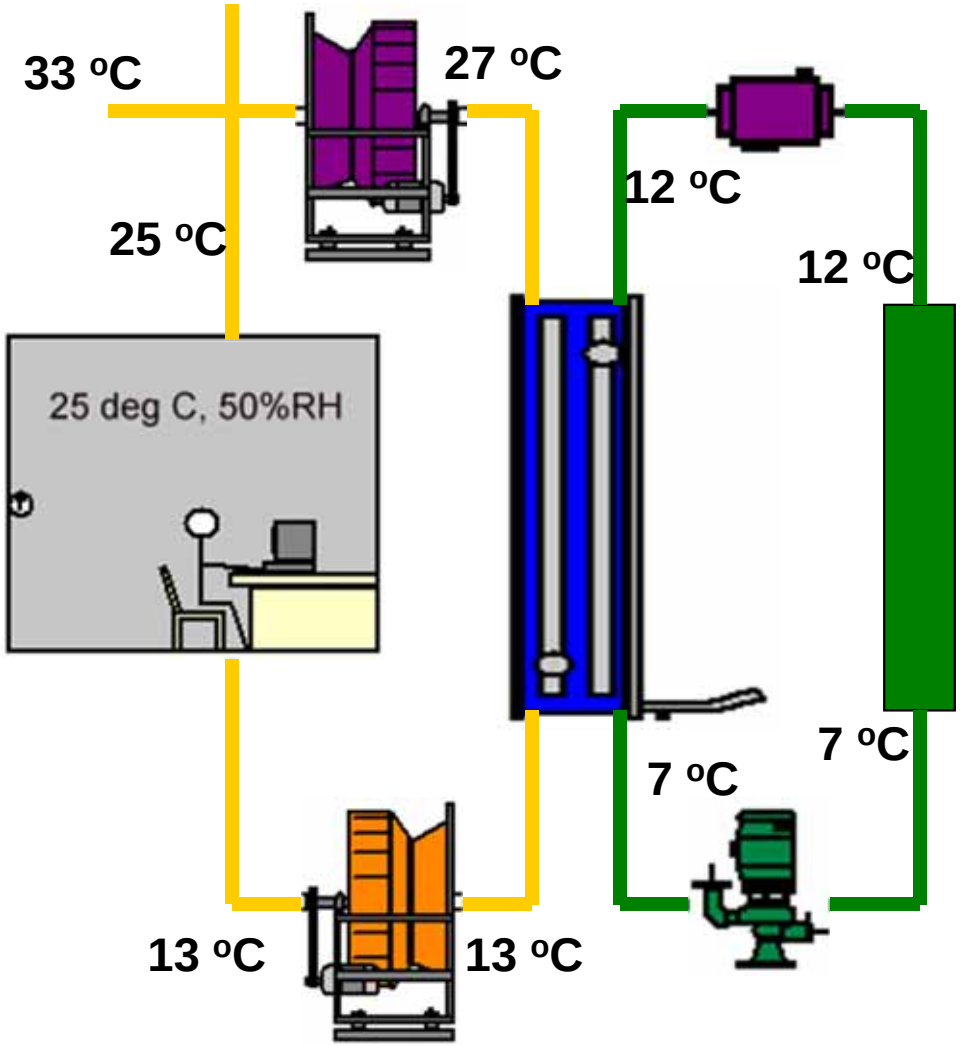
33 °C, 28 °C



Air side system

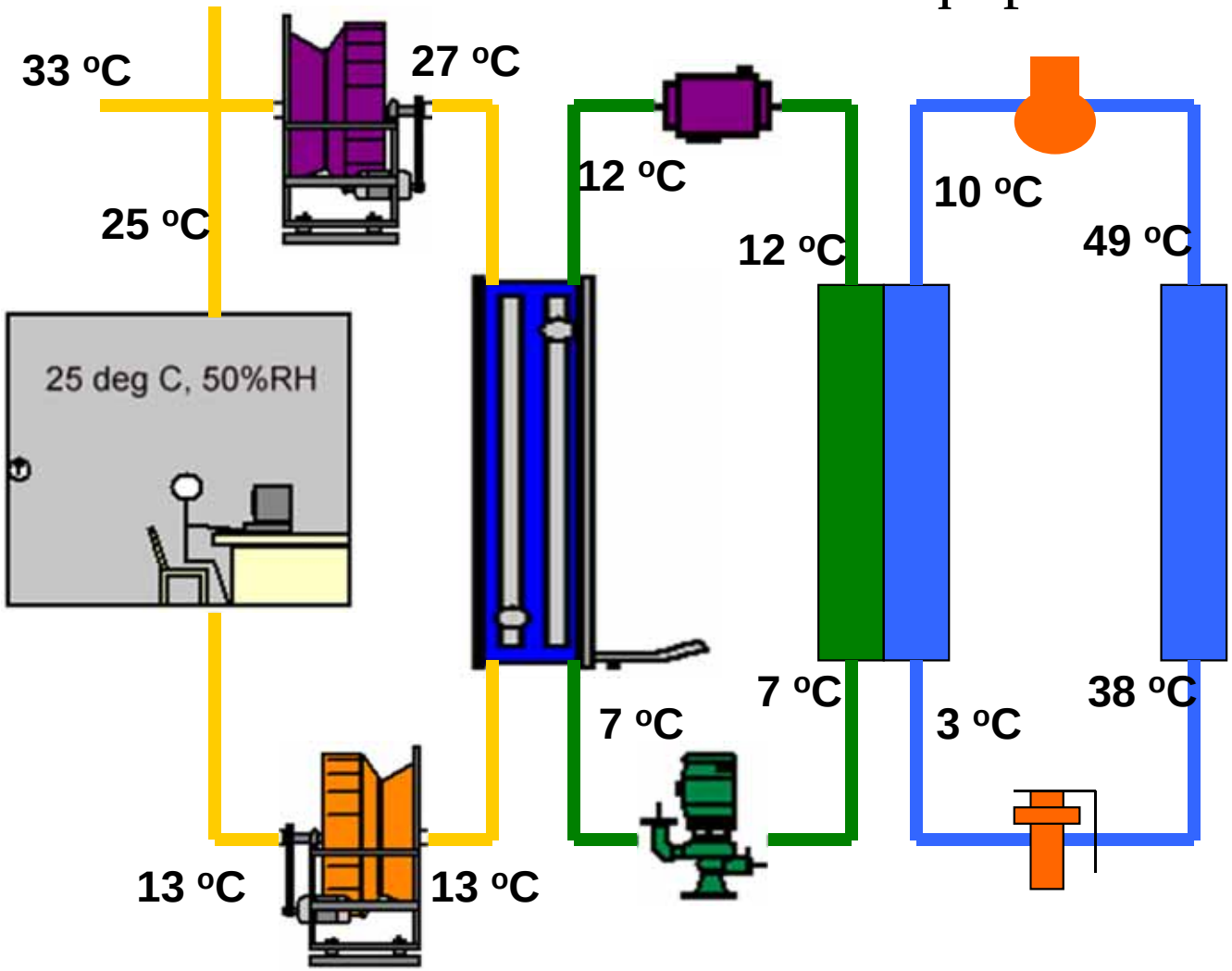
33 ºC, 28 ºC

Chilled water system



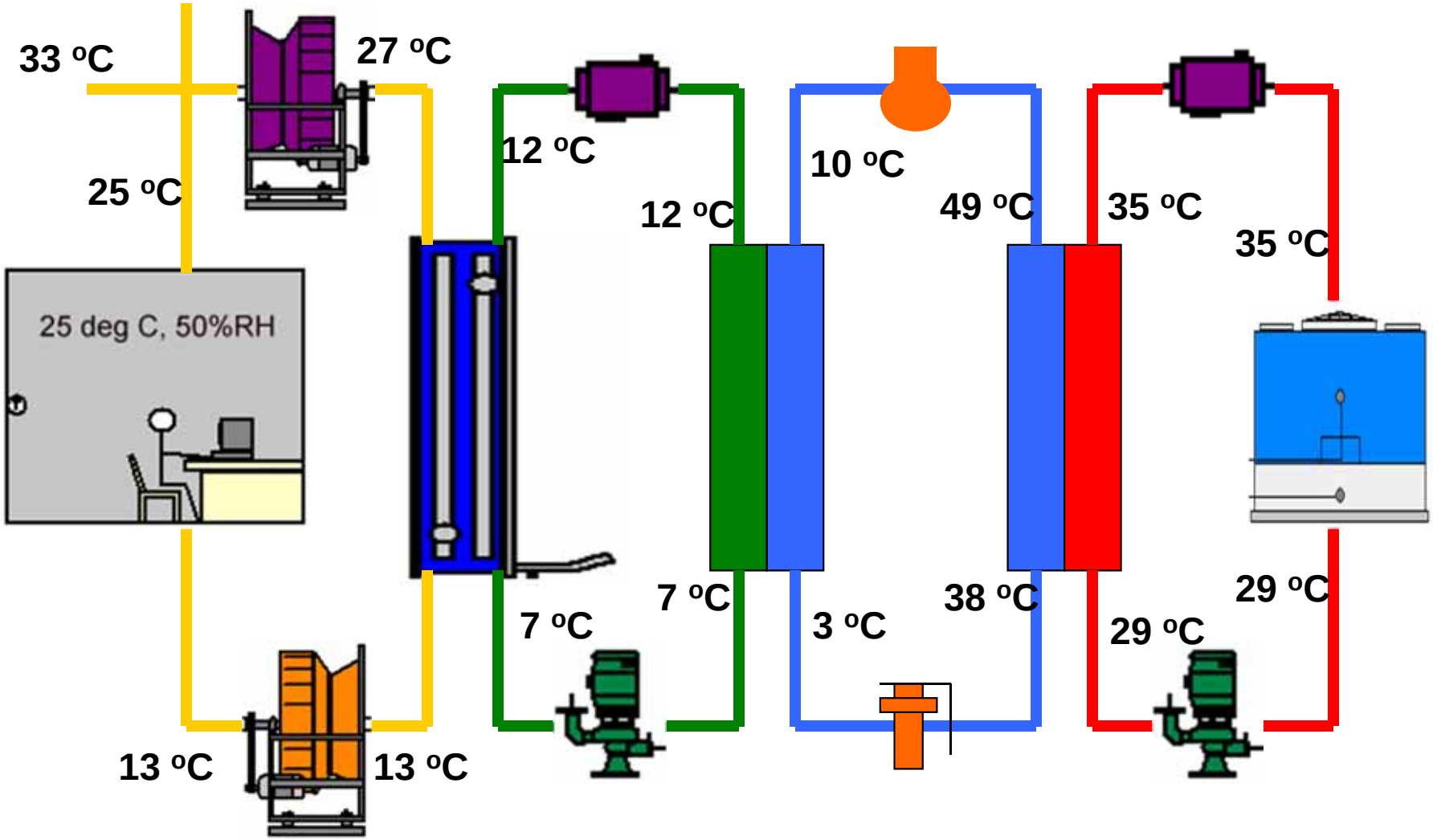
33 ºC, 28 ºC

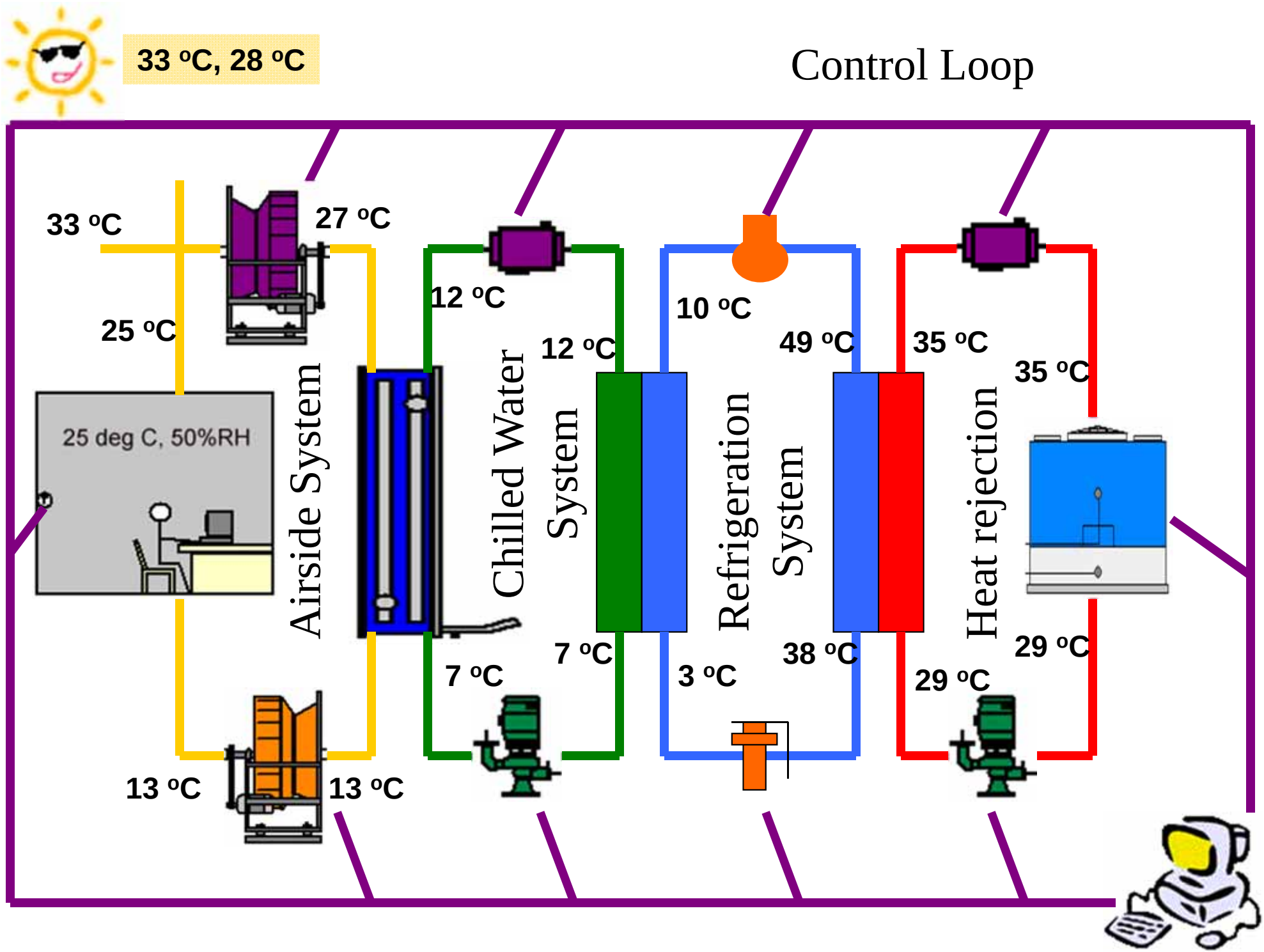
Refrigeration equipment



33 °C, 28 °C

Heat rejection

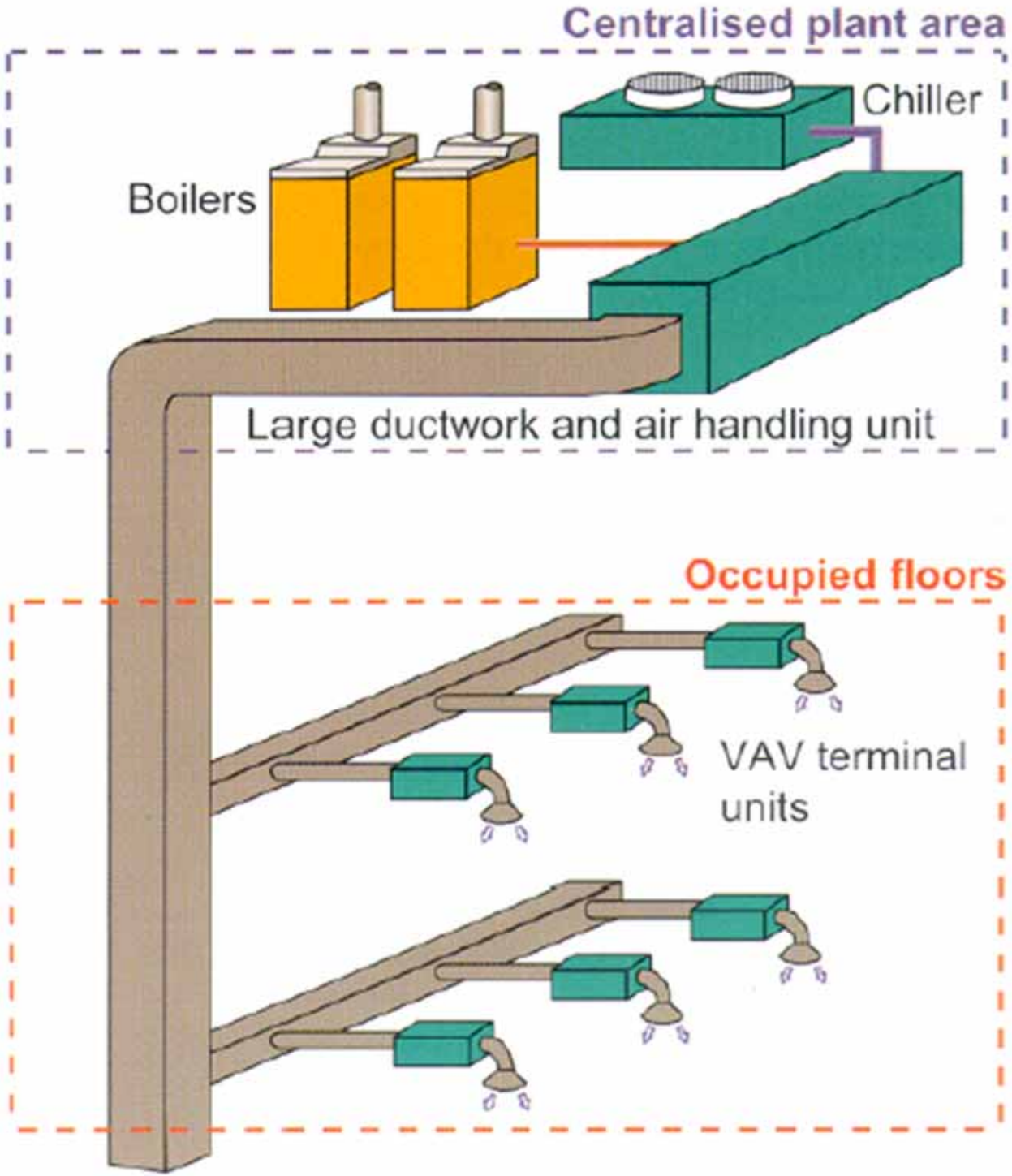



33 °C, 28 °C
Control Loop
33 °C
27 °C
25 °C
25 deg C, 50%RH
Airside System
12 °C
Chilled Water System
12 °C
7 °C
7 °C
10 °C
Refrigeration System
49 °C
38 °C
3 °C
35 °C
Heat rejection
35 °C
29 °C
29 °C
13 °C
13 °C

Air Conditioning

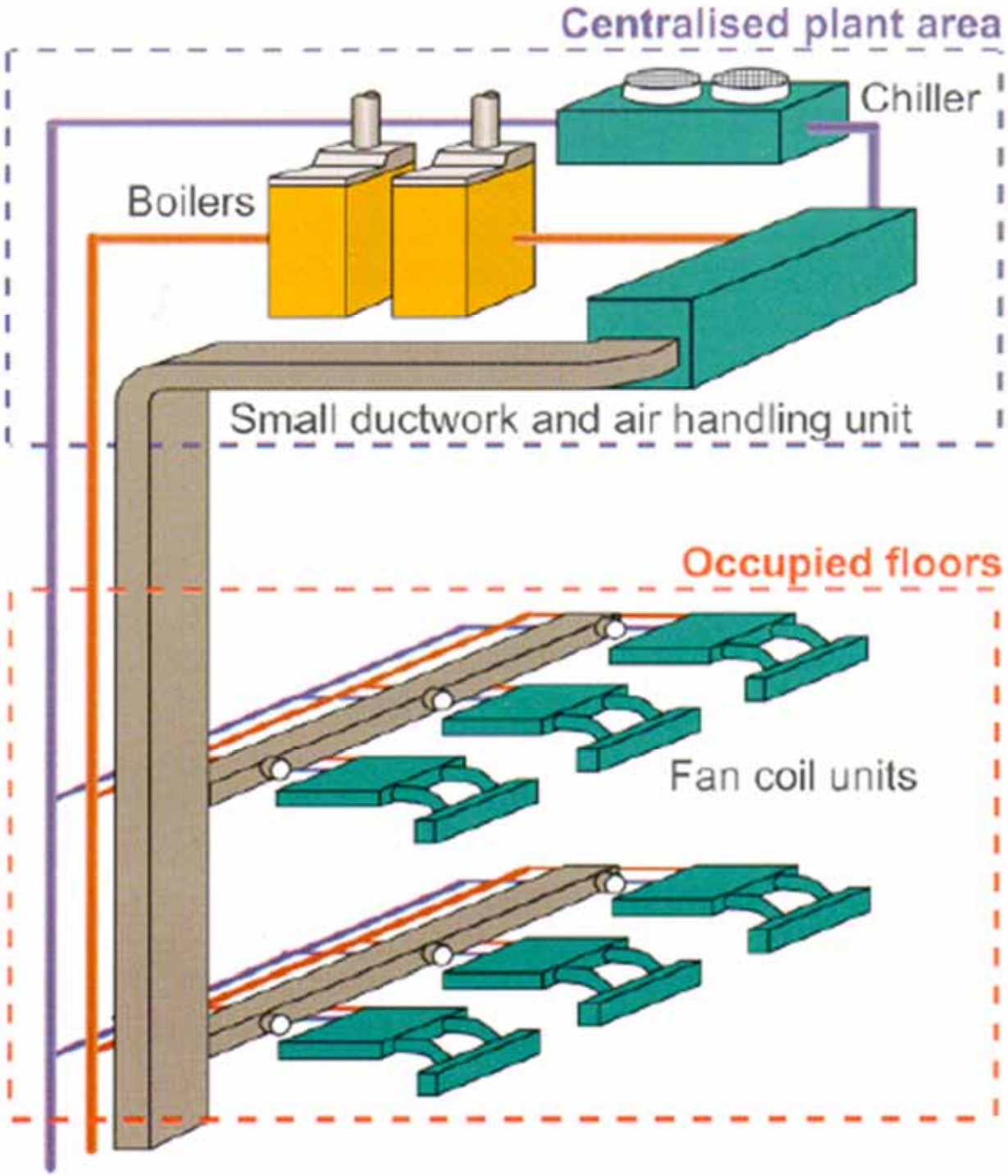
- Three generic types of systems:
  - Centralised all air systems
    - Such as CAV, VAV, dual duct
  - Partially centralised air/water systems
    - Such as FCU, induction units, chilled beams/ceilings
  - Local systems
    - Such as window-type units, split-type packages, VRV/VRF (?)

Centralised air system *(VAV example)*

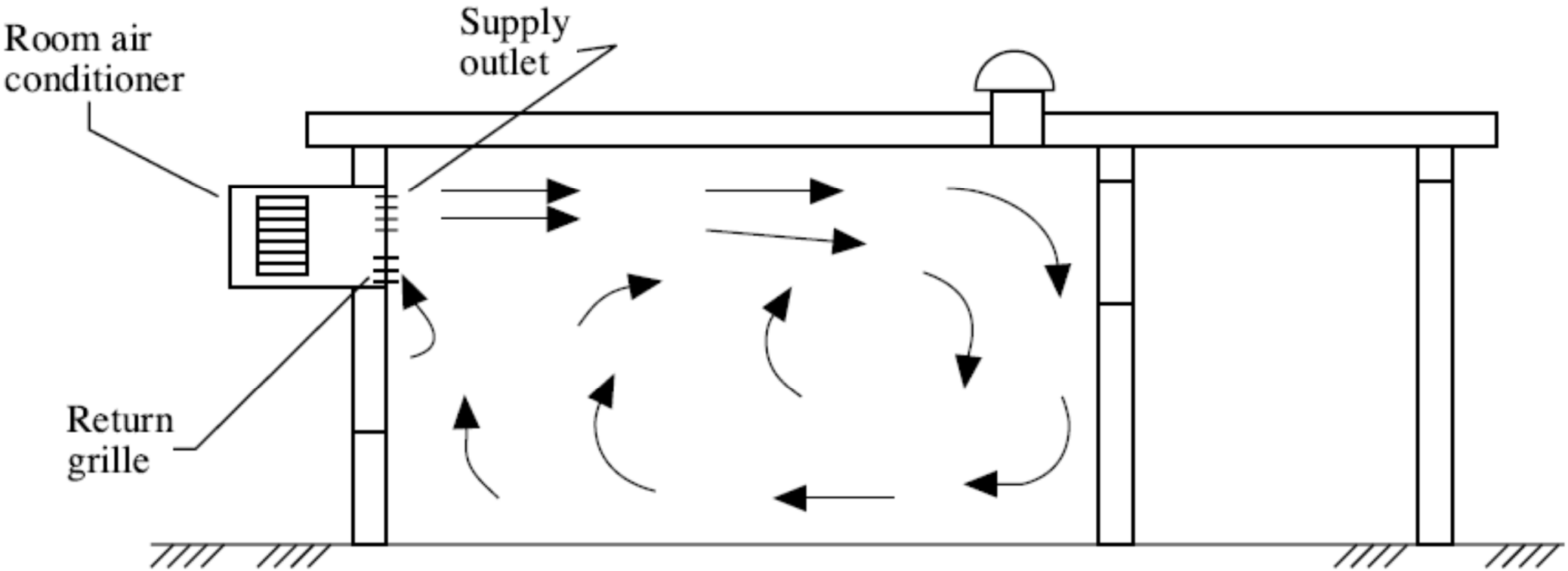


Partially centralised air/water system

(Fan coil example)

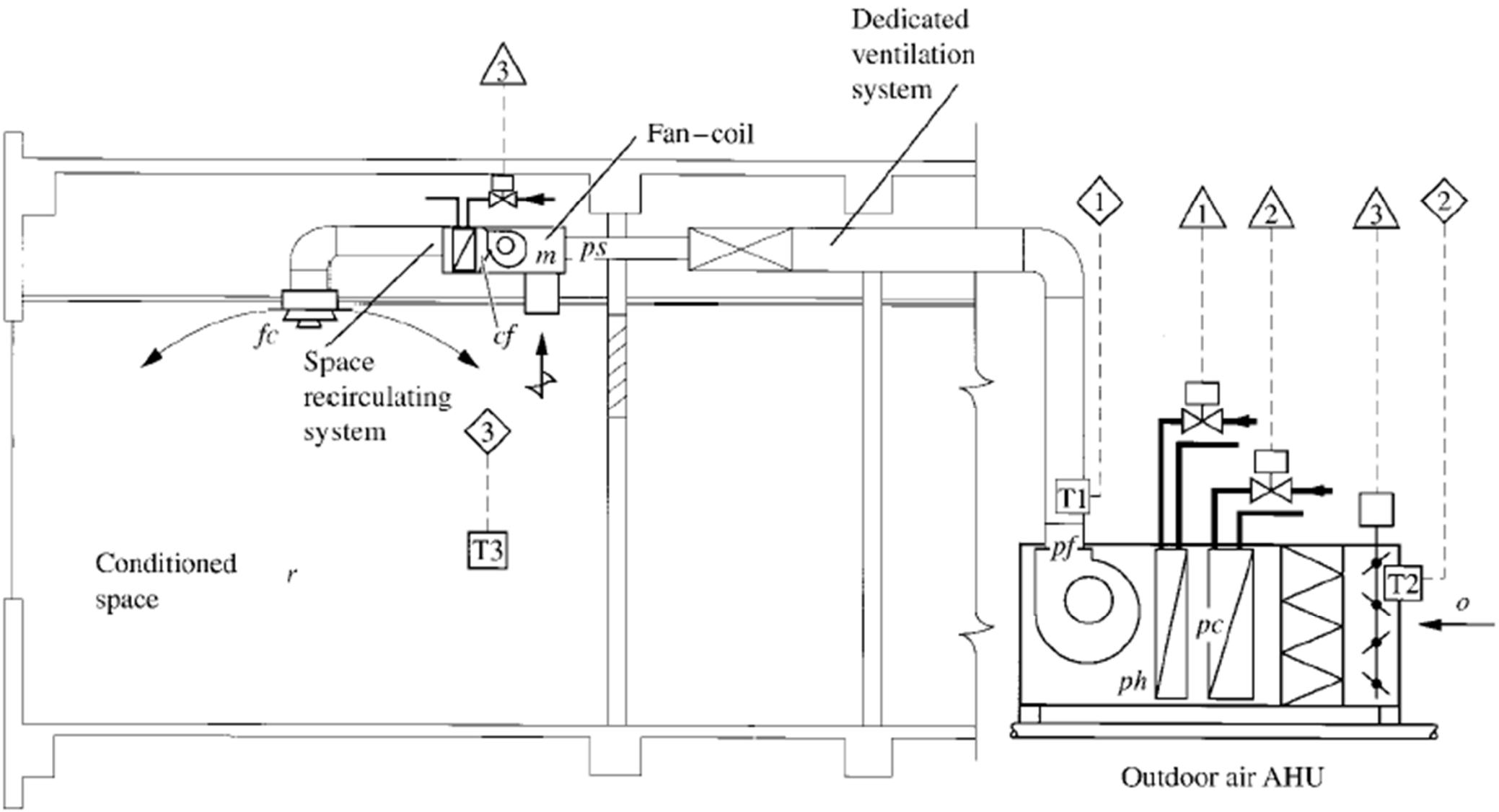


An individual room air-conditioning system



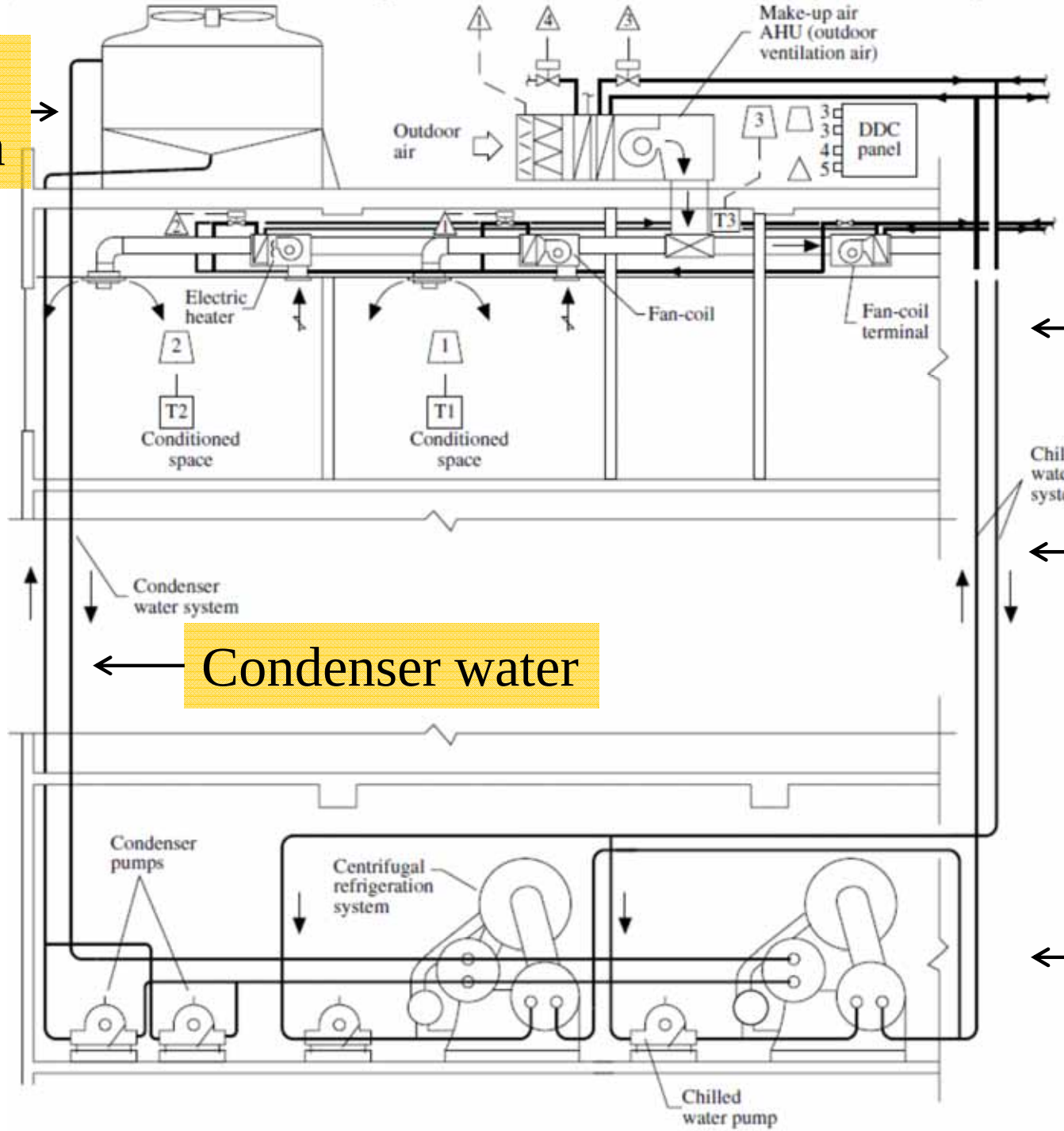
(Source: Wang, S. K., Lavan, Z. and Norton, P., 2000. *Air Conditioning and Refrigeration Engineering*)

Primary air fan coil unit (PA-FCU) system



(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.*ng*)

A space-conditioning air-conditioning system (fan-coil system)



Heat rejection

Air side

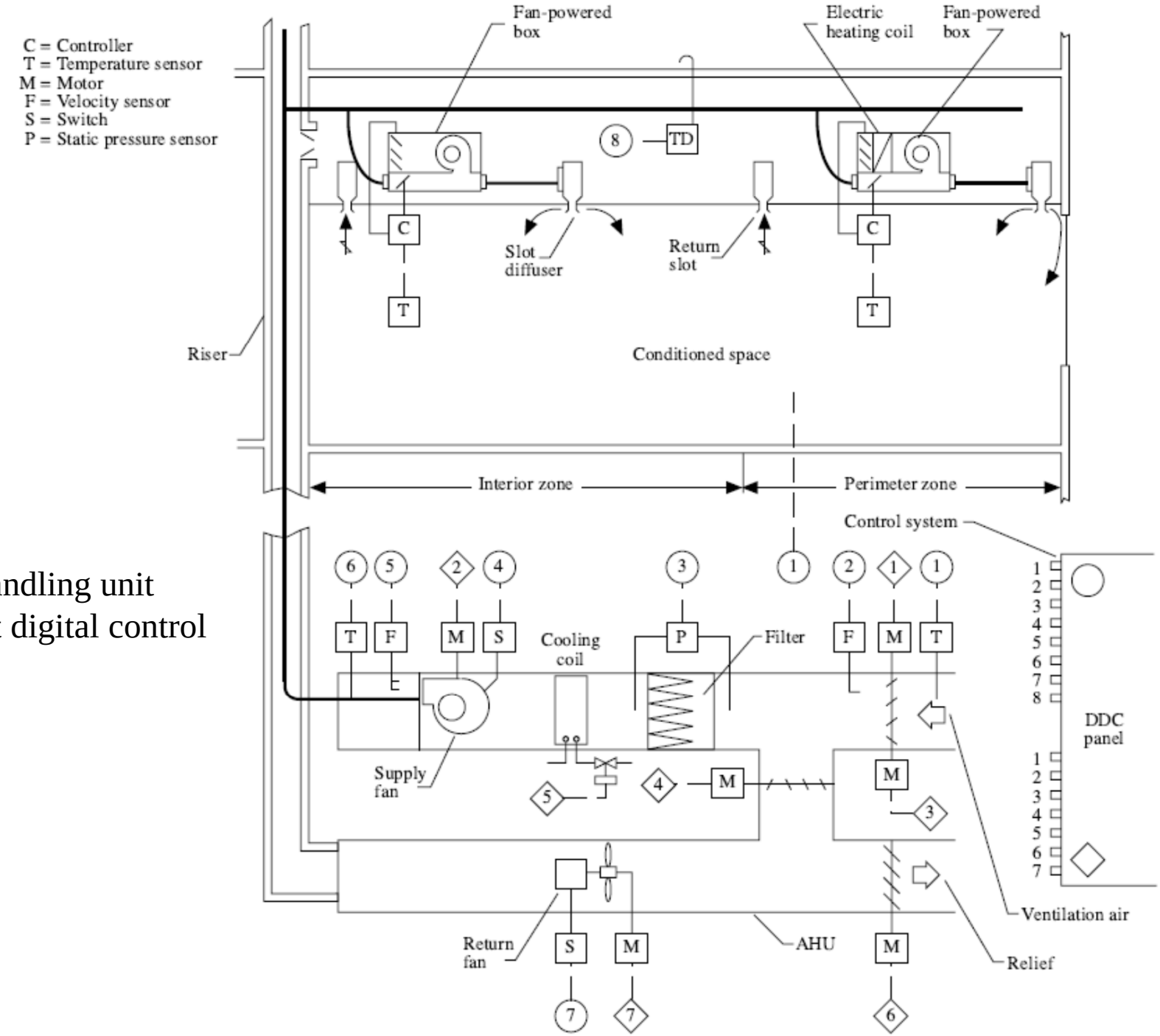
Chilled water

Condenser water

Refrigeration

(Source: Wang, S. K., Lavan, Z. and Norton, P., 2000. *Air Conditioning and Refrigeration Engineering*)

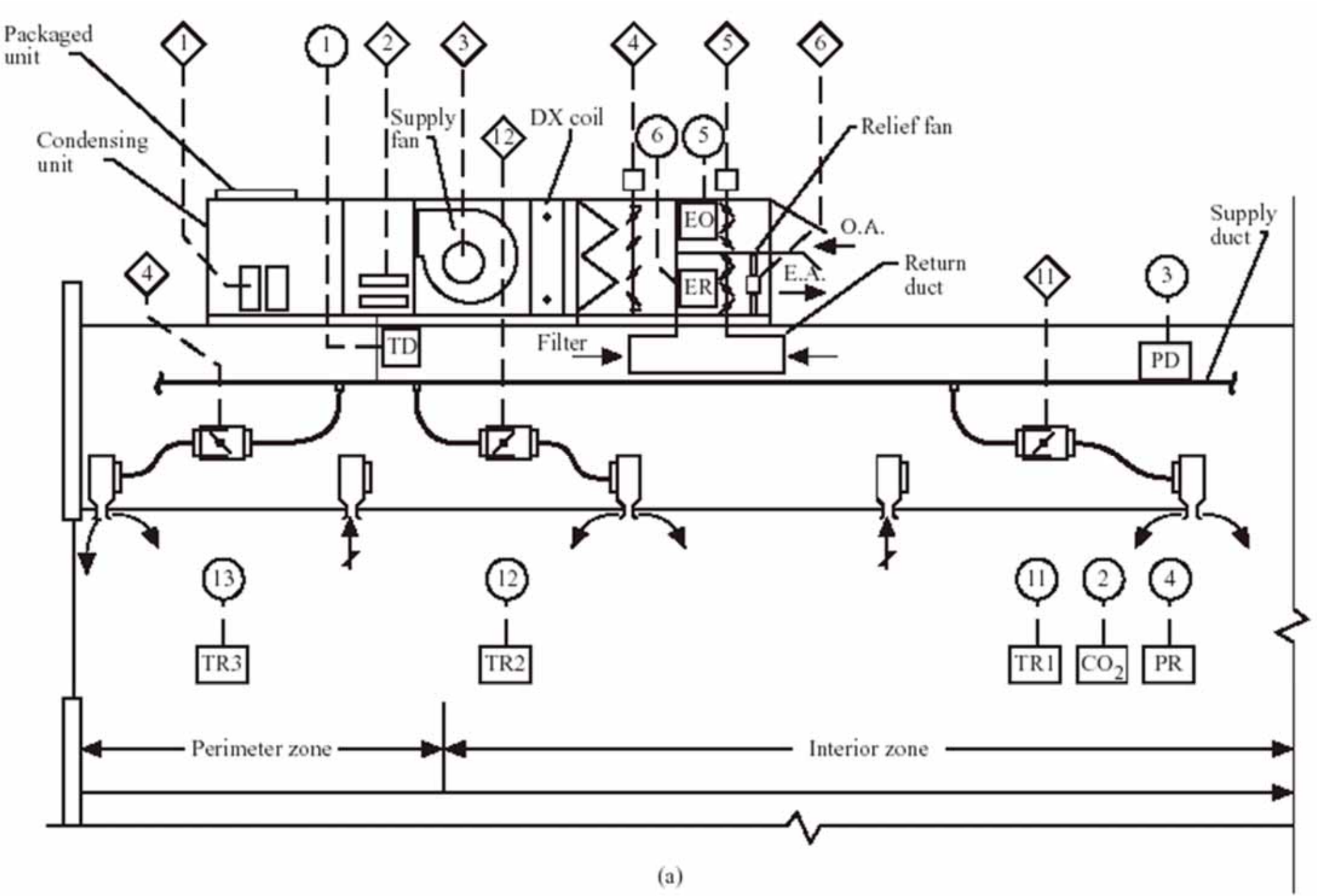
Air-side and control systems for a typical floor of a central system



AHU = air handling unit
DDC = direct digital control

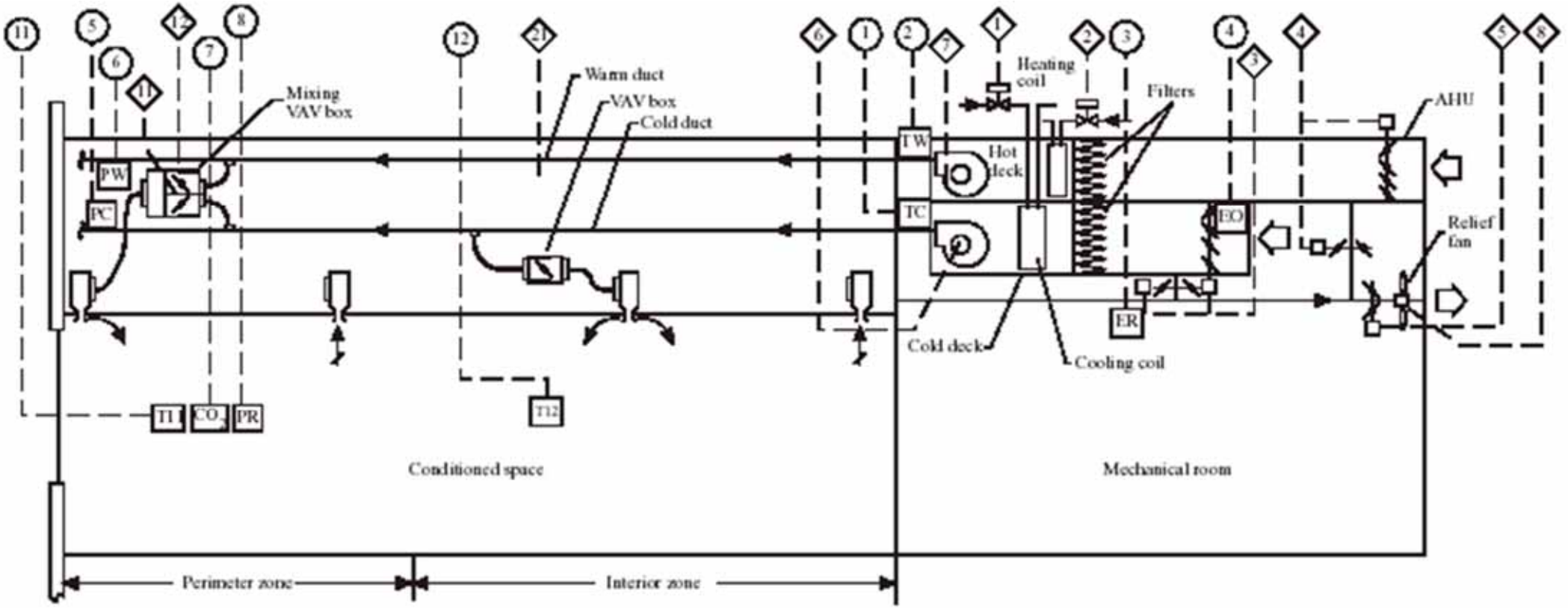
(Source: Wang, S. K., Lavan, Z. and Norton, P., 2000. *Air Conditioning and Refrigeration Engineering*)

Variable-air volume (VAV) package system (rooftop unit)



(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.*ng*)

A dual-duct VAV central system



(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.*ng*)

Air Conditioning

- Videos: (Introduction to air conditioning)
  - Air Conditioning 1 - Introduction (0:47), http://youtu.be/rUJjj6Fnhz4
  - Air Conditioning 2 - Air Cycle (1:46), http://youtu.be/nDUrjUgjADE
  - Air Conditioning 3 - Chilled and Condenser Water Cycles (1:51), http://youtu.be/IIzv1TJPyYQ
  - Air Conditioning 4 - Constant Air Volume (CAV) System (3:12), http://youtu.be/ZJBSDTpwUpY
  - Air Conditioning 5 - Variable Air Volume (VAV) System (1:50), http://youtu.be/YCogTVa3XOw
  - Air Conditioning 6 - Fan Coil Unit (FCU) (1:58), http://youtu.be/QI0O5xZ3liI
  - Air Conditioning 8 - Air Conditioning Design (1:32), http://youtu.be/do6TnHuZn5A

Air Conditioning

- Practical design strategy: integrated approach
  - AIM to meet the requirements of the people & processes without being excessive & wasteful
    - Energy efficiency, technically & economically sound
  - LINK with the design of building fabric (architecture) to maximise passive design potential
  - BASED on clear understanding of the building, client and end-user needs
  - FOLLOWED by effective commissioning, handover and building management

Air Conditioning

- Establish key performance requirements, e.g.
  - Demands of building occupants & activities
  - Reliability, adaptability & flexibility
  - Maintenance requirements
  - Control quality & complexity
  - Aesthetics, time constraints & security
  - Investment criteria & whole life cycle costs
  - Energy/environmental targets
  - Indoor environmental standards

Air Conditioning

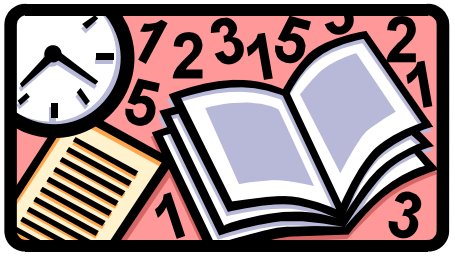
- Video: Fundamentals of Air Conditioning (24 min.)
  - HVAC at Heathrow Airport Terminal 4, London
  - Basic psychrometric principles
  - HVAC equipment and components
  - Design factors:
    - Building
    - System
    - Climate
    - Economic

Hong Kong International Airport

Stansted Airport, UK

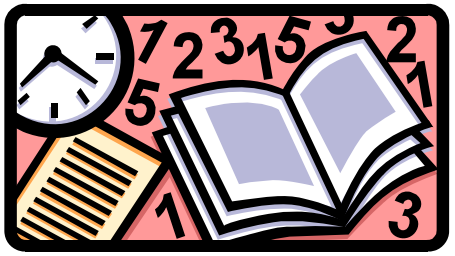
KL International Airport, Malaysia

Further Reading



- Introduction to Air Conditioning
  - www.arca53.dsl.pipex.com/index_files/ac1.htm
- Howell, R. H., Coad, W. J. and Sauer, H. J., 2013. *Principles of Heating, Ventilating, and Air Conditioning*, 7th ed., Chp. 1, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.
- Kreith, F. and Goswami, D. Y. (eds.), 2005. *The CRC Handbook of Mechanical Engineering*, 2nd ed., CRC Press, Boca Raton, FL. [621 C9][ebook via ENGnetBASE]
  - Chapter 9. Air-Conditioning and Refrigeration (by Herbert A. Ingley, Shan K. Wang, Ari Rabl, Peter S. Curtiss, Zalman Lavan) OR
  - Wang, S. K., Lavan, Z. and Norton, P., 2000. Air *Conditioning and Refrigeration Engineering*, Chp. 1, CRC Press, Boca Raton. [697.93 W246 a]

References



- Useful references: (with ebooks)
  - ASHRAE, 2013. *ASHRAE Handbook Fundamentals 2013*, American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc., Atlanta, GA.
  - Grondzik, W. (ed.), 2007. *Air-conditioning Systems Design Manual*, Second Edition, Butterworth-Heinemann, Burlington, MA.
  - Jones, W. P., 2001. *Air Conditioning Engineering*, 5th ed., Butterworth-Heinemann, Oxford & Boston.

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ASHRAE Publications

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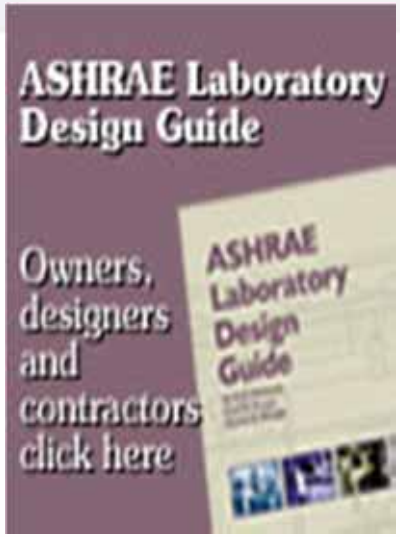
  - Fundamentals
  - Systems & Equipment
  - Applications
  - Refrigeration
- Journal
- E-newsletters
- Books

Handbook

Journal



Guidelines

(Source: www.ashrae.org)

(Source: www.ashrae.org)