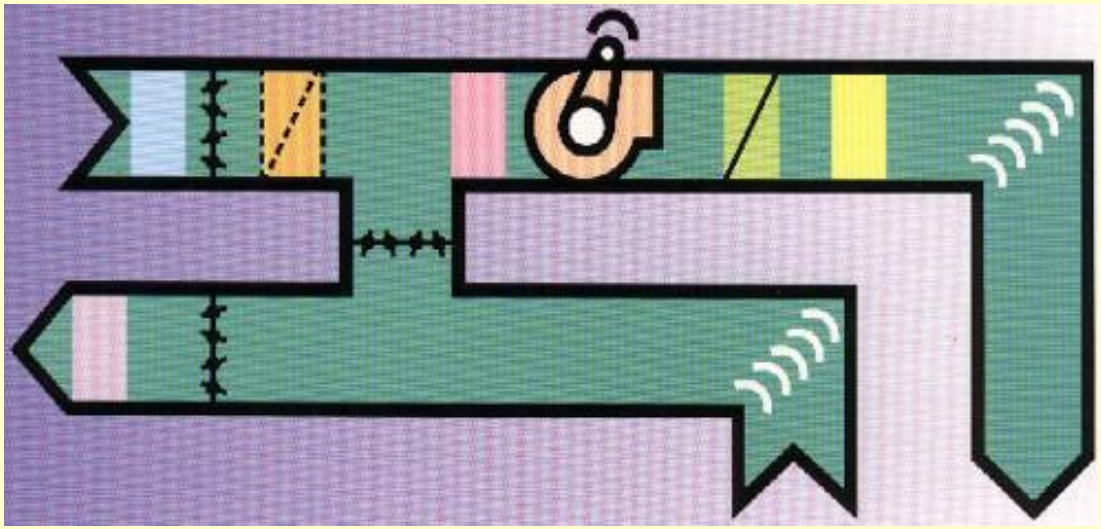
MECH3423 Building Services Engineering II

http://me.hku.hk/bse/MECH3423/



Introduction to HVAC

Dr. Sam C. M. Hui

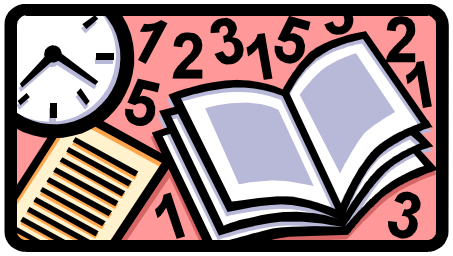
Department of Mechanical Engineering

The University of Hong Kong

E-mail: cmhui@hku.hk

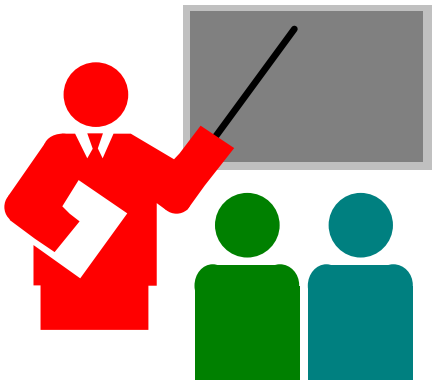
Dec 2015

Background

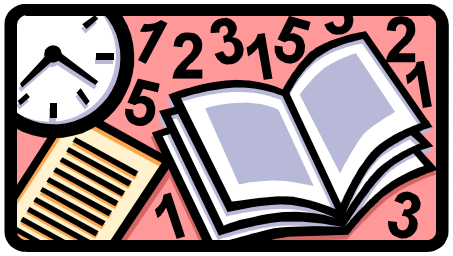


- Learning Outcomes: (MECH3423 BSE II)
  - Explain the fundamental principles and design concepts of HVAC and fire services systems.
  - Understand the characteristics and engineering design of these systems.
  - Design these systems and achieve effective and efficient design solutions
- Assessment:
  - Examination (65%)
  - In-course Assessment (20%)
  - Practical Work (15%)

Design

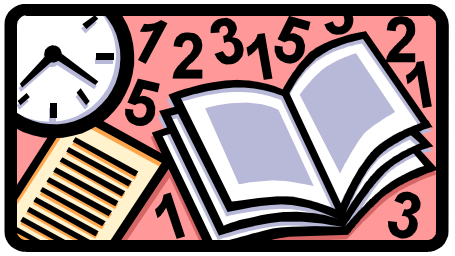


Background

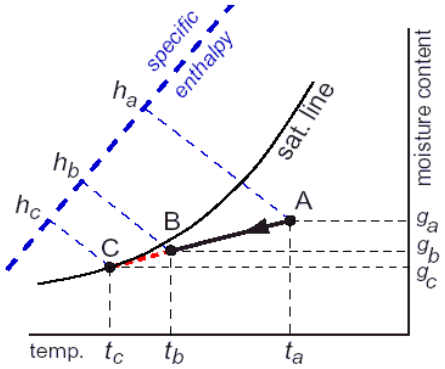


- Required basic knowledge:
  - Thermofluids, Engineering Thermodynamics, Mechanics of Fluids
- Related courses:
  - MECH3422 Building Services Engineering I
  - MECH3023/4423 Building Energy Management and Control Systems
- This course may be useful to your industrial training & capstone project

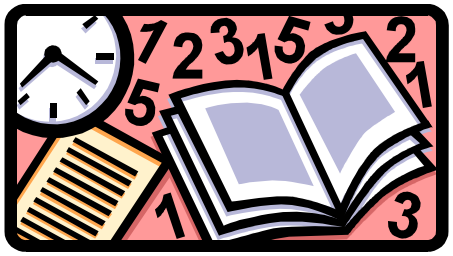
Background



- Study topics of HVAC:
  - Introduction to HVAC
  - Psychrometry
  - Thermal comfort
  - Load and energy calculations
  - Air-side systems
  - Water-side and refrigeration systems
  - Mechanical and natural ventilation



Background



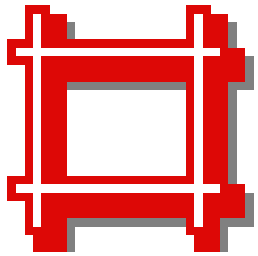
- Useful HVAC references: (ebooks)
  - Howell, R. H., Coad, W. J. and Sauer, H. J., 2013. *Principles of Heating, Ventilating, and Air Conditioning*, 7th ed., …[ASHRAE Catalog: 697 A82 T4]
  - Jones, W. P., 2001. *Air Conditioning Engineering*, 5th ed., Butterworth-Heinemann, Oxford & Boston. [697.93 J79 a]
  - Mcdowall, R., 2007. *Fundamentals of HVAC Systems*, SI edition, …[697 M13]
- Further reading and learning materials: (ebook & online)
  - Hundy, G. F., Trott, A. R. and Welch, T. C., 2008. *Refrigeration and Air-conditioning*, 4th ed., Butterworth-Heinemann/Elsevier, Amsterdam and Boston.
  - NPTEL E-learning course -- Refrigeration and Air Conditioning http://nptel.ac.in/courses/112105129/

What is HVAC&R?

HVAC&R

- What is HVAC&R?
  - HVACR is an acronym or abbreviation for the products and services related to the functions of:
  - **H**eating 採暖
  - **V**entilation 通風
  - **A**ir-**C**onditioning 空調
  - **R**efrigeration 製冷

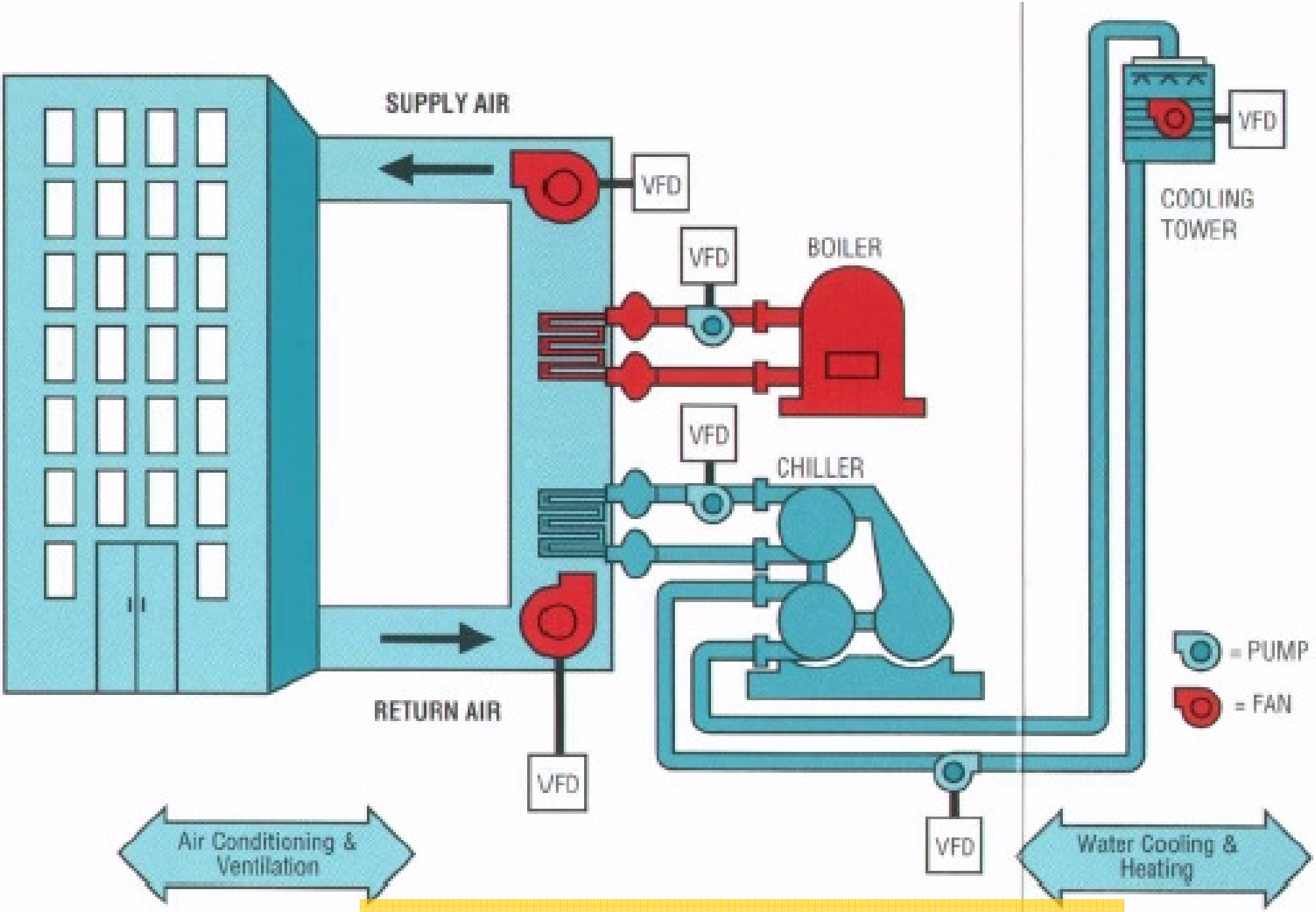
HVAC&R



- 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)

(Video: HVAC Training - Basics of HVAC (10:20) http://www.youtube.com/watch?v=ScVBPAitibQ)

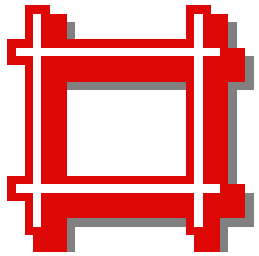
Example of a centralised HVAC system



Do you know the HVAC components?

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

HVAC&R



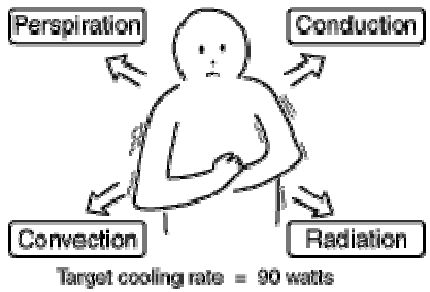
- Understand the purpose of HVAC design
  - To provide adequate indoor air quality by removing and/or diluting indoor pollutants
  - To provide adequate ventilation for processes
  - To remove heat & maintain thermal comfort
  - To control humidity & prevent condensation
- Understand the climate
  -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

HVAC&R

- Interactions affecting HVAC design
  - Building fabric (architectural design)

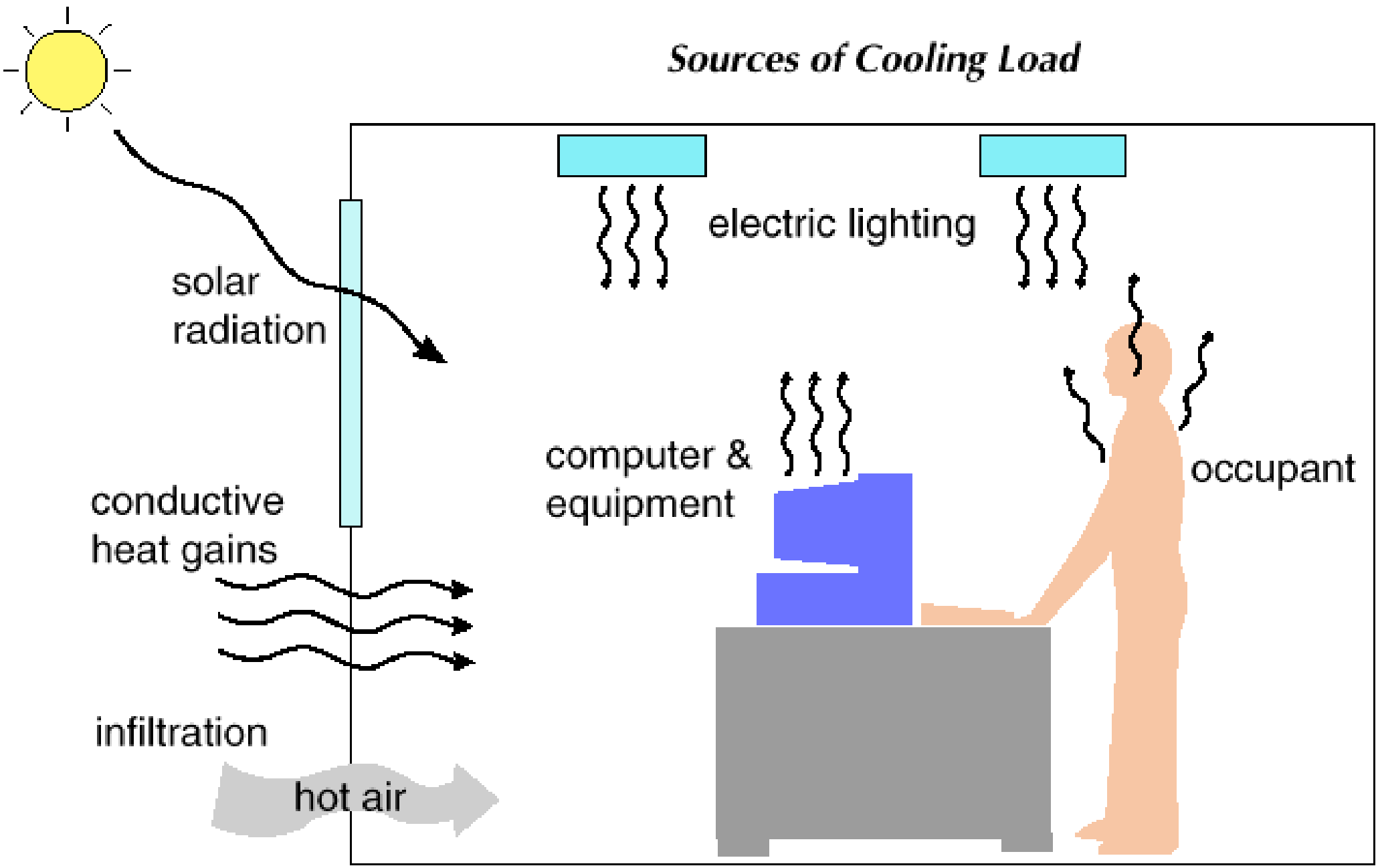
    - Site orientation & conditions
    - Built form, shading, window performance, thermal mass
    - Thermal insulation, reducing infiltration/air leakage
  - Building services elements, e.g.
    - Lighting system & daylighting
    - Small power or equipment loads

  - Occupants' behaviour (human factors)
    - How users behave and react

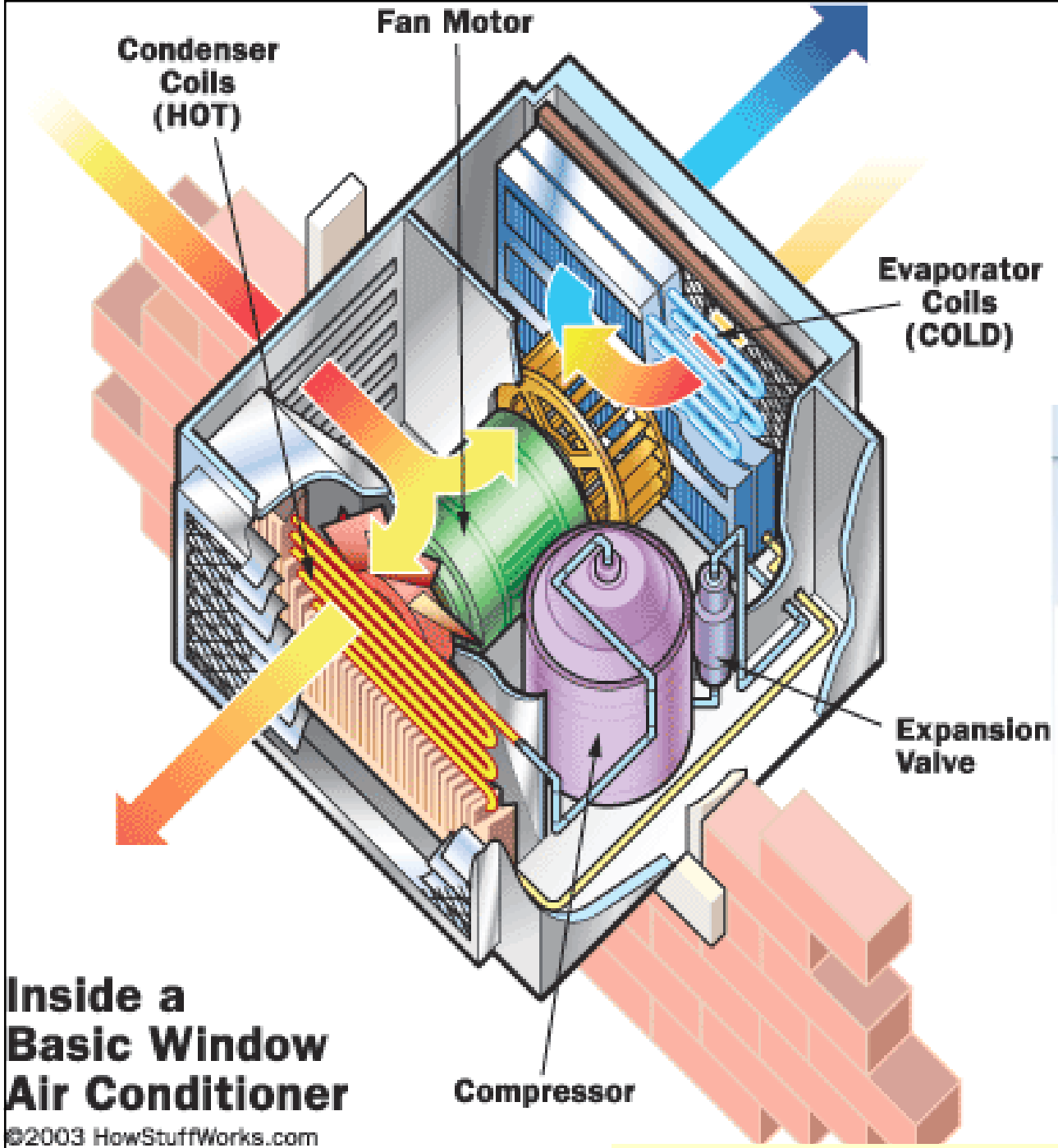


Outdoor weather

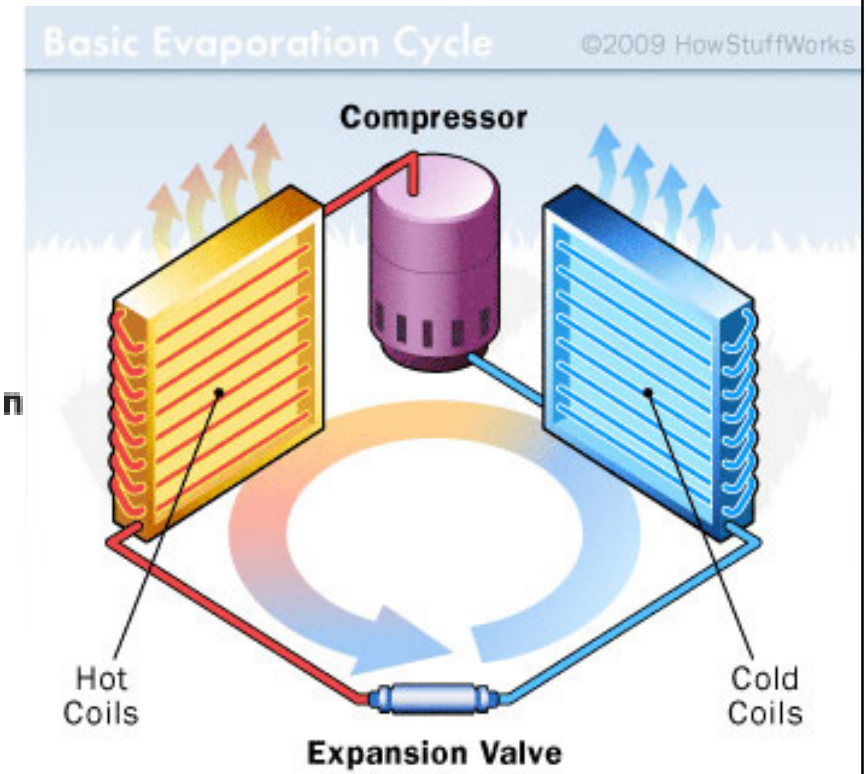
Can you identify all the heat gains?



Indoor conditions and activities



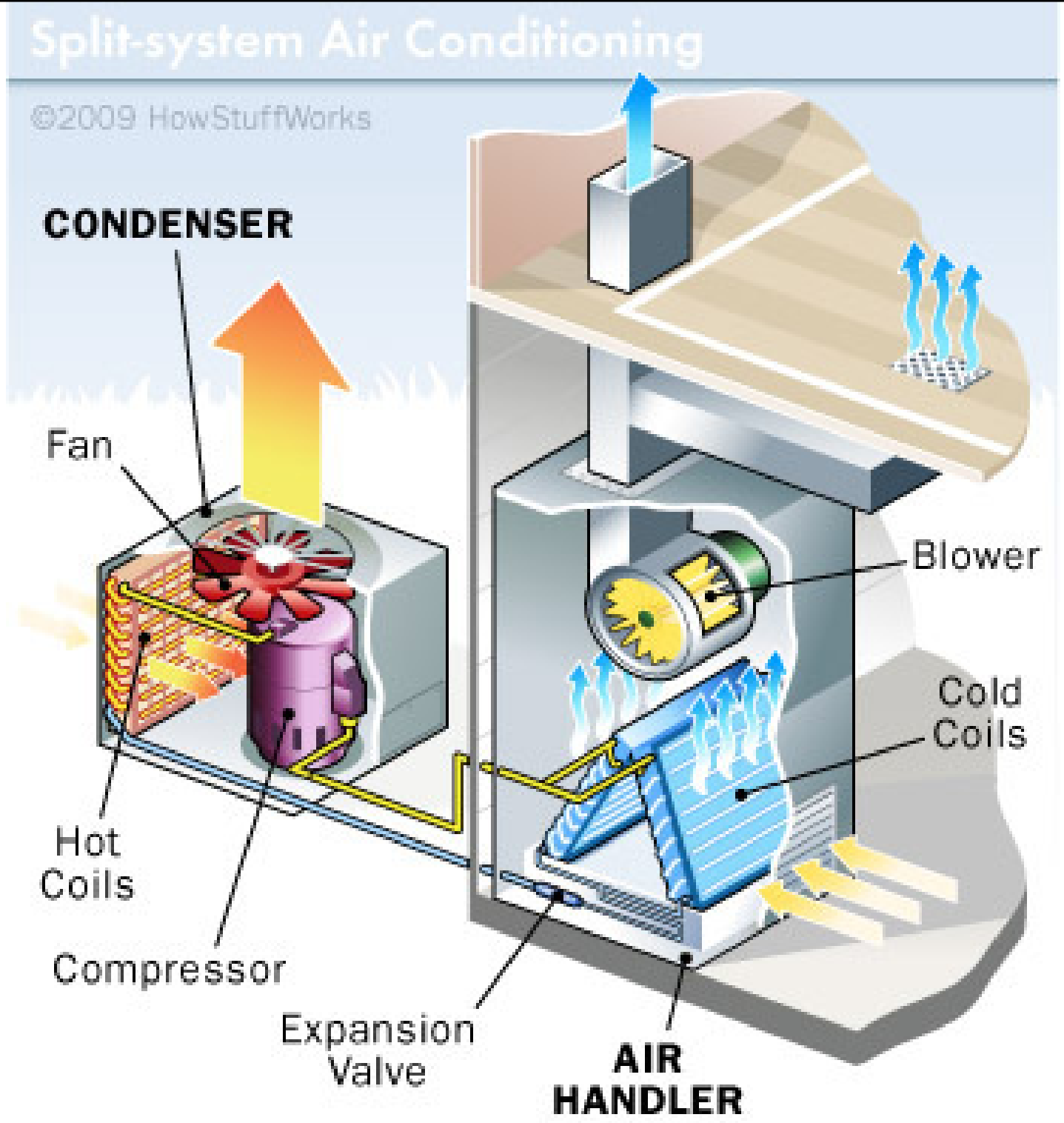
Window-type air conditioner



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

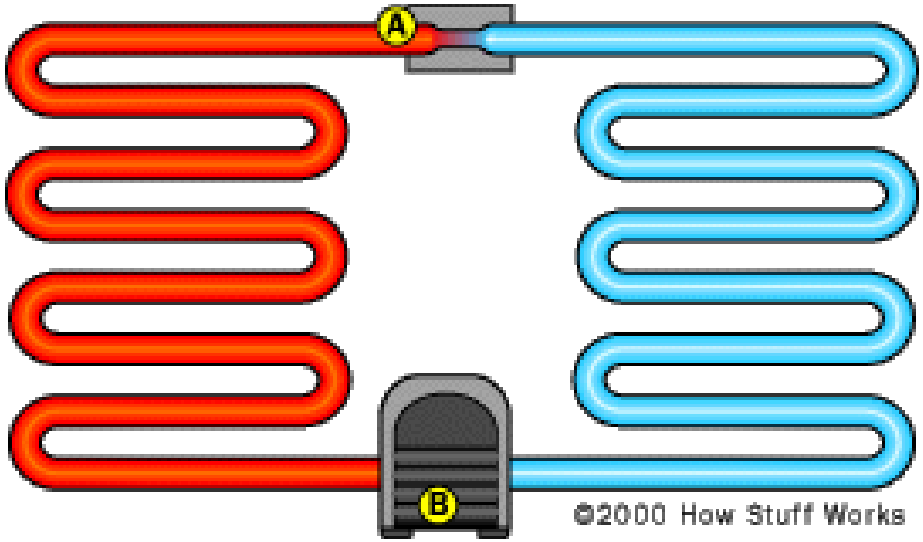
(Source: www.howstuffworks.com/ac.htm)

Split-type air conditioner



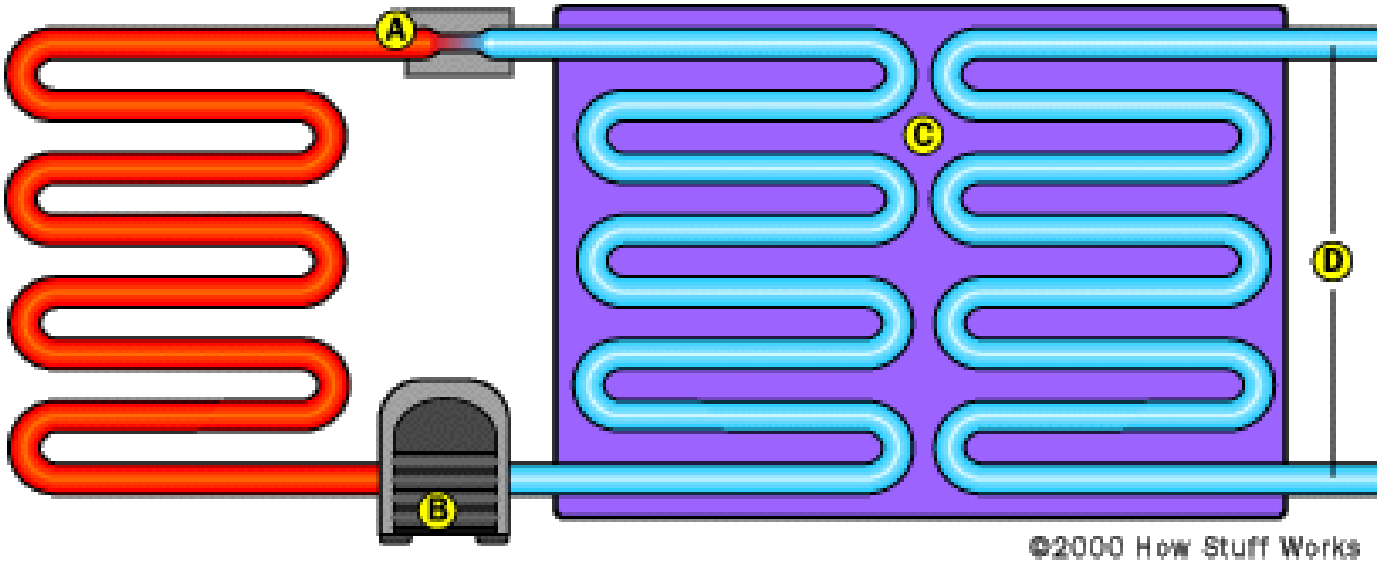
(Source: www.howstuffworks.com/ac.htm)

Refrigerant cycle



What are the major components?

A typical air conditioner



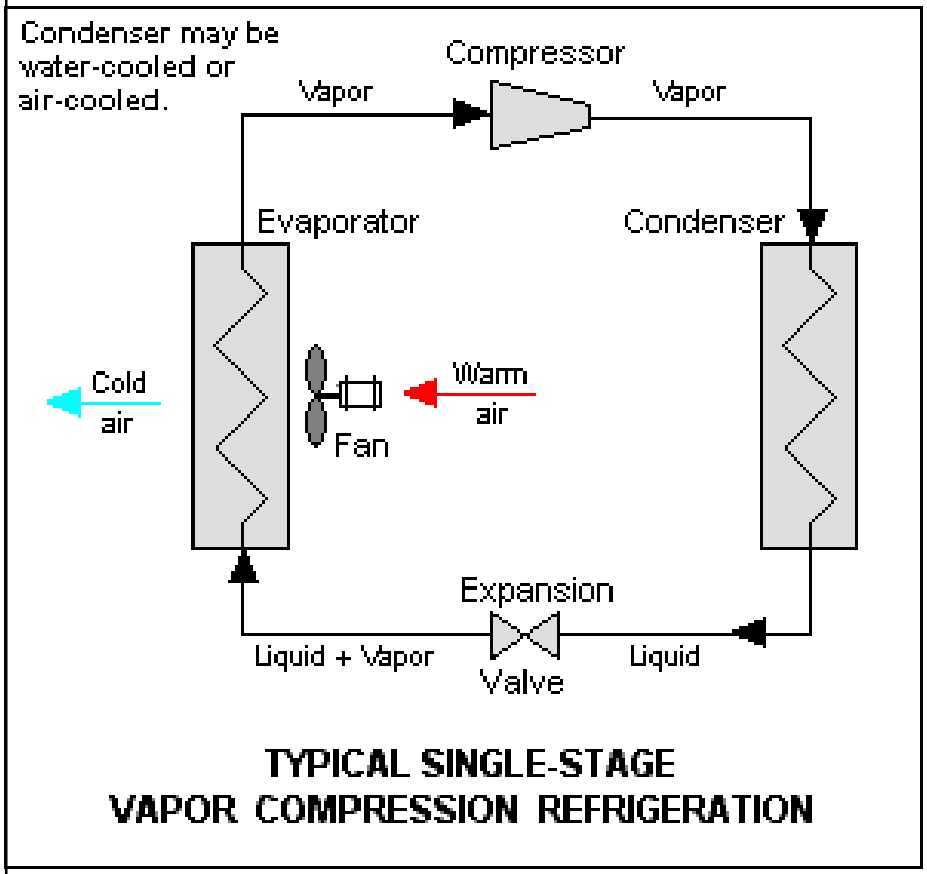
Chilled water system

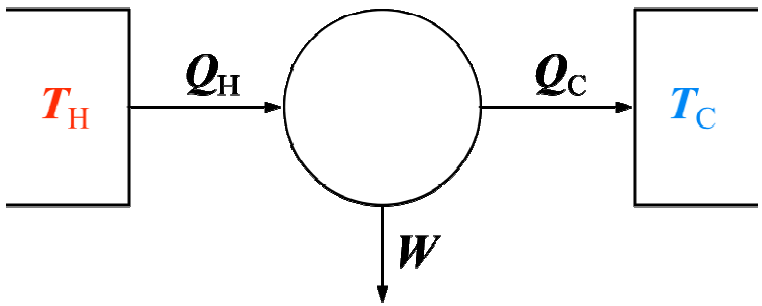
Air conditioning with a chilled water system

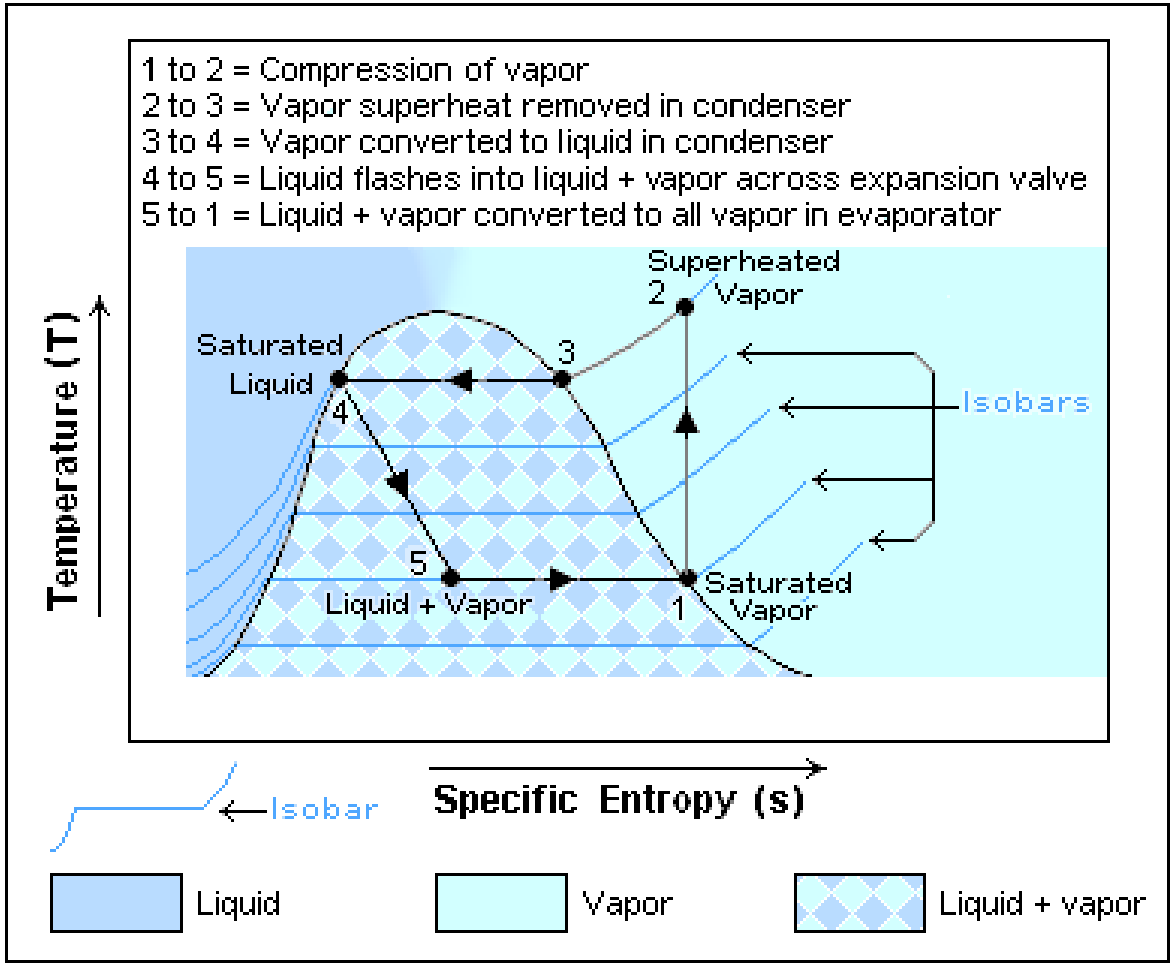
(Source: www.howstuffworks.com/ac.htm)

Vapour compression refrigeration

Can you explain the principles?





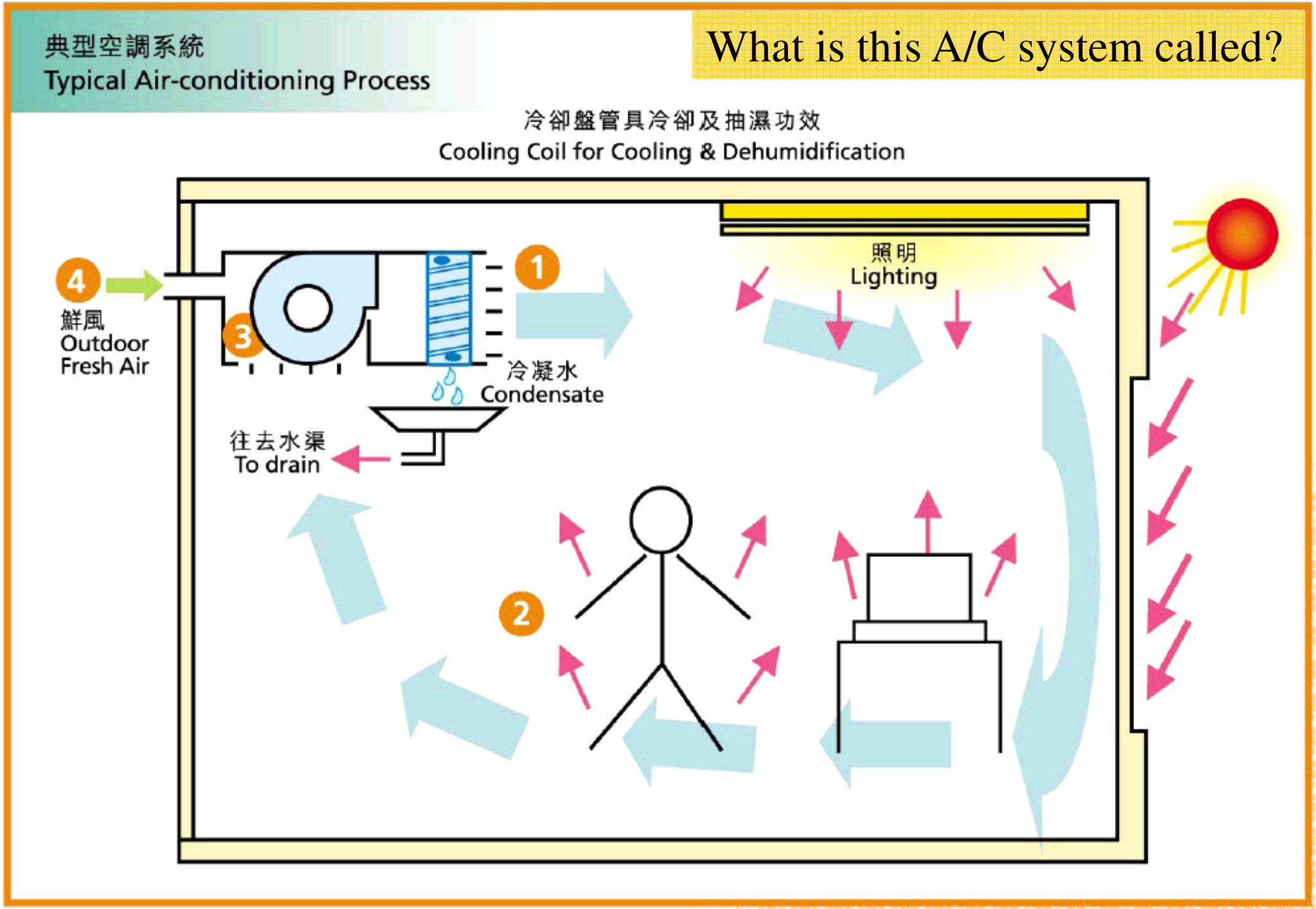


COP of a refrigerator = Cooling Effect/Work Input = $Q_L/W_{net,in}$

COP of a heat pump = Heating Effect/Work Input = $Q_H/W_{net,in}$

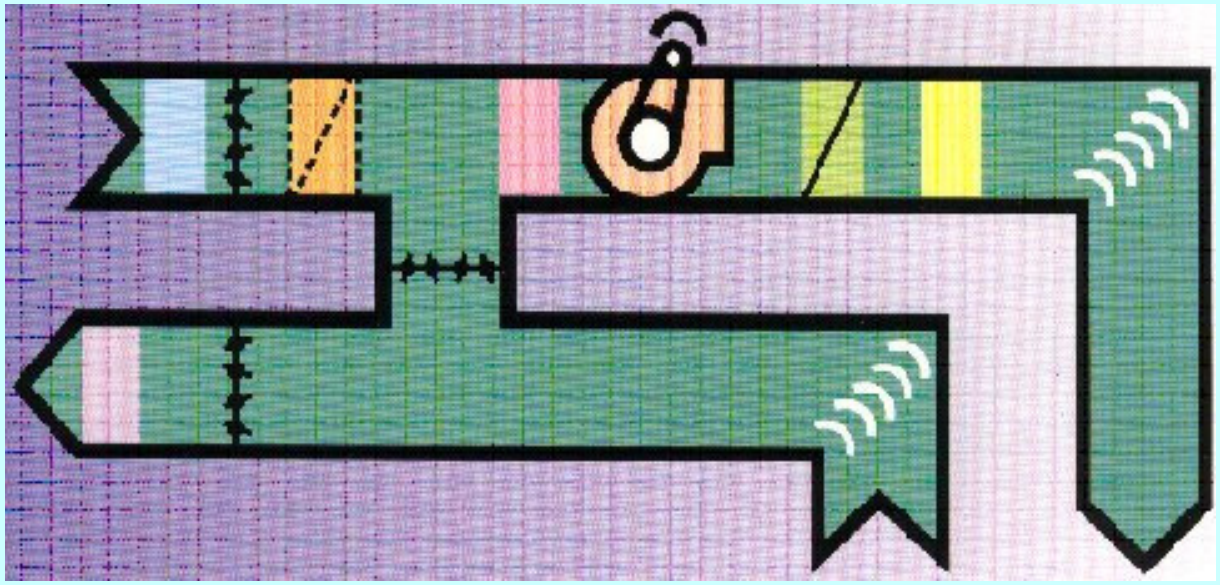
(Source: http://en.wikipedia.org/wiki/Heat_pump_and_refrigeration_cycle)

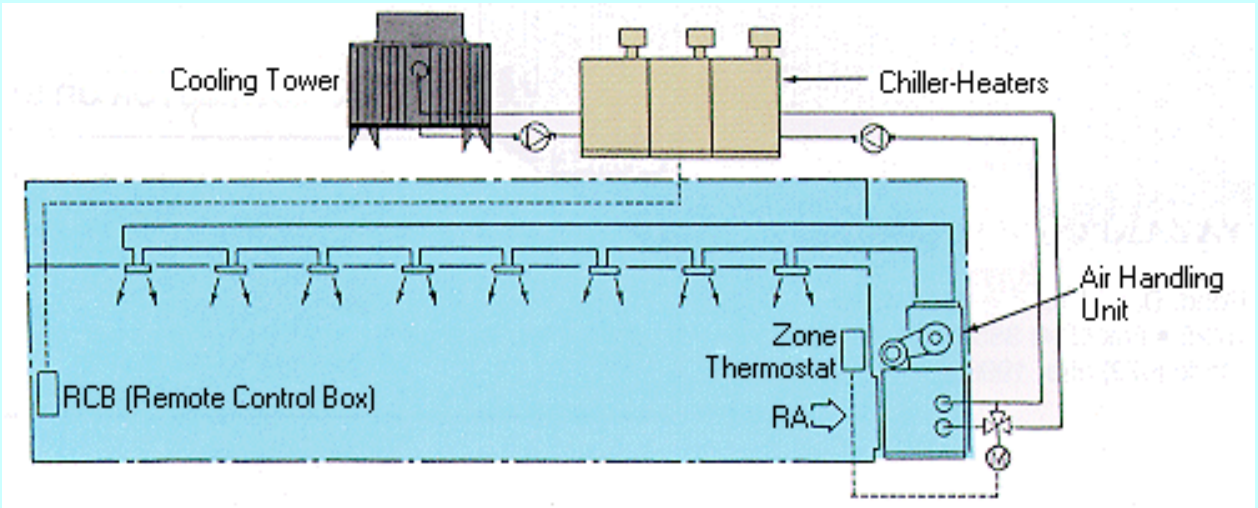
What is this A/C system called?



(Source: EnergyWitts newsletter, EMSD)

Air Conditioning





Air Conditioning

- The term “air conditioning” has gradually changed, from meaning just cooling to the total control of:
  - Temperature
  - Moisture in the air (humidity)
  - Supply of outside air for ventilation
  - Filtration of airborne particles
  - Air movement in the occupied space

“冷氣”

▼

“空氣調節”

“空調”

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 cooling (air conditioning)
  - To meet comfort requirements of occupants

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

Air Conditioning

- Seven main air-conditioning processes:
  - 1. Heating (adding thermal energy)
  - 2. Cooling (removing thermal energy)
  - 3. Humidifying (adding moisture)
  - 4. Dehumidifying (removing moisture)
  - 5. Cleaning (removing particulates/contaminants)
  - 6. Ventilating (exchanging air between the outdoors and the conditioned space)
  - 7. Air Movement (circulating and mixing air)

History of refrigeration and air conditioning

Seasonal harvesting of snow and ice has begun earlier than 1000 B.C. (Store ice in winter for summer use), e.g. ice cellars of ancient Chinese

(Source: 5 Smart Ways to Keep Cool of Ancient Chinese http://www.chinawhisper.com/5-smart-ways-to-keep-cool-of-ancient-chinese/)

Do you know ways to keep cool of ancient Chinese?

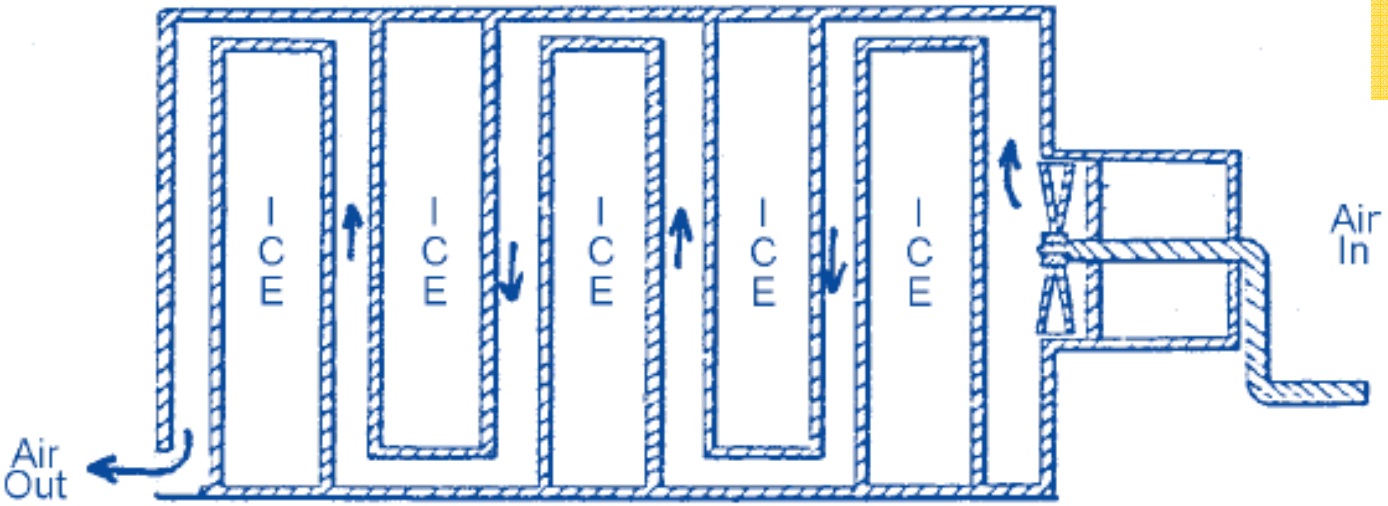


Figure 1: Shaler's patented cooler for ventilating air, 1865.

(Source: ASHRAE Journal, Feb 1999, https://www.ashrae.org/File%20Library/docLib/Public/200362710047_326.pdf)

- Ice cooling
- Evaporative cooling
- Ventilation (air flow)
- Porcelain pillows
- Salt solution cooling

Air Conditioning

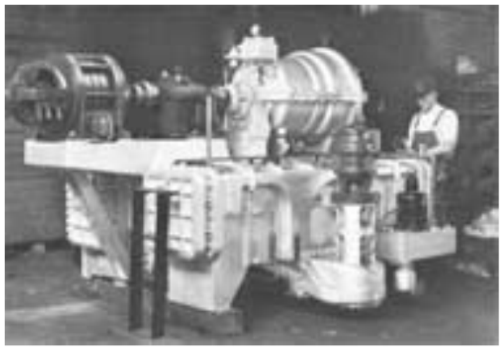
- The History of Modern Air Conditioning
  - http://www.air-conditioners-and-heaters.com/air_conditioning_history.html
    - 1830: Dr. John Gorrie (ice for cooling hospital rooms)
    - 1881: James Garfield (device w/ melted ice water)
    - Late 19th century: "manufactured air" (controlling humidity 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

(Video: Air Conditioning History (1:09) http://www.youtube.com/watch?v=6NFmsU3Am7c)

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



(Video: Air Conditioning History (5:31) http://www.youtube.com/watch?v=rf5okqLX-Uo)

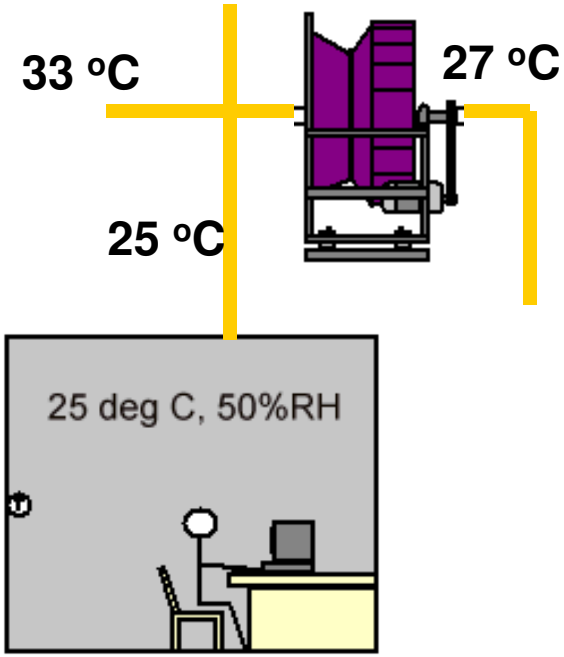
Air Conditioning

- Applications of air conditioning:
  - Industrial sector
    - e.g. textile mills, electronics, pharmaceutical
  - Commercial sector
    - e.g. offices, hotels, retails
  - Residential sector
    - e.g. apartments, houses
  - Transport sector
    - e.g. aircrafts, buses, private cars, trains

Air Conditioning

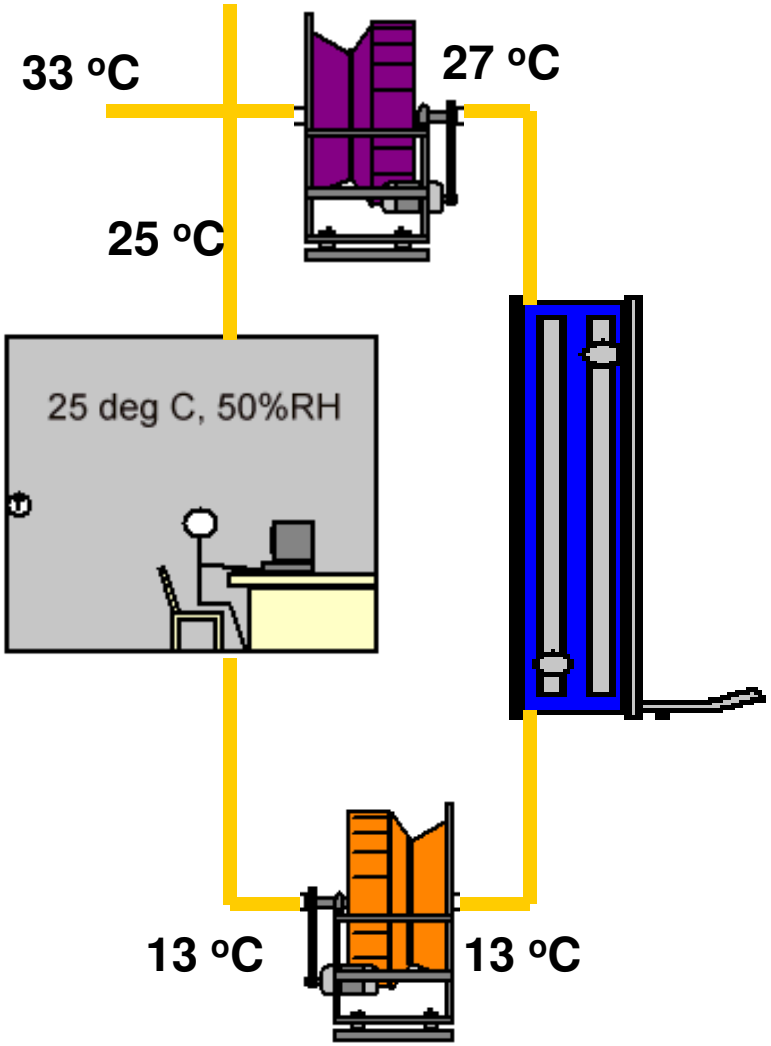
- To understand better, air conditioning system can be divided into five subsystems or loops:
  - 1. Air-side
  - 2. Chilled water
  - 3. Refrigeration equipment
  - 4. Heat rejection
  - 5. Controls

33 °C, 28 °C



Conditioned space

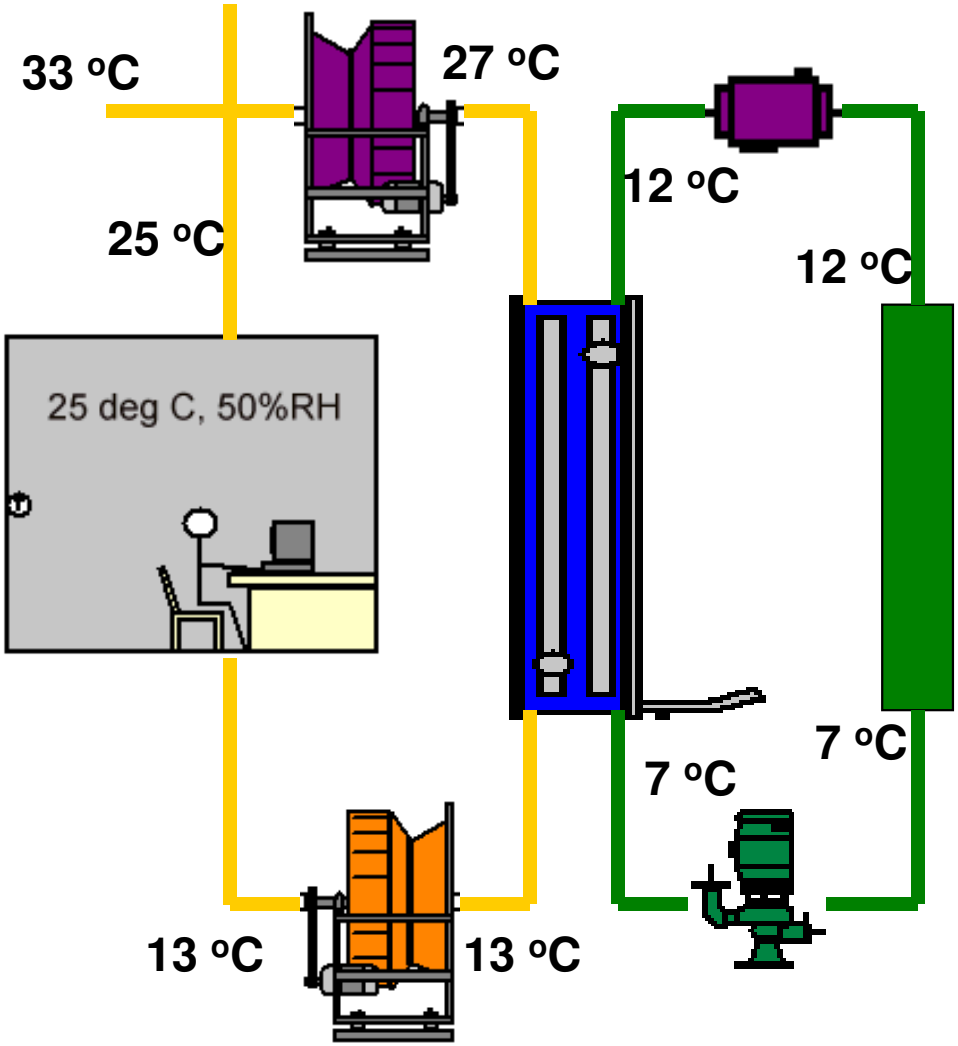
33 °C, 28 °C



Air side system

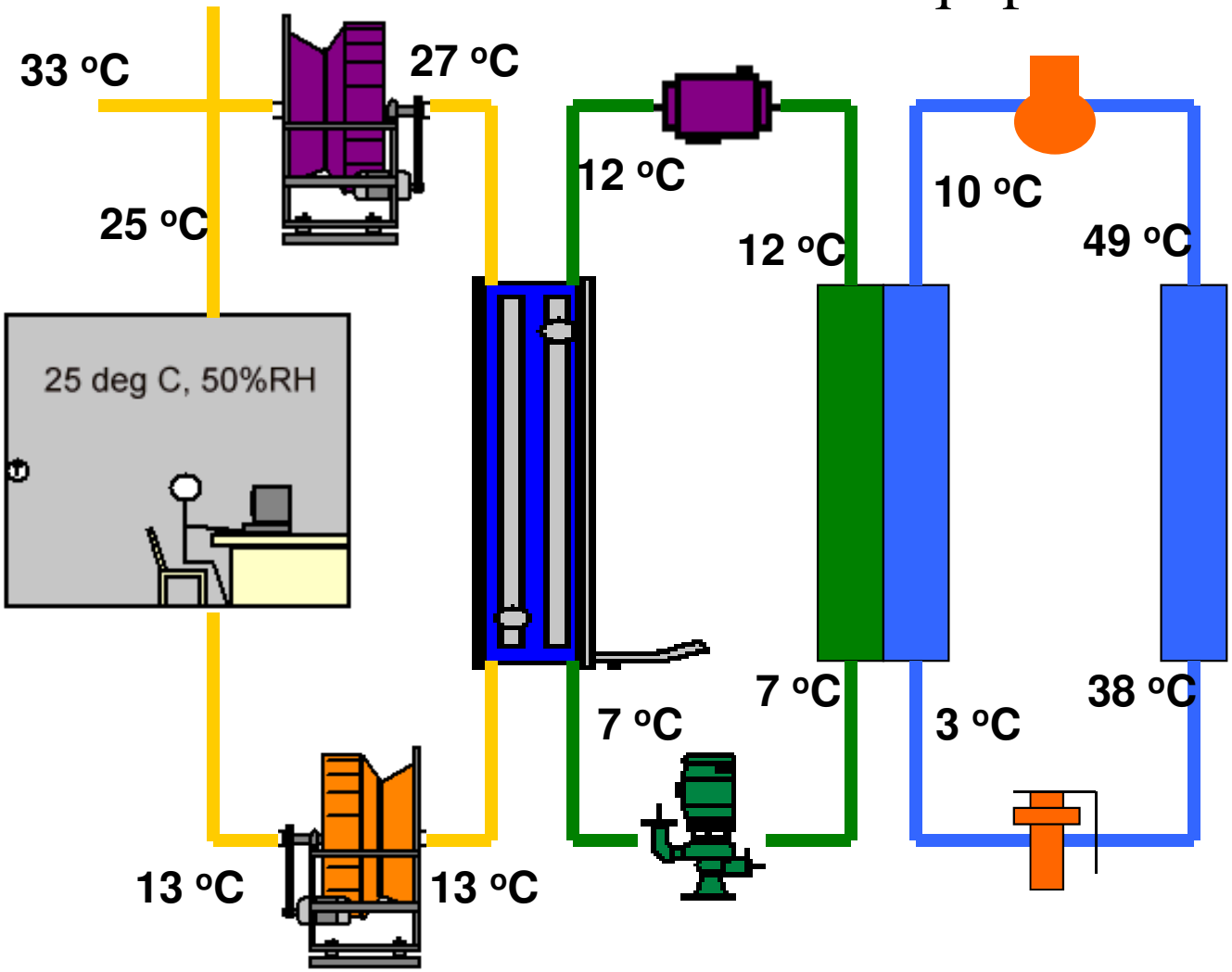
33 °C, 28 °C

Chilled water system



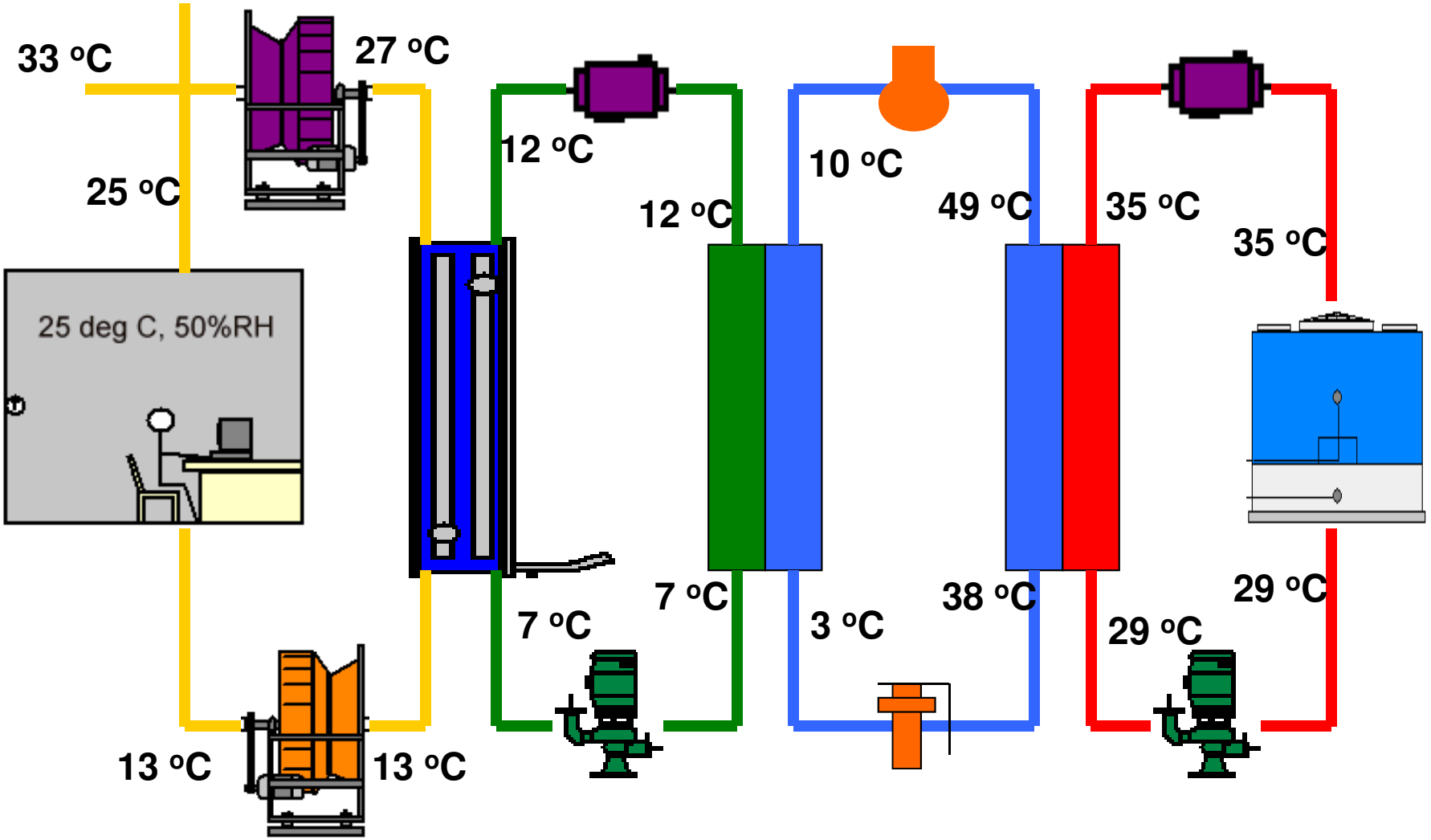
33 °C, 28 °C

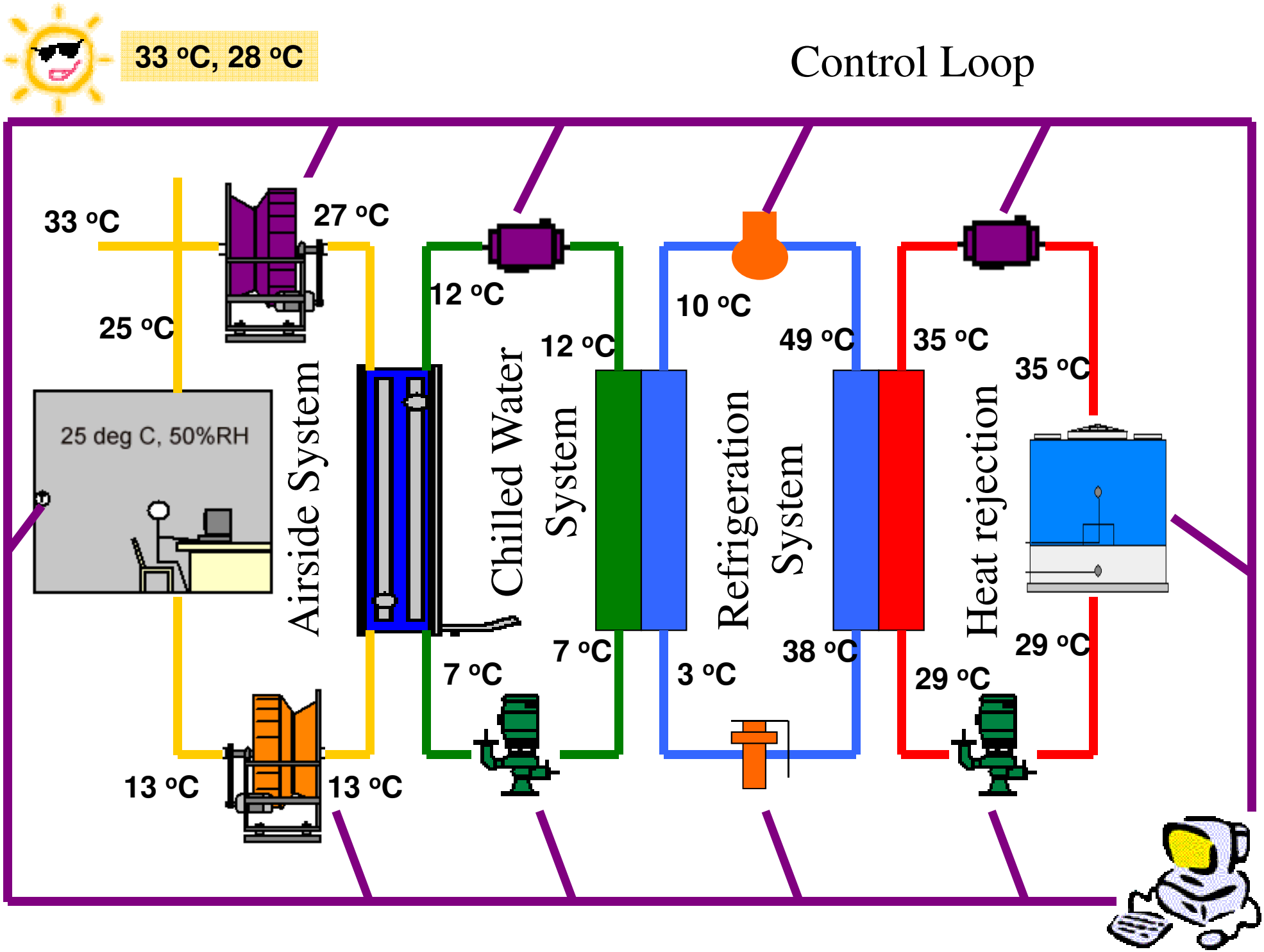
Refrigeration equipment



33 °C, 28 °C

Heat rejection

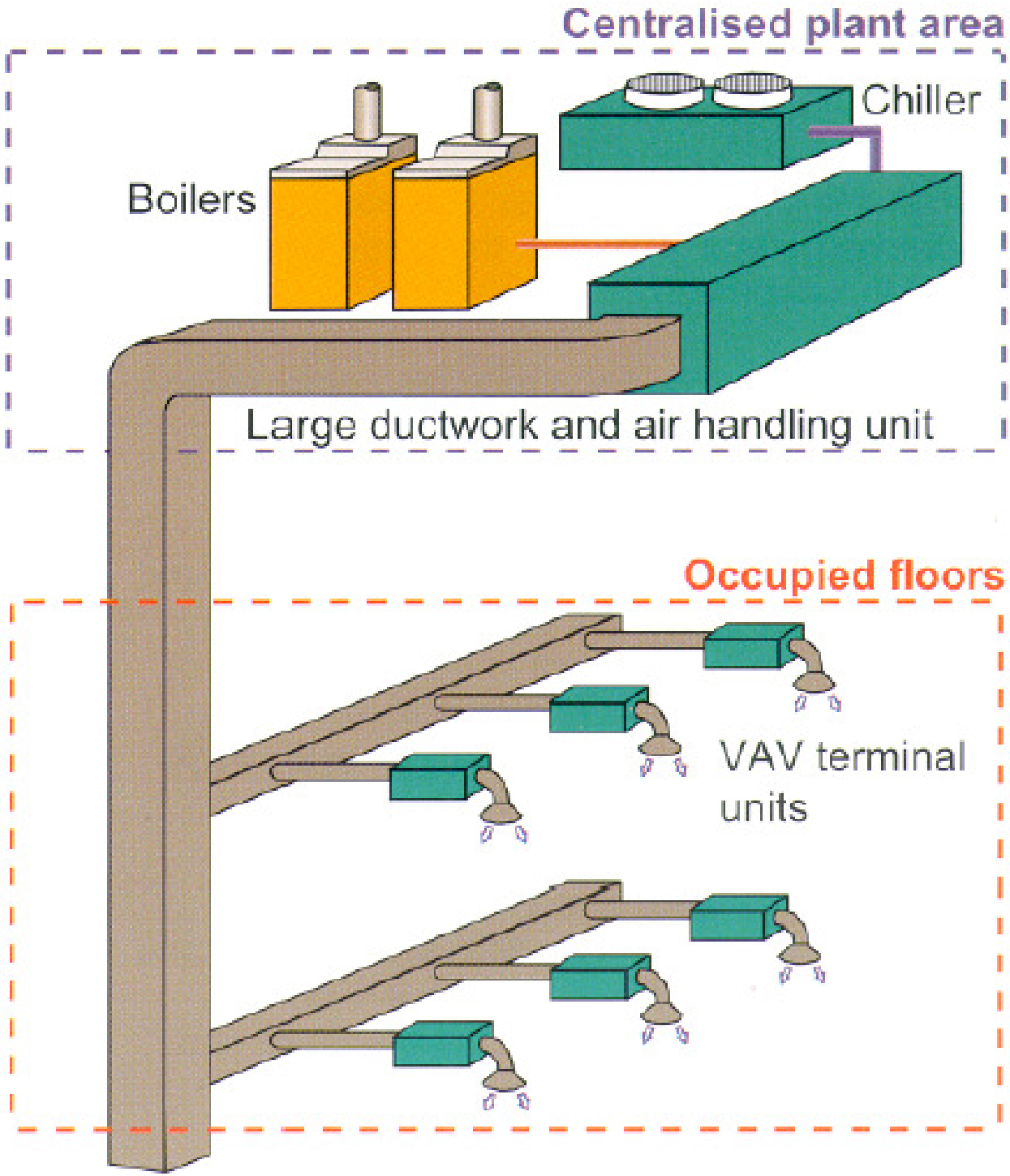



33 °C, 28 °C
Control Loop
33 °C
27 °C
25 °C
25 deg C, 50%RH
Airside System
12 °C
Chilled Water System
12 °C
7 °C
7 °C
10 °C
Refrigeration System
49 °C
38 °C
3 °C
35 °C
Heat rejection
35 °C
29 °C
29 °C
13 °C
13 °C

Design of HVAC Systems

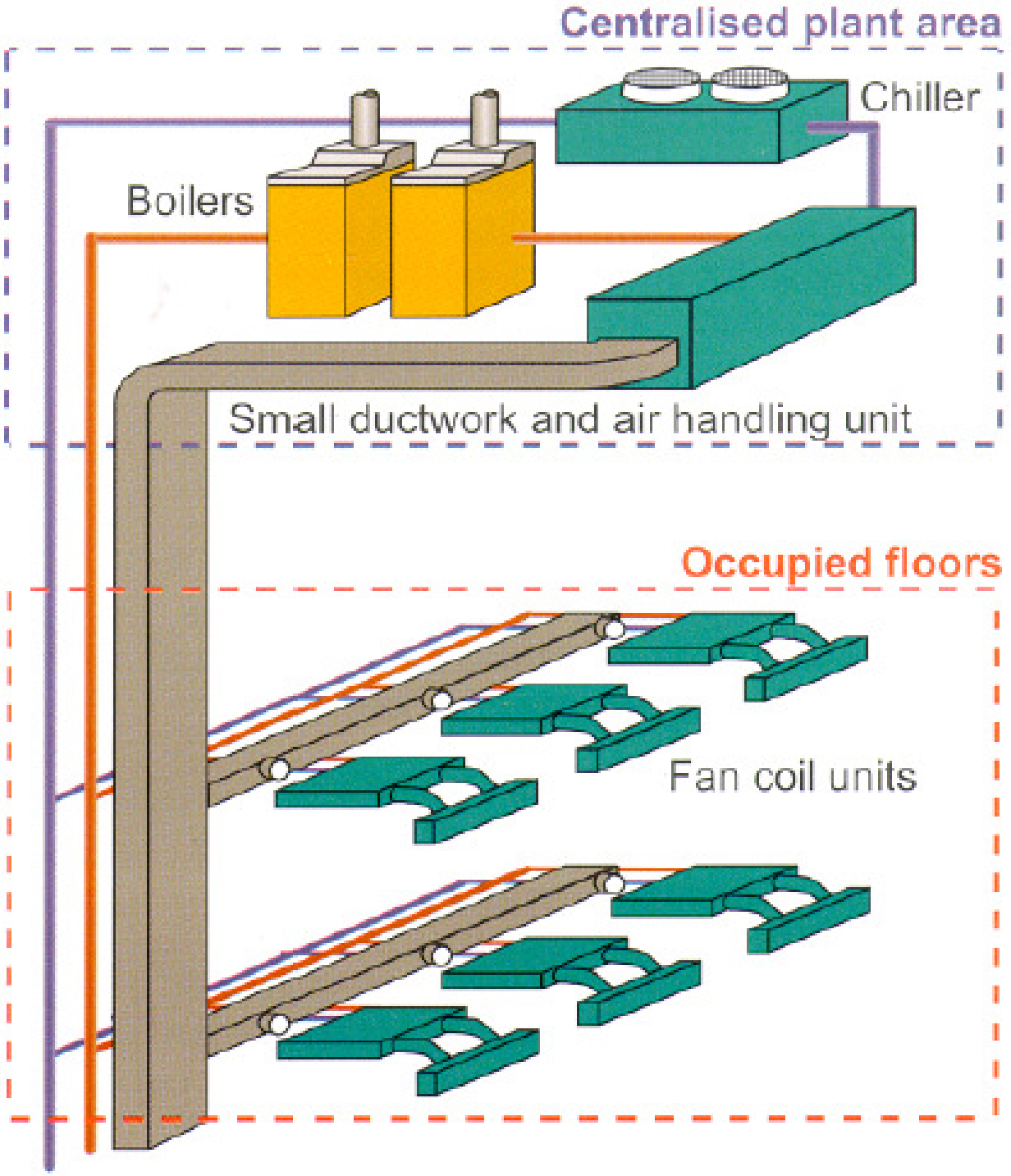
- Classification of HVAC systems -- three generic types of systems:
  - Centralised all air systems
    - Such as CAV (constant air volume), VAV (variable air volume), dual duct, multizone
  - Partially centralised air/water systems
    - Such as FCU (fan coil unit), induction units
  - Local systems (mainly direct expansion systems)
    - Such as window-type units, split-type systems, VRF (variable refrigerant flow)(?)

Centralised air system *(VAV example)*

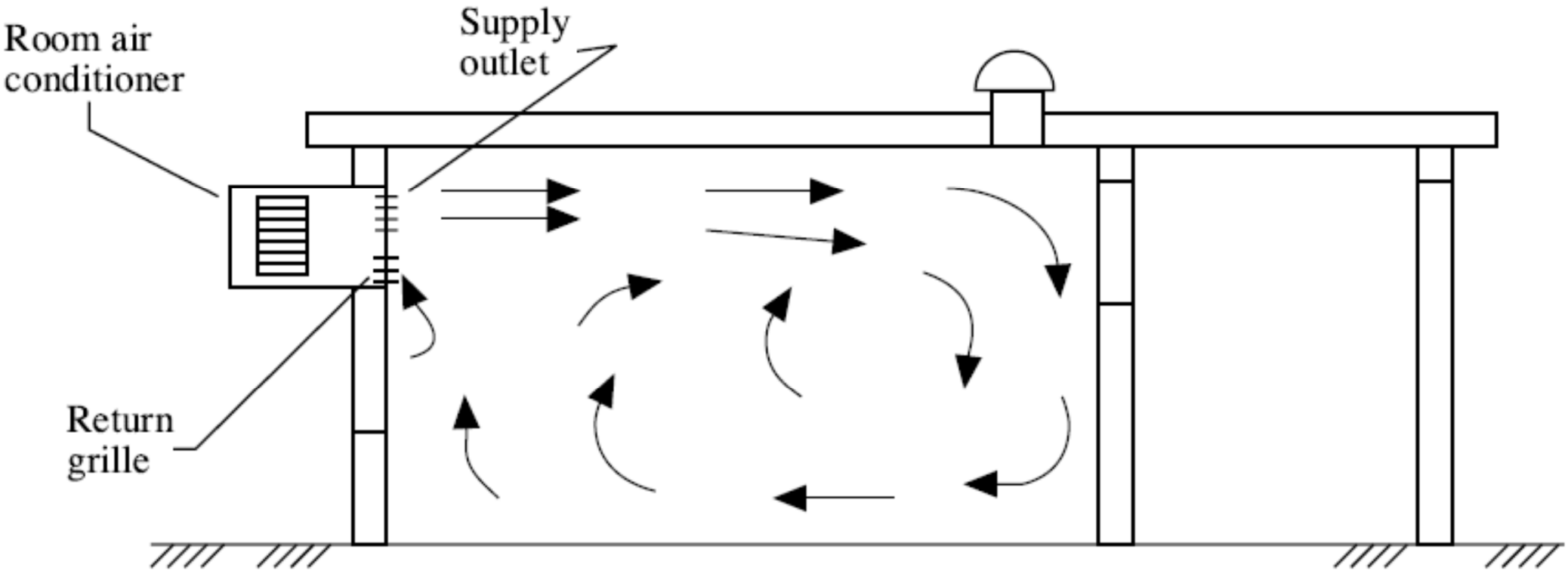


Partially centralised air/water system

(Fan coil example)

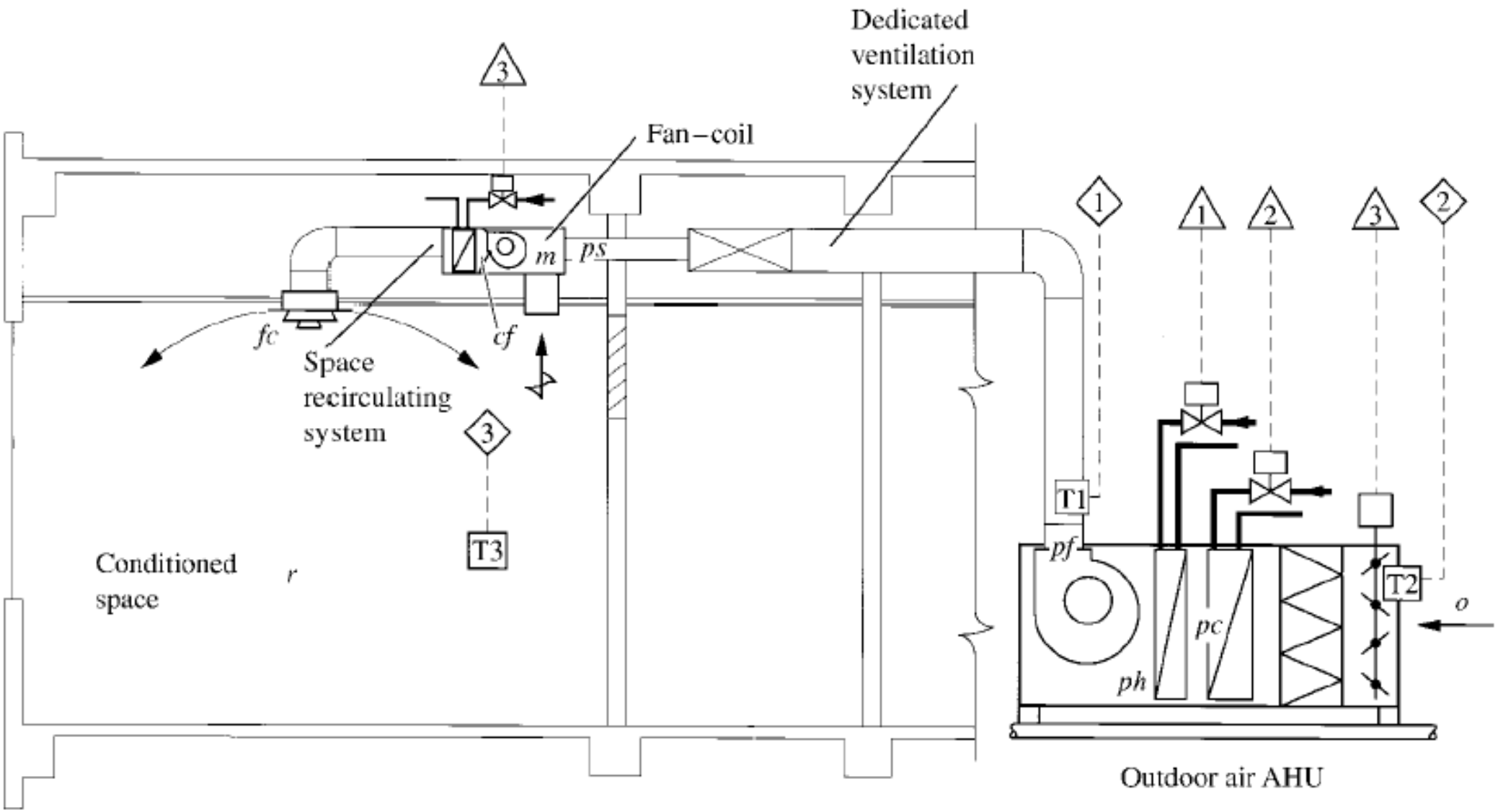


An individual room air-conditioning system



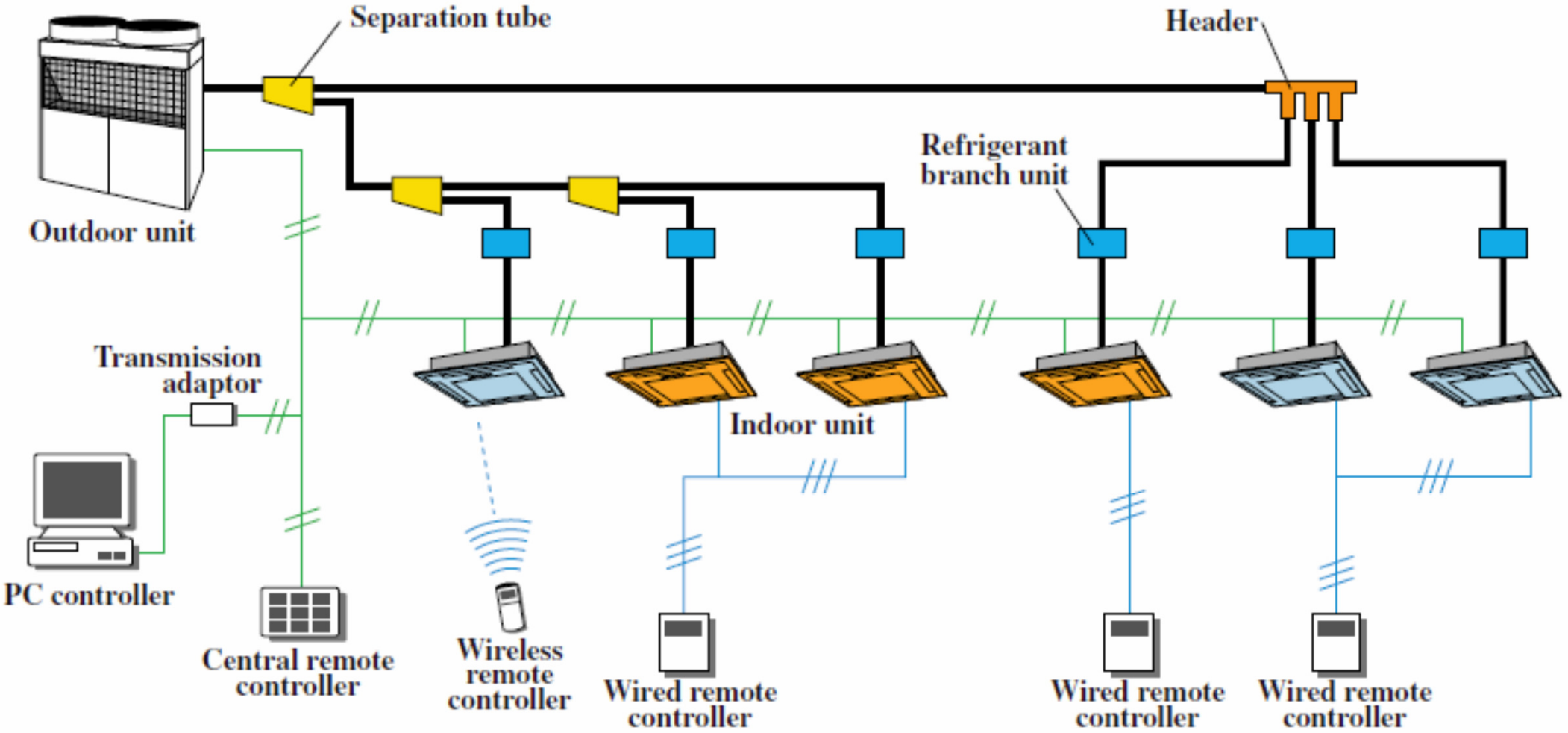
(Source: Wang, S. K., Lavan, Z. and Norton, P., 2000. *Air Conditioning and Refrigeration Engineering*)

Primary air fan coil unit (PA-FCU) system



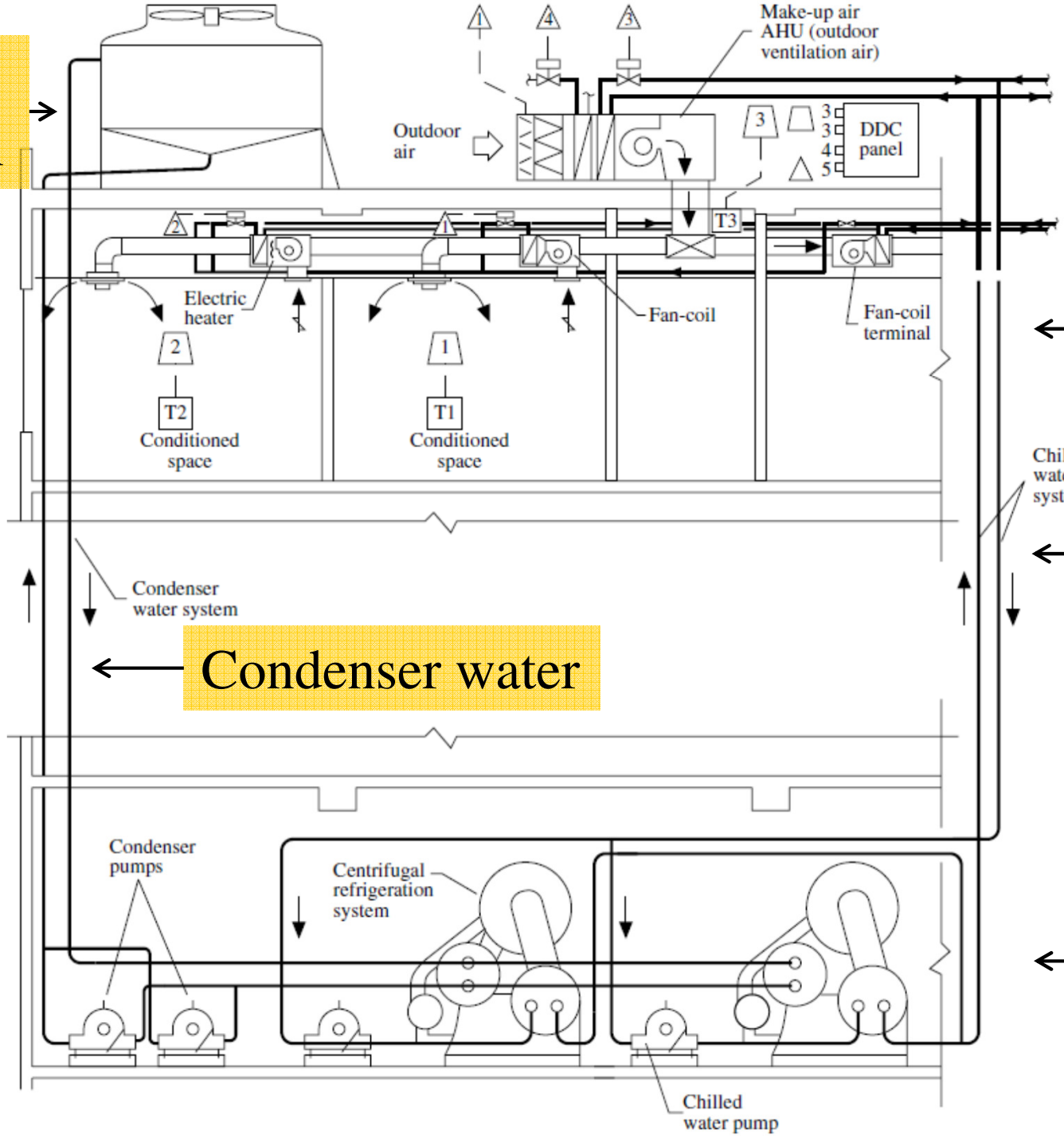
(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.)

Variable refrigerant flow (VRF) system



(Source: Fujitsu) (See also: http://en.wikipedia.org/wiki/Variable_refrigerant_flow)

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*)

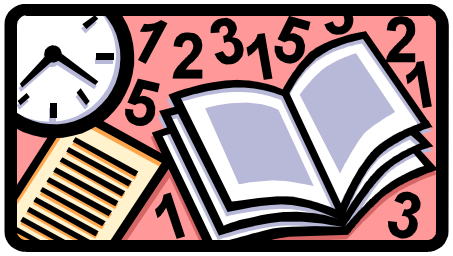
Design of HVAC Systems

- Design of an HVAC system includes:
  - 1. Calculation of the maximum cooling and heating loads for the spaces to be served
  - 2. Selection of the type of system to be used
  - 3. Calculation of piping and/or duct sizes
  - 4. Selection of the type and size of equipment (chillers, boilers, fans, air handling units, heat exchangers, etc.)
  - 5. A layout of the system and schematic diagrams

(See also: Lesson 36 Selection Of Air Conditioning Systems http://nptel.ac.in/courses/112105129/36)

Hong Kong International Airport

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.
- Videos:
  - Air Conditioning 1 - Introduction (0:47), http://youtu.be/rUJjj6Fnhz4
  - Air Conditioning 2 - Air Cycle (1:46), http://youtu.be/nDUrjUgjADE
  - Home Cooling System Design Issues (5:07), http://youtu.be/3r1bMdFS4NA
- Lesson 36 Selection Of Air Conditioning Systems http://nptel.ac.in/courses/112105129/36