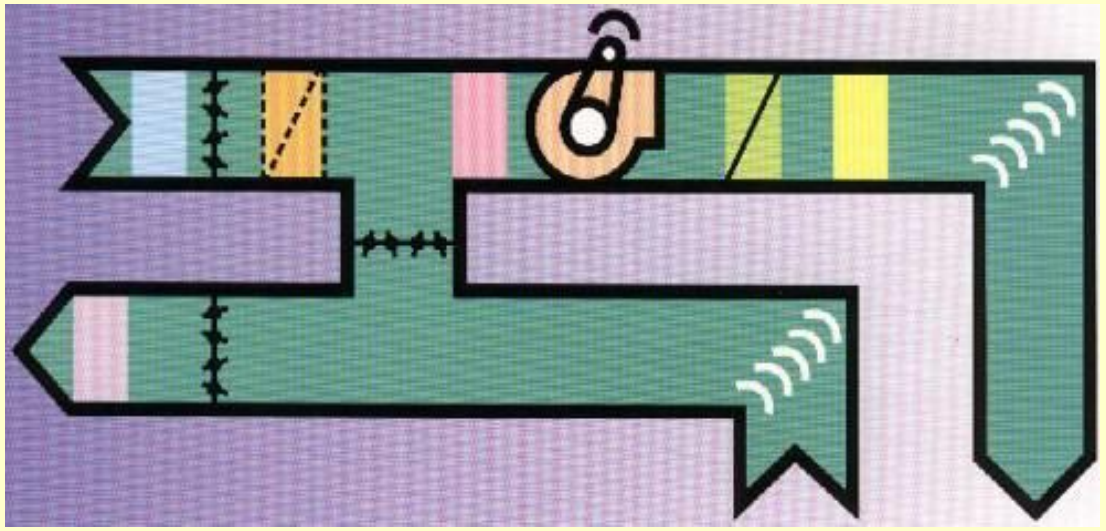
SBS5225 HVACR I

http://ibse.hk/SBS5225/



Introduction to HVAC&R systems

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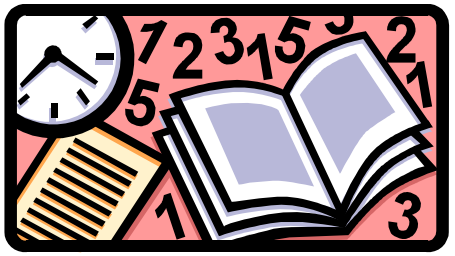
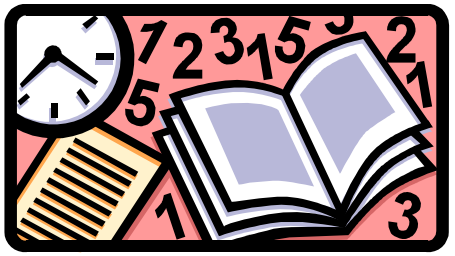
Aug 2016

Background



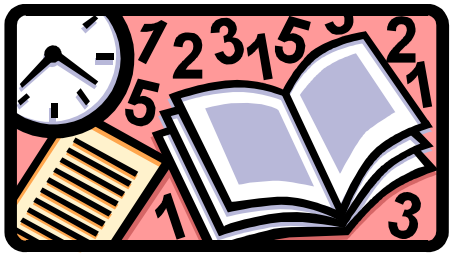
- Required basic knowledge:
  - Fluid Mechanics, Thermodynamics
- Related courses:
  - SBS5311 HVACR II
  - SBS5397 Final Year Project 1 (BSE Conceptual Design)
  - SBS5499 Final Year Project 3 (MEP Design)
- This course may be useful to SBS5498 Final Year Project 2 (Applied Research Project)

Background

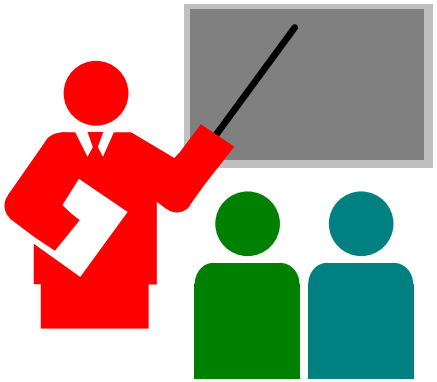


- Learning Outcomes:
  - 1. apply psychrometric analysis to determine the operating conditions such as heat and moisture transport in air- conditioning processes and cycles;
  - 2. estimate the contributions of various sources of heat gains and losses to design cooling and heating loads of zones and buildings;
  - 3. analyse the ventilation requirements for occupants ;
  - 4. determine duty and power demand of fans in HVAC air handling and distribution;
  - 5. critically review performance of HVAC air handling and distribution with constant air volume (CAV) control and variable air volume (VAV) control for premises within buildings; and
  - 6. discuss the considerations that lead to the selection of control methods in HVAC air handling and distribution

Background



- Lecturers:
  - Dr. Sam C. M. Hui (cmhui@vtc.edu.hk)
  - Dr. Yimo LUO, Constance (yimo.luo@vtc.edu.hk)
- Assessment Methods:
  - Coursework (25%): Mid-term test (10%), Laboratory/Field work (15%)
  - Mini design project (15%)
  - Examination (60%) (3 hours)
- Course Website: (with links and resources)
  - http://ibse.hk/SBS5225/



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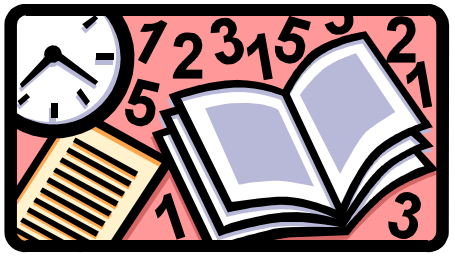
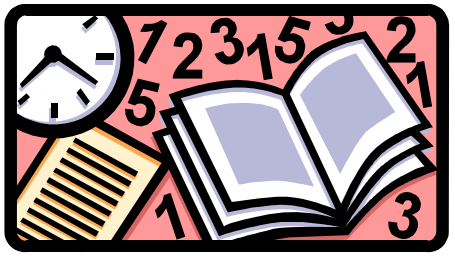


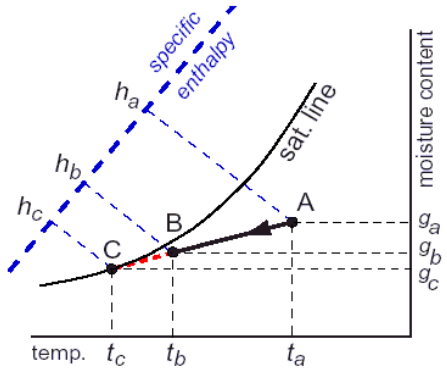
- ***Ir. Dr. Sam C. M. Hui*** (*Building Services Engineer*)
  - PhD, BEng(Hons), CEng, CEM, BEAP, BEMP, HBDP, MASHRAE, MCIBSE, MHKIE, MIESNA, LifeMAEE, AssocAIA
    - CEng = Chartered Engineer
    - CEM = Certified Energy Manager
    - BEAP = Building Energy Assessment Professional
    - BEMP = Building Energy Modeling Professional
    - HBDP = High-performance Building Design Professional
    - LifeMAEE = Life Member, Association of Energy Engineers
  - ASHRAE Distinguished Lecturer (2009-2011)
  - 20 yrs. teaching in HKU Departments of Architecture and Mech. Engg.
  - Research interests: energy efficiency in buildings and sustainable building technologies

Background



- Study topics:
  - Introduction to HVAC&R systems
  - Thermal comfort
  - Psychrometry
  - Air conditioning processes and cycles
  - Load estimation
  - Energy calculations
  - HVAC air-side systems
  - Air duct design
  - Space air diffusion
  - Mechanical and natural ventilation
  - Sound and ventilation noise
  - HVAC air handling control methods

Dr. Hui



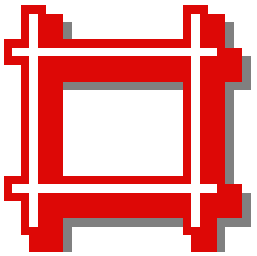
Dr. Luo

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

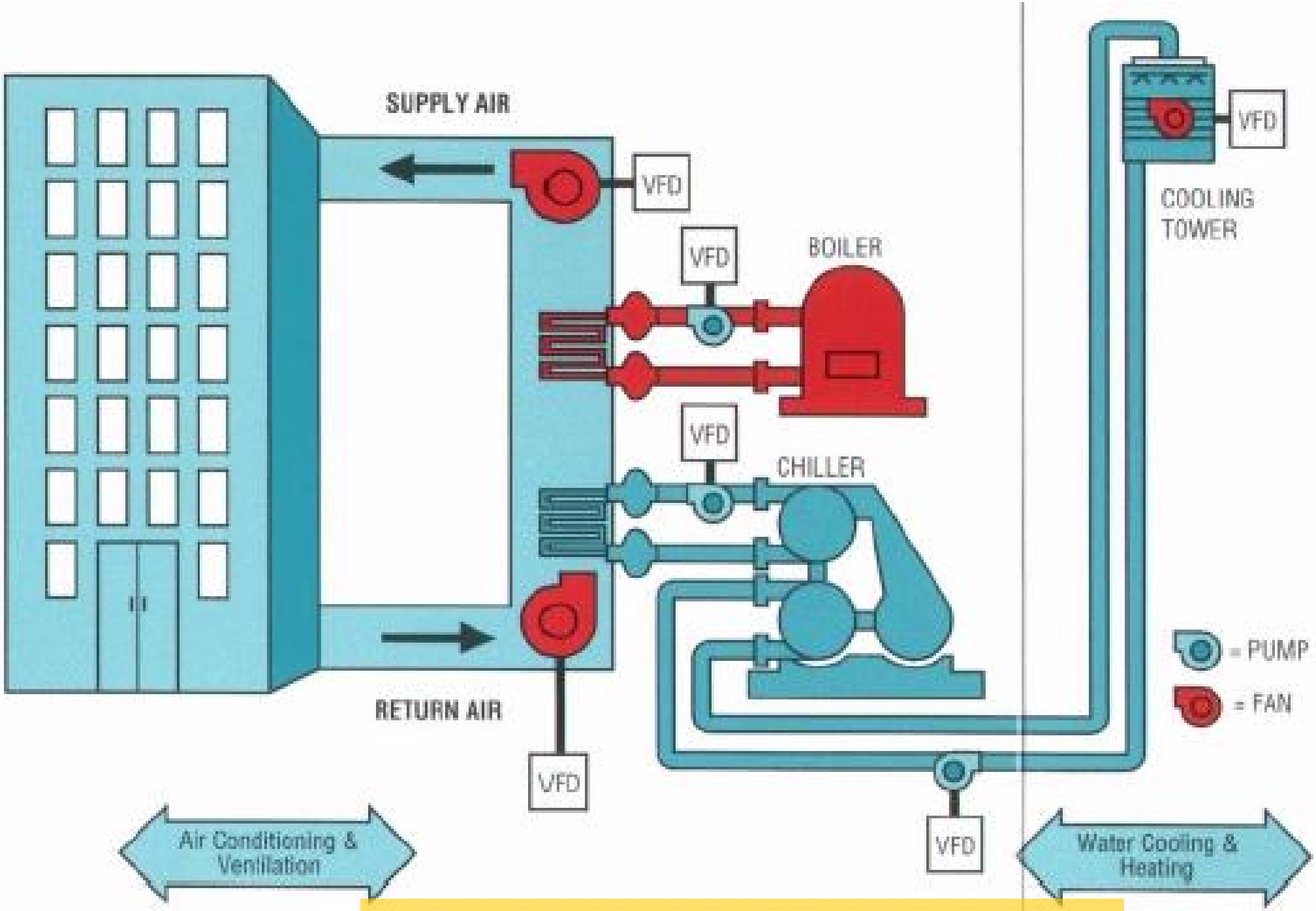
HVAC&R



- 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)

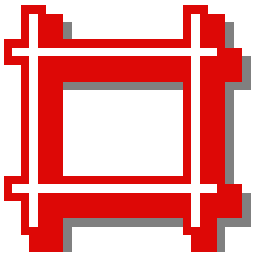
Example of a centralised HVAC system



Do you know the HVAC components?

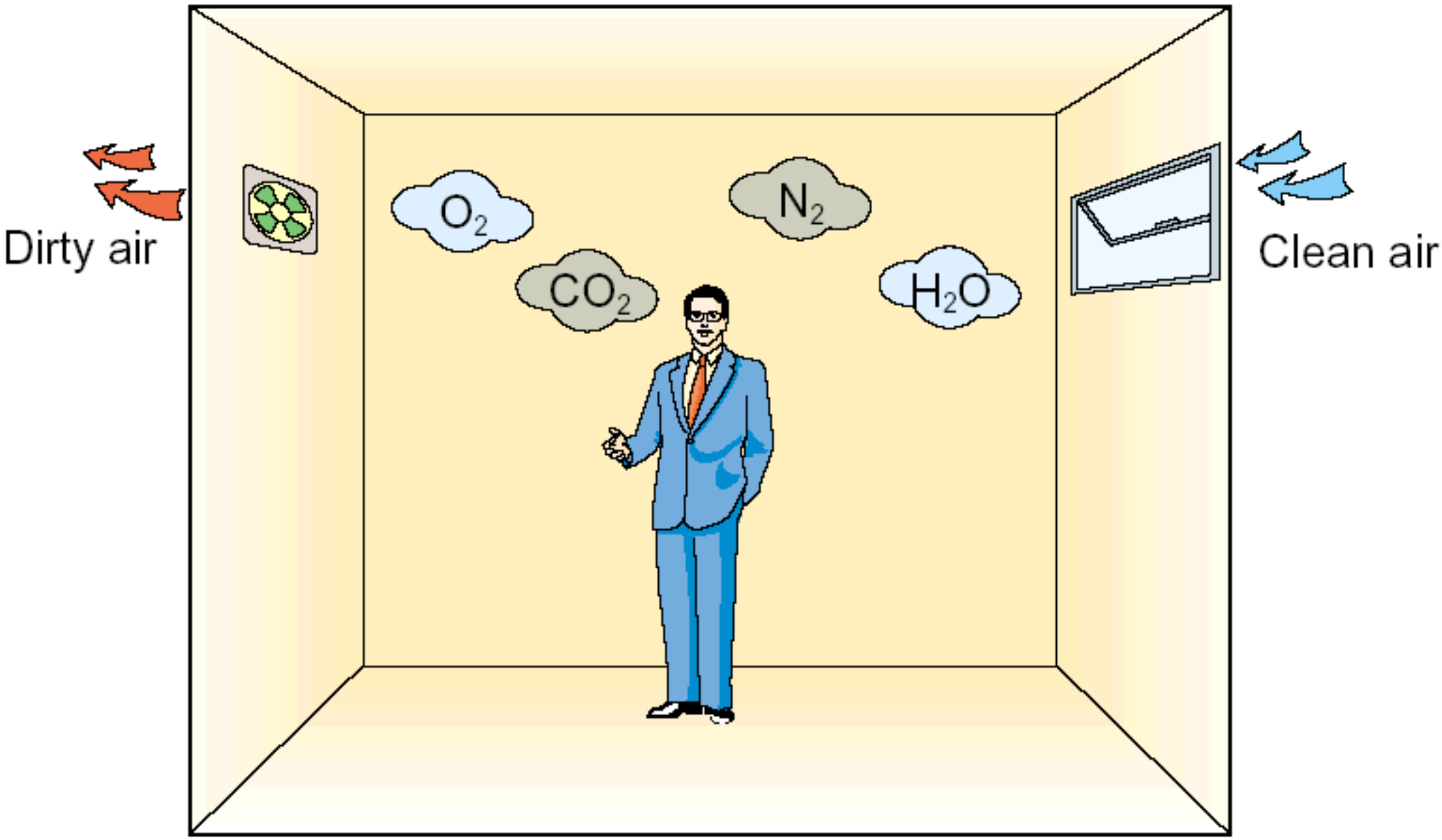
(Source: http://www.allhvacinfo.com/)

HVAC&R



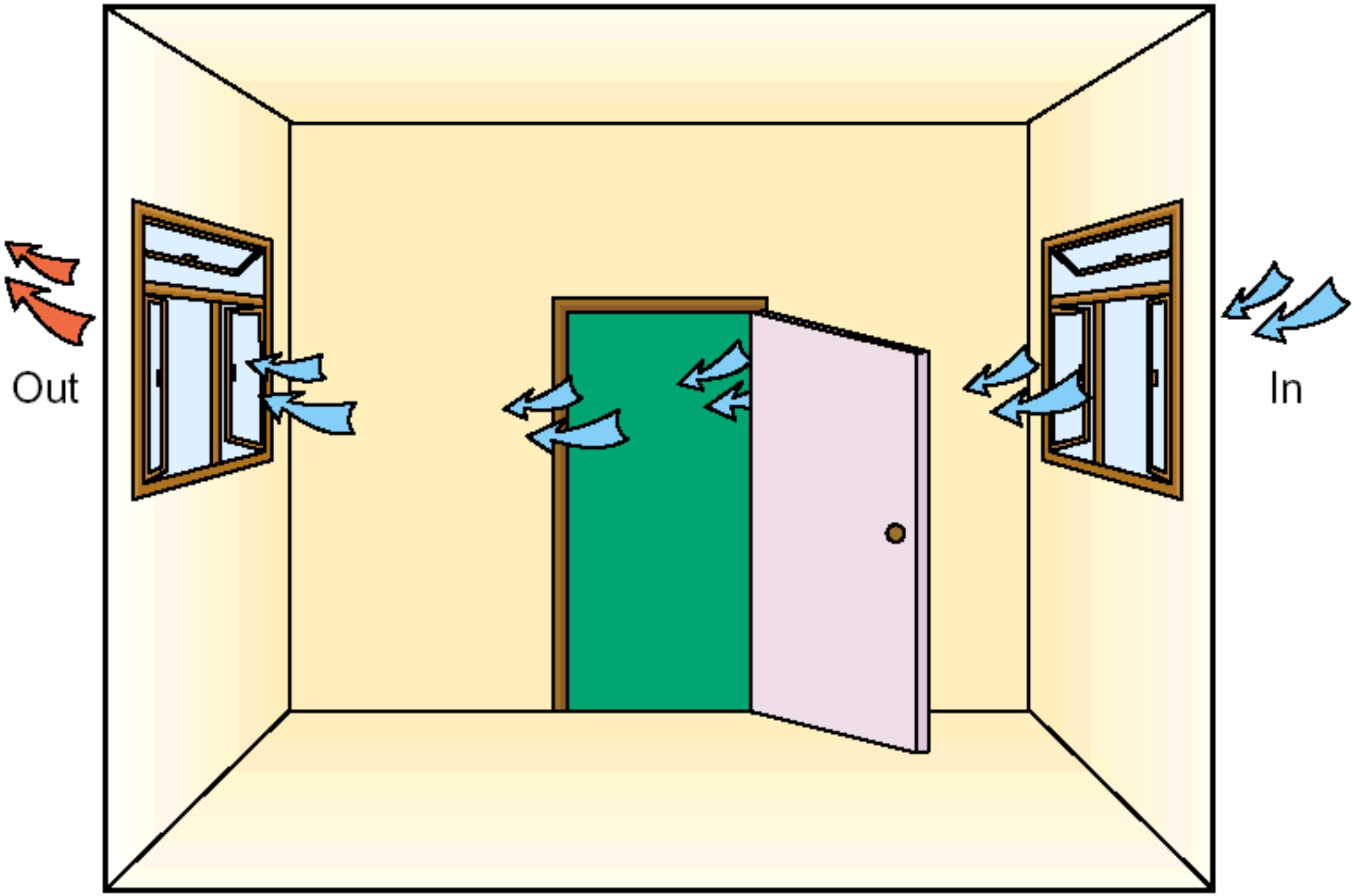
- Understand the purpose of HVAC design
  - To provide adequate indoor air quality by removing and/or diluting indoor pollutants
  - To provide adequate ventilation for processes
  - To remove heat & maintain thermal comfort
  - To control humidity & prevent condensation
- Understand the climate
  -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

Simple ventilation design



(Source: www.iaq.hk)

Cross ventilation



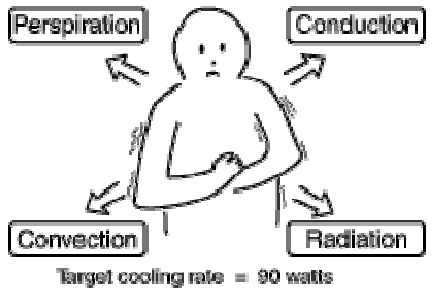
(Source: www.iaq.hk)

HVAC&R

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

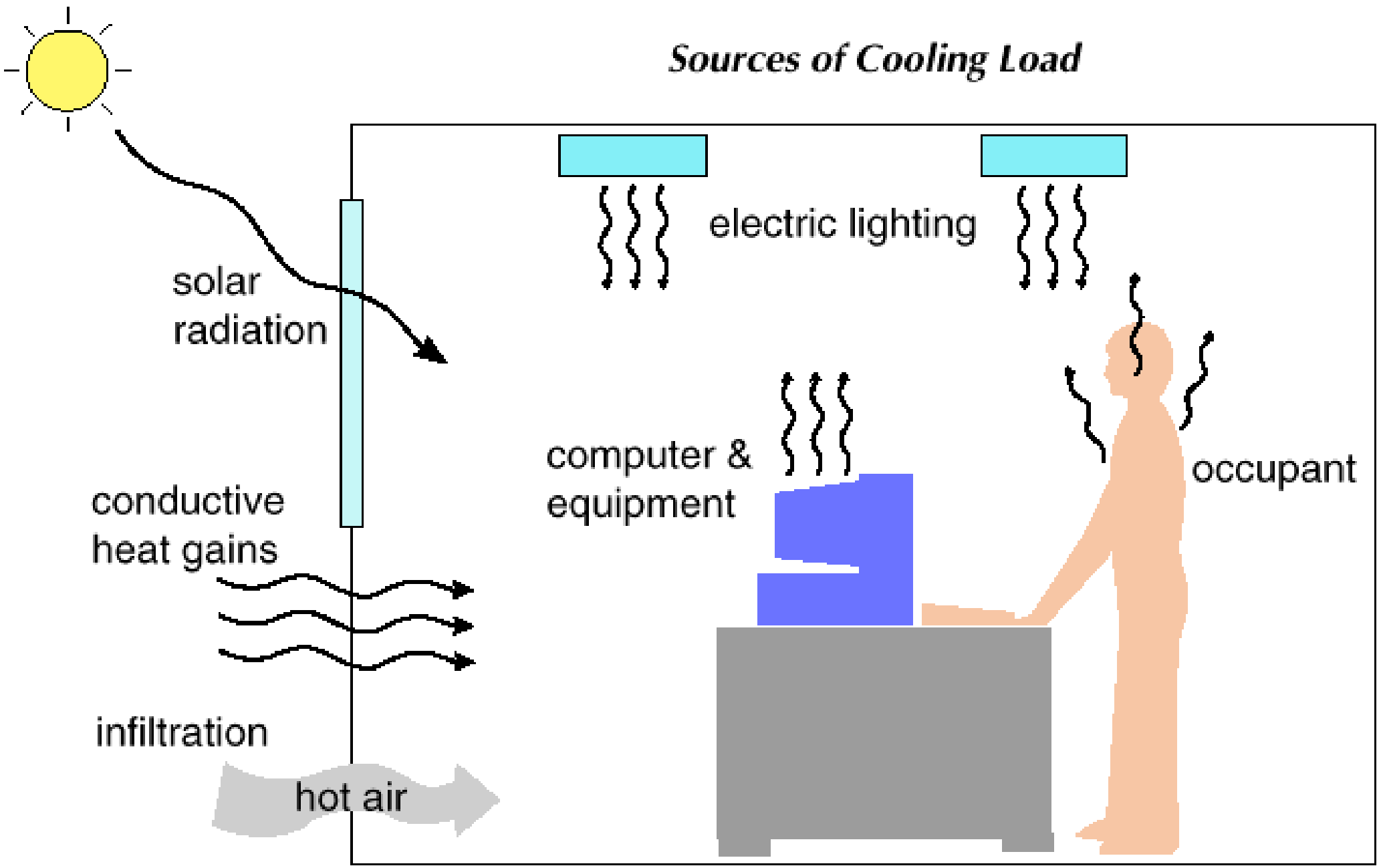
    - Site orientation & conditions
    - Built form, shading, window performance, thermal mass
    - Thermal insulation, reducing infiltration/air leakage
  - Building services elements, e.g.
    - Lighting system & daylighting
    - Small power or equipment loads

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

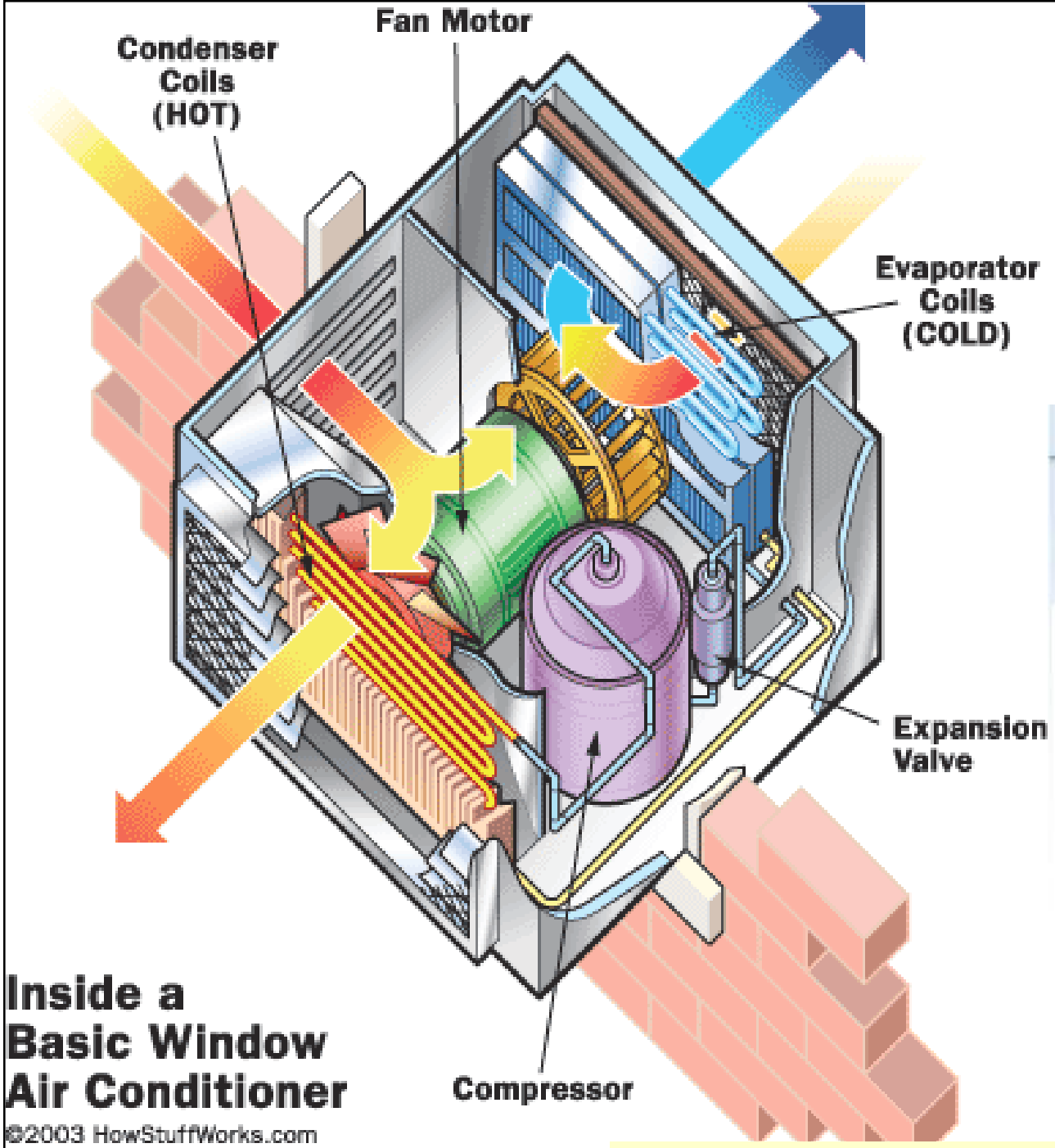


Outdoor weather

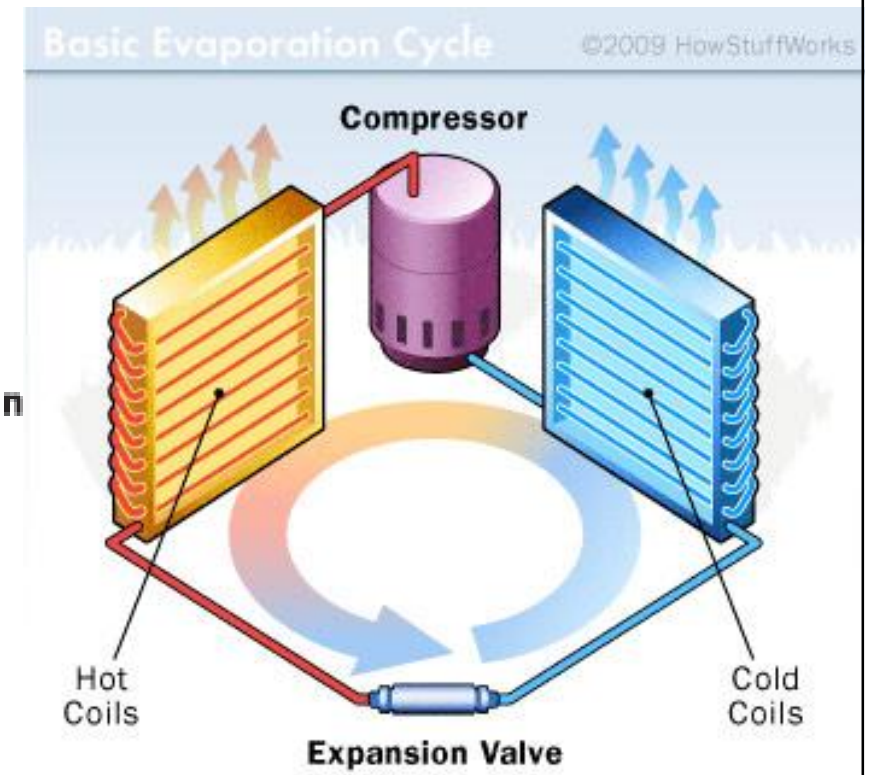
Can you identify all the heat gains?



Indoor conditions and activities



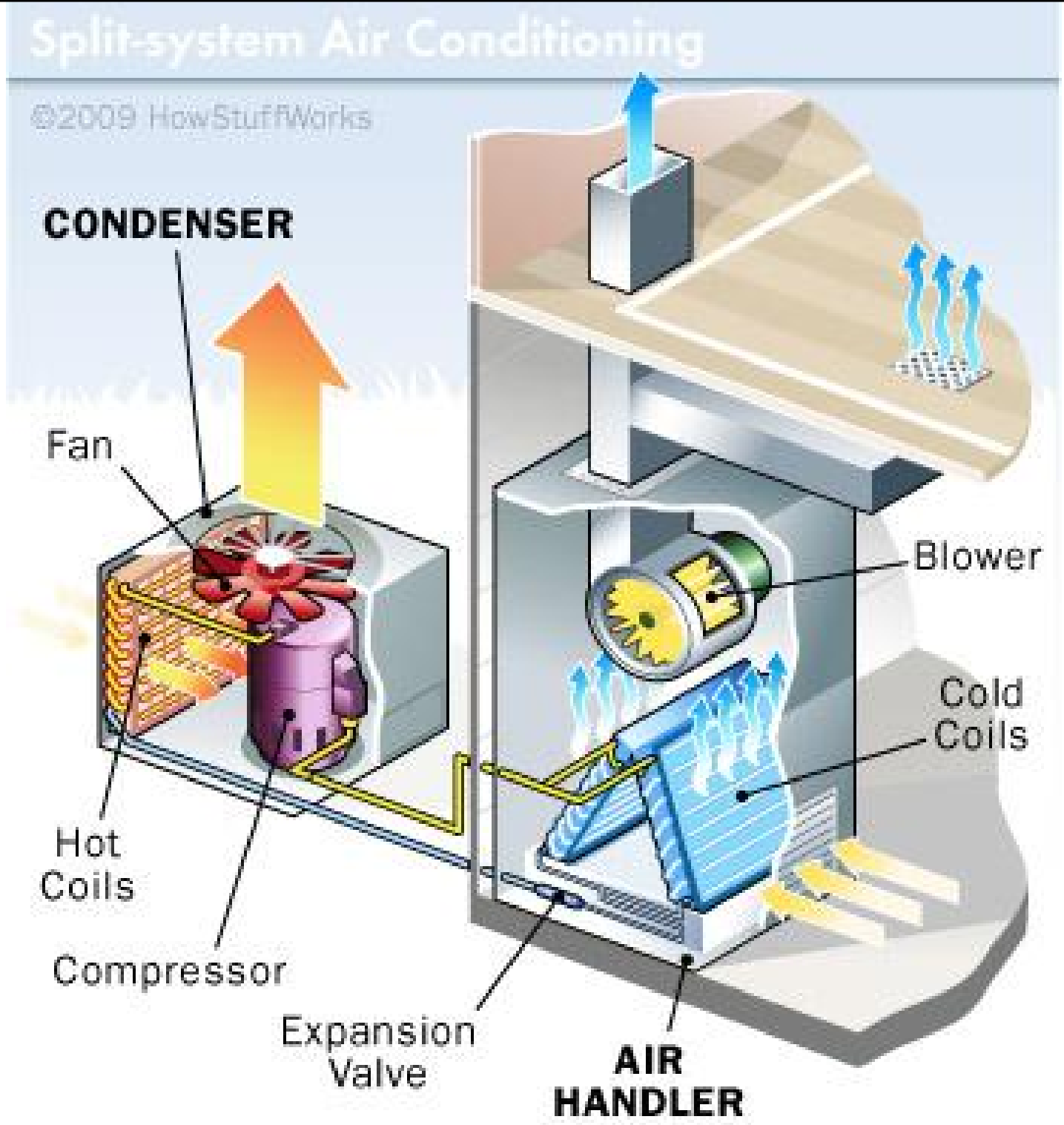
Window-type air conditioner



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

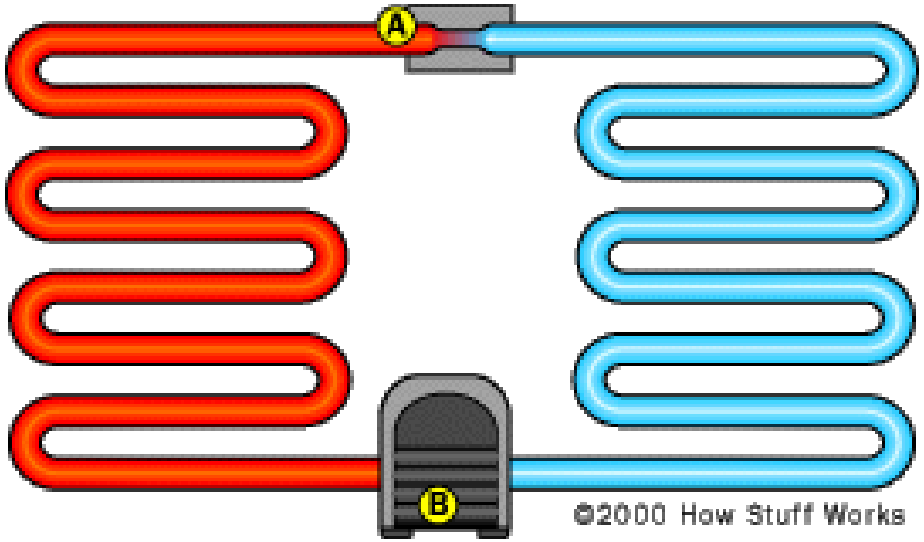
(Source: www.howstuffworks.com/ac.htm)

Split-type air conditioner



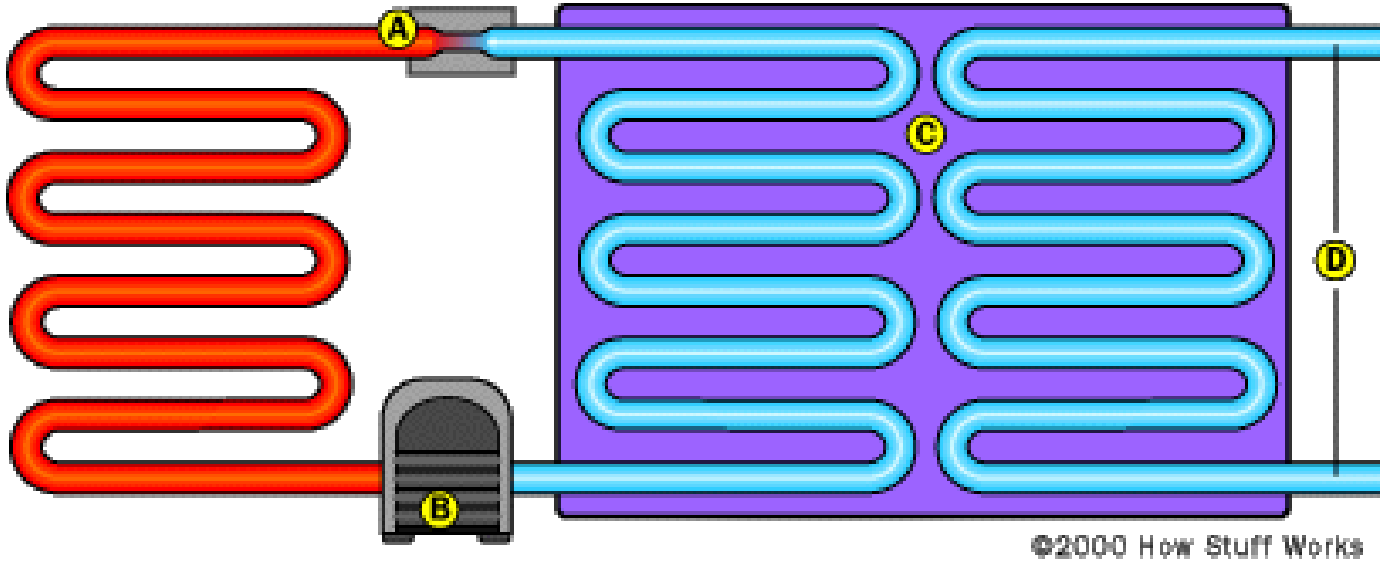
(Source: www.howstuffworks.com/ac.htm)

Refrigerant cycle



What are the major components?

A typical air conditioner



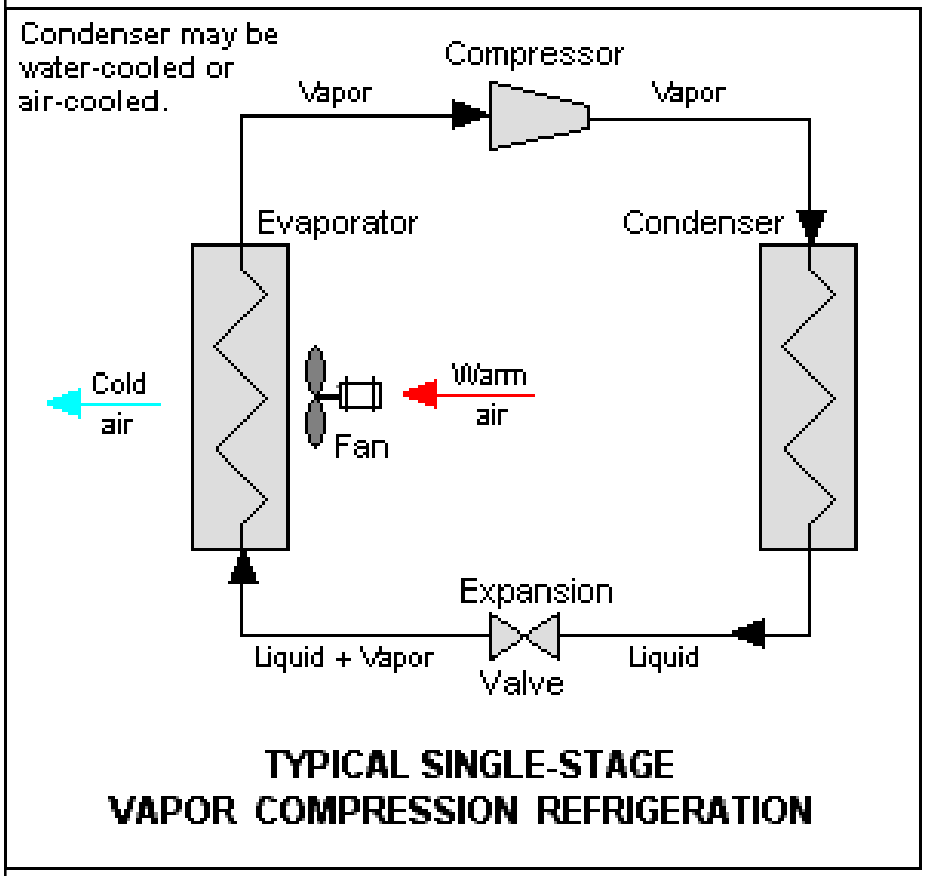
Chilled water system

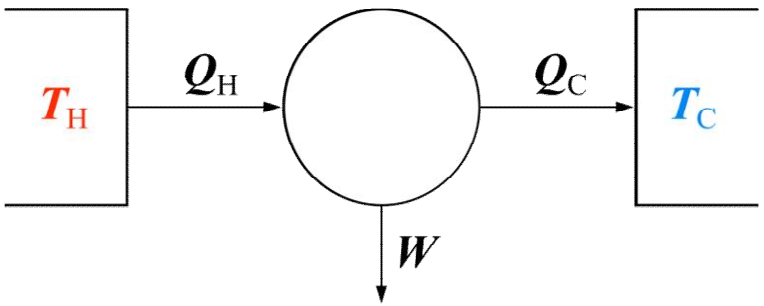
Air conditioning with a chilled water system

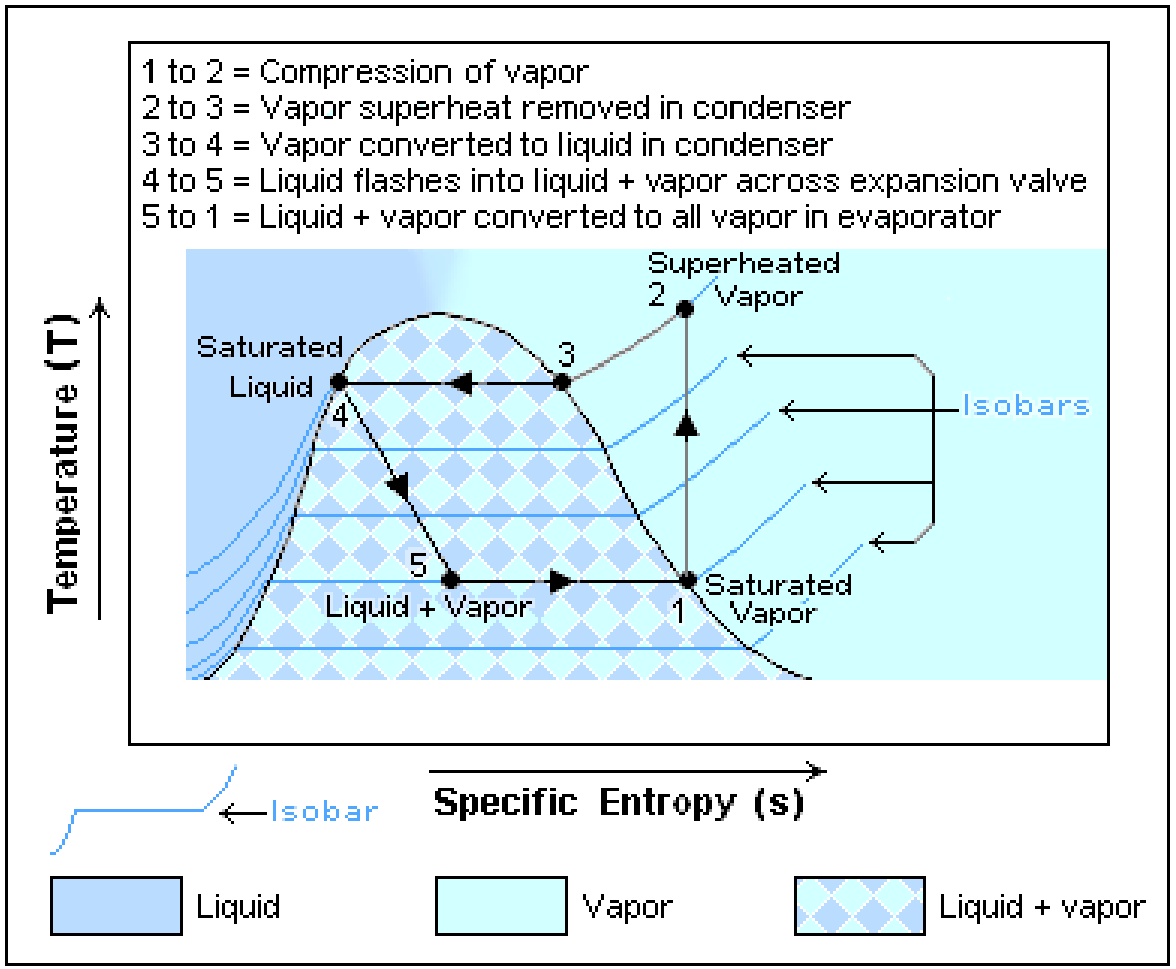
(Source: www.howstuffworks.com/ac.htm)

Vapour compression refrigeration

Can you explain the principles?





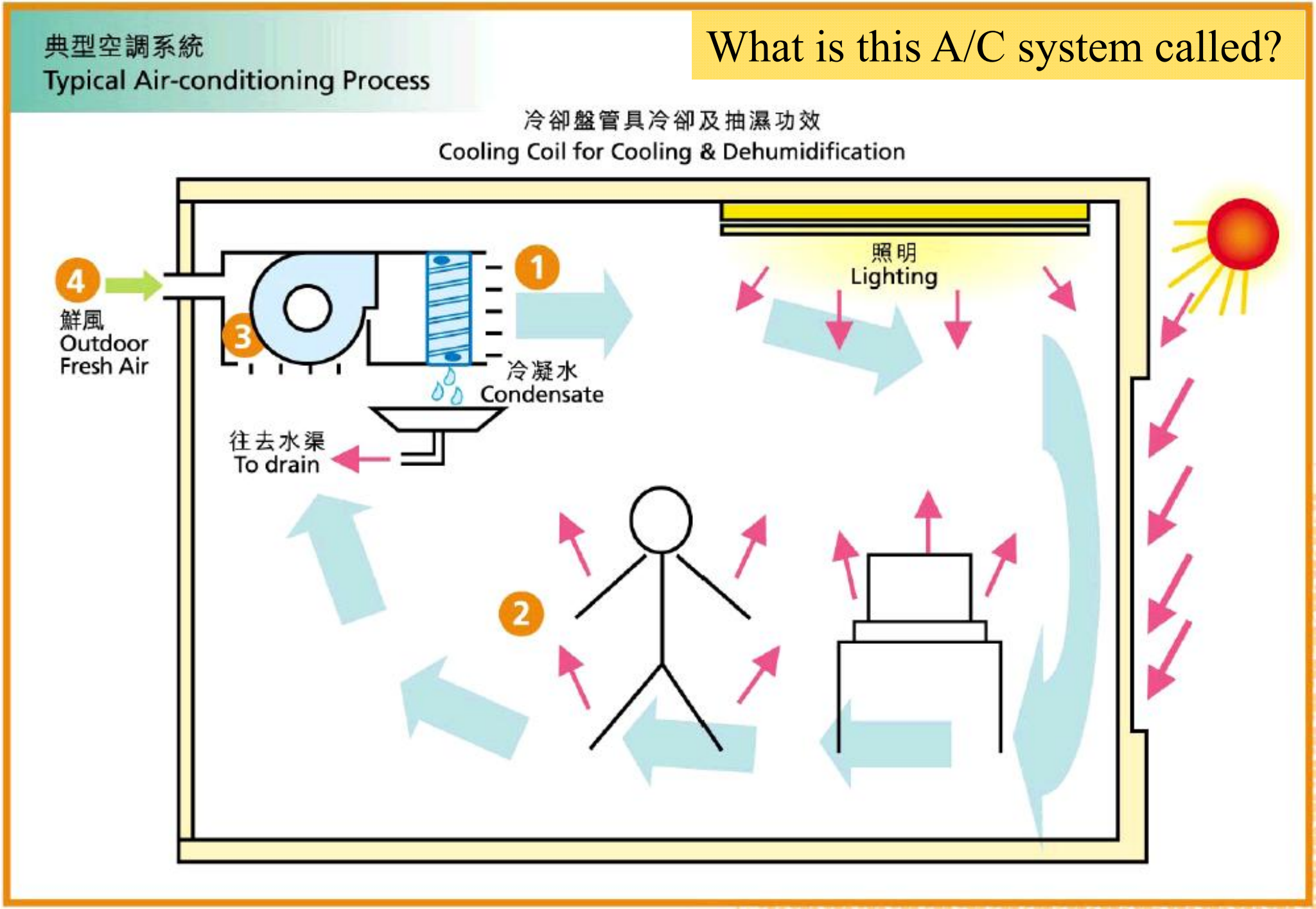


COP of a refrigerator = Cooling Effect/Work Input = $Q_L/W_{net,in}$

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

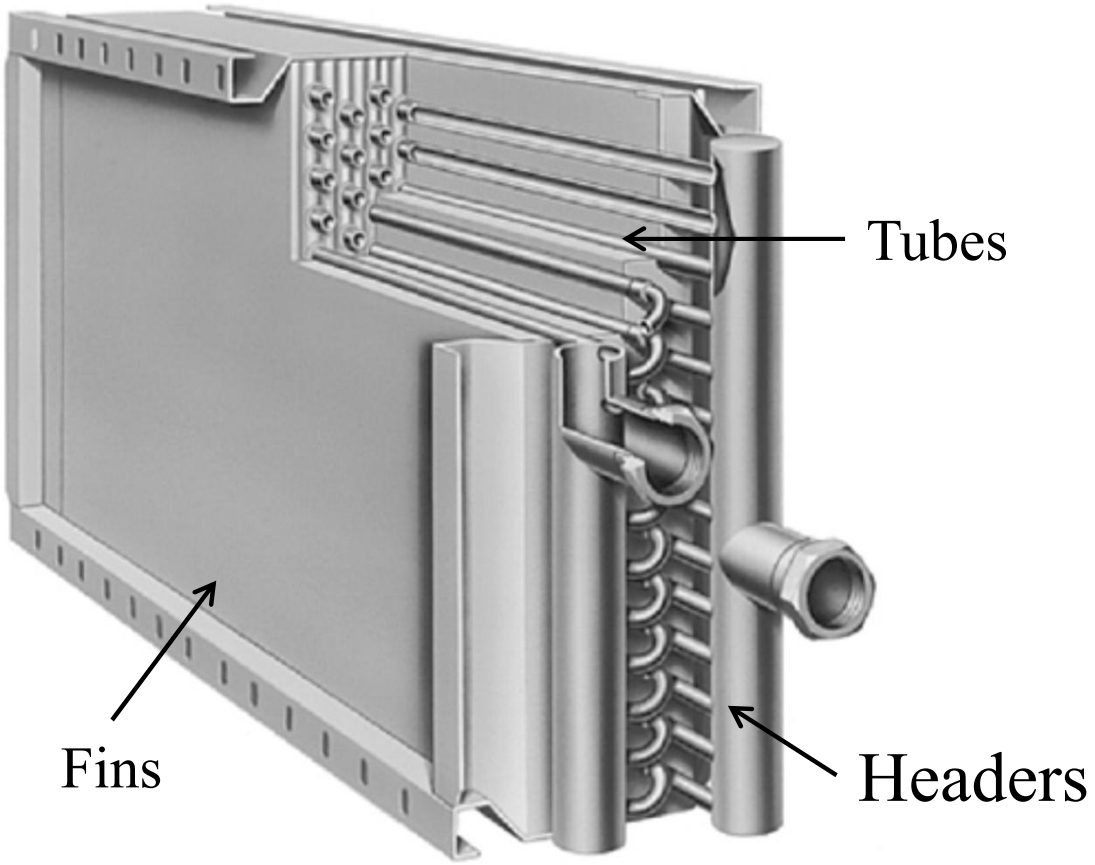
(Source: http://en.wikipedia.org/wiki/Heat_pump_and_refrigeration_cycle)

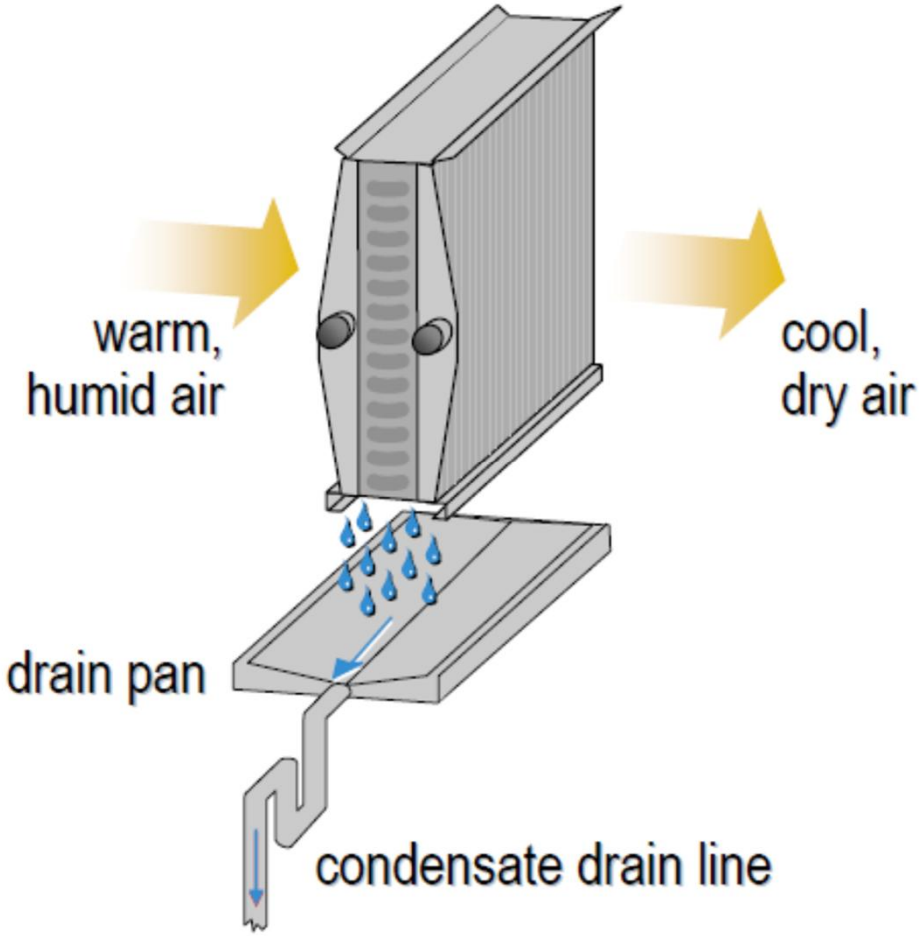
What is this A/C system called?



(Source: EnergyWitts newsletter, EMSD)

Chilled water cooling coil (a heat exchanger)



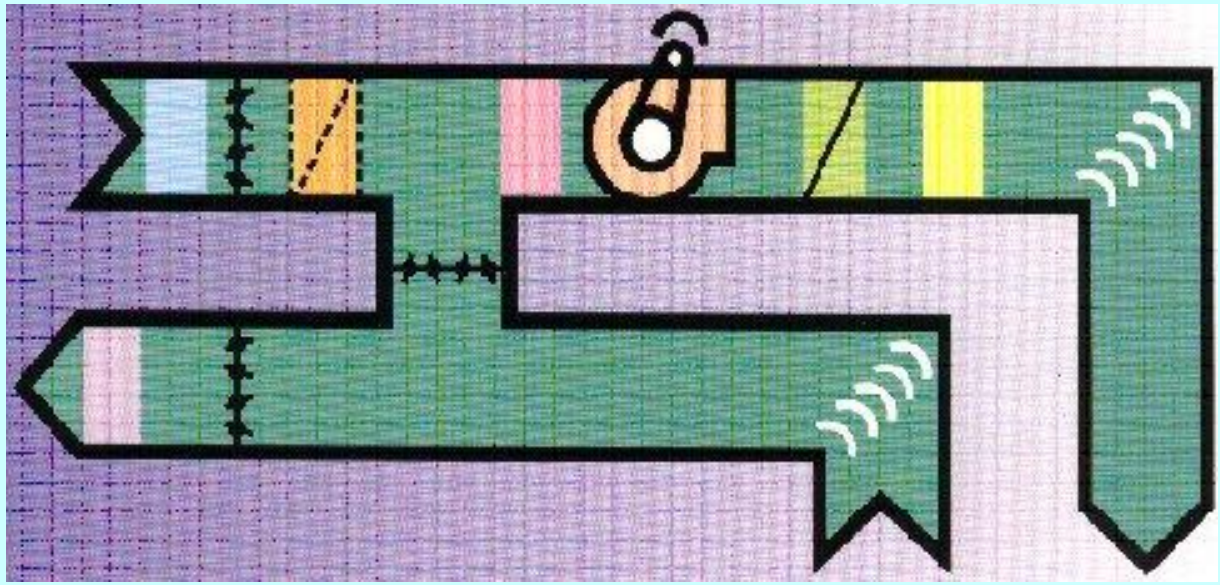


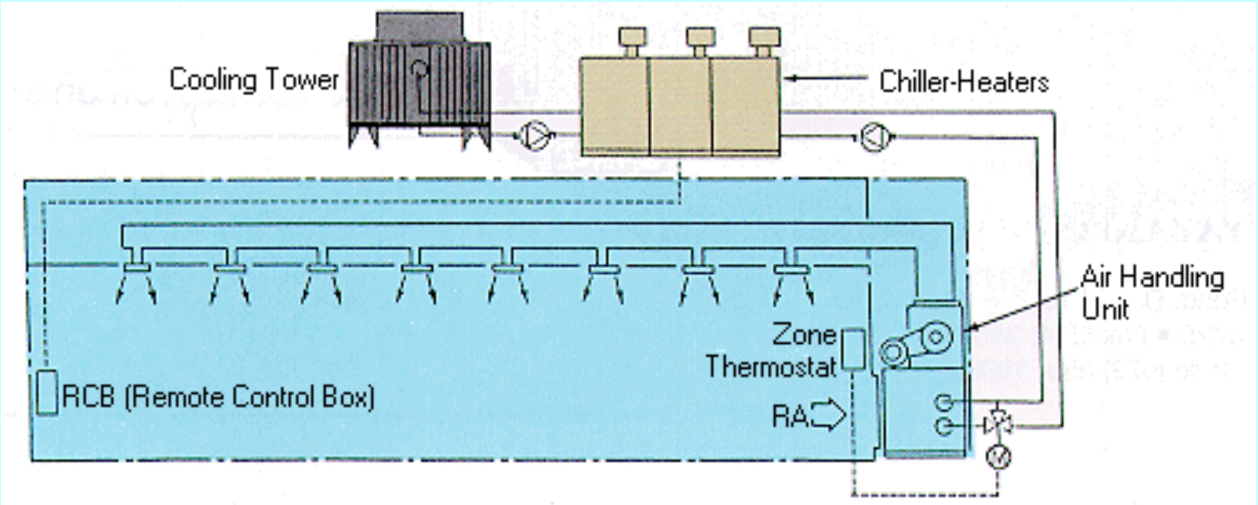
Sensible heat exchange: $q_S = m_a \text{ x } c_p \text{ x } (t_b - t_a)$

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

(Source: Trane)

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?

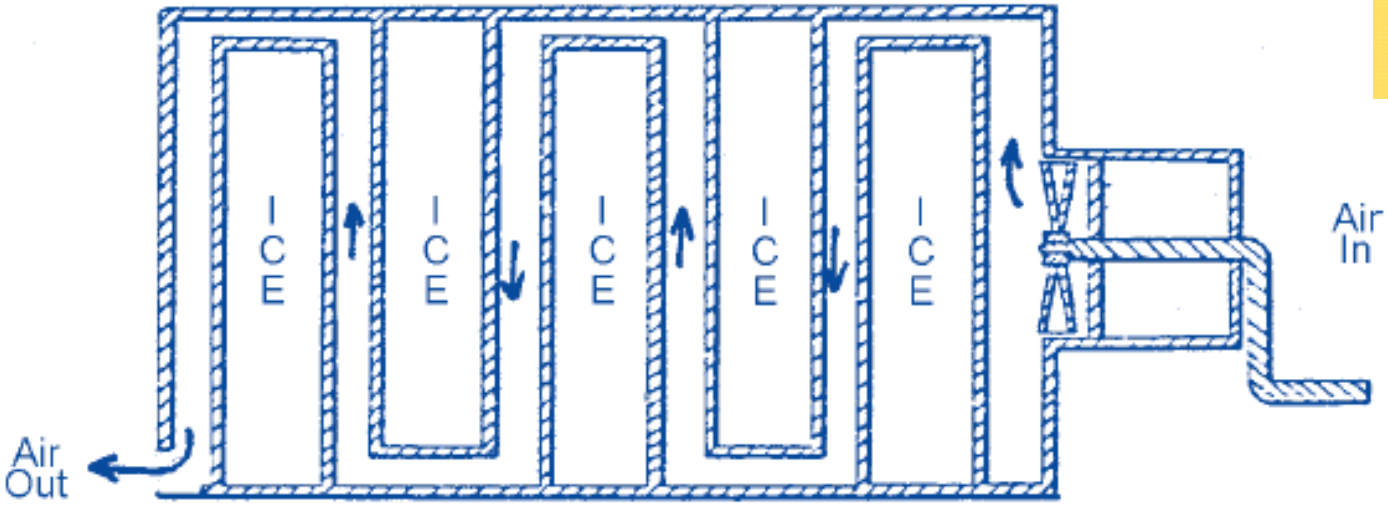


Figure 1: Shaler's patented cooler for ventilating air, 1865.

(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

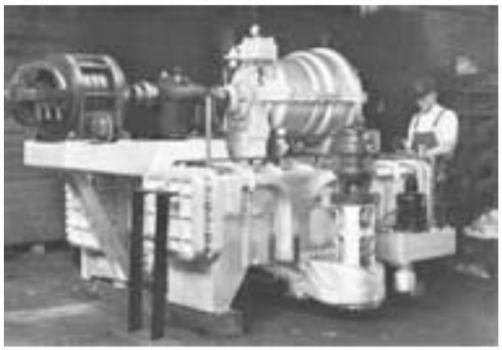
- The History of Modern Air Conditioning
  - http://www.air-conditioners-and-heaters.com/air_conditioning_history.html
    - 1830: Dr. John Gorrie (ice for cooling hospital rooms)
    - 1881: James Garfield (device w/ melted ice water)
    - Late 19th century: "manufactured air" (controlling humidity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

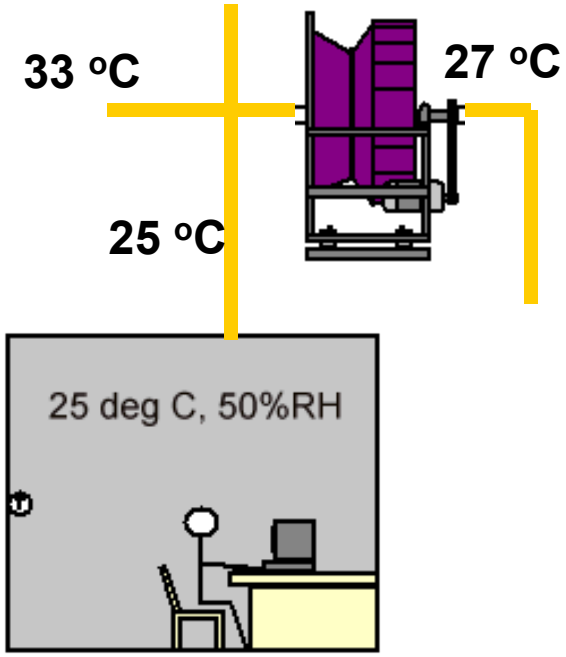
Air Conditioning

- Significance of 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

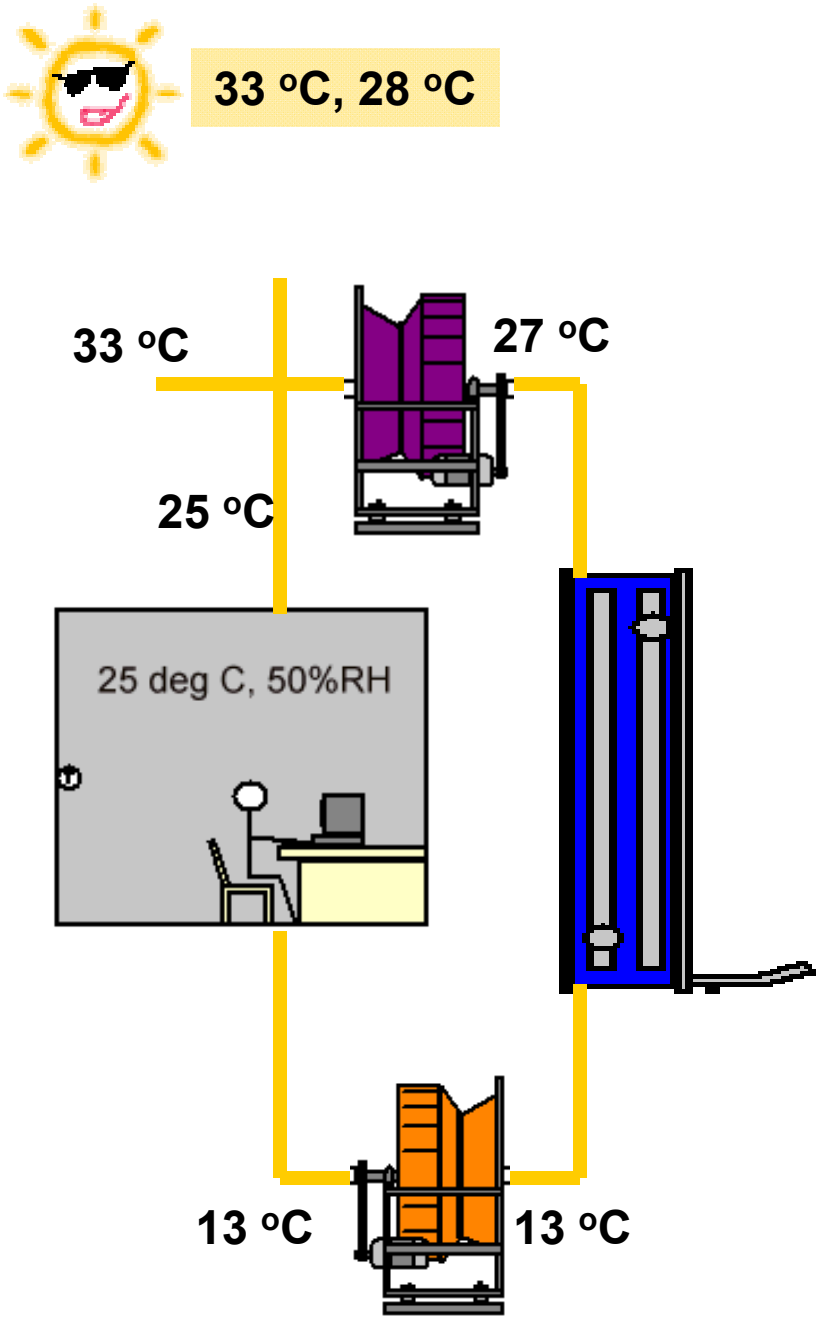
Air Conditioning

- 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



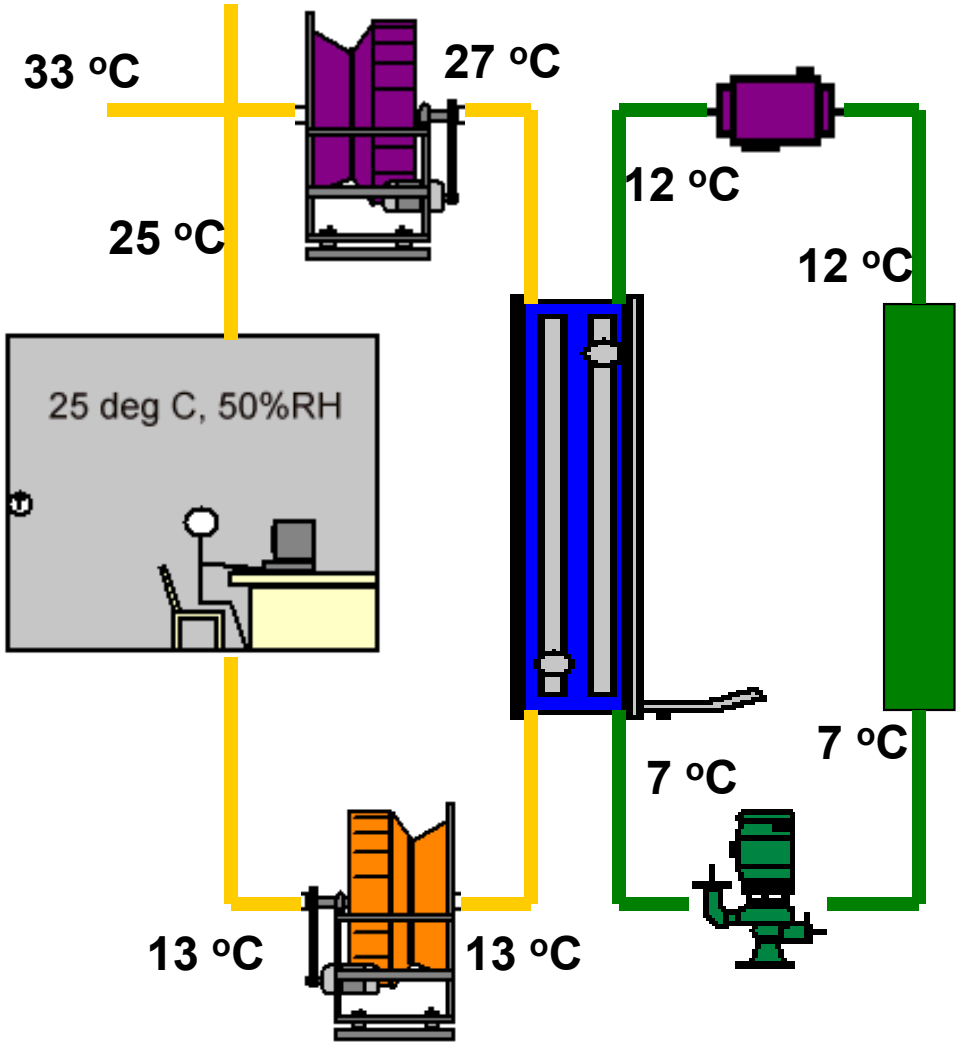
Conditioned space



Air side system

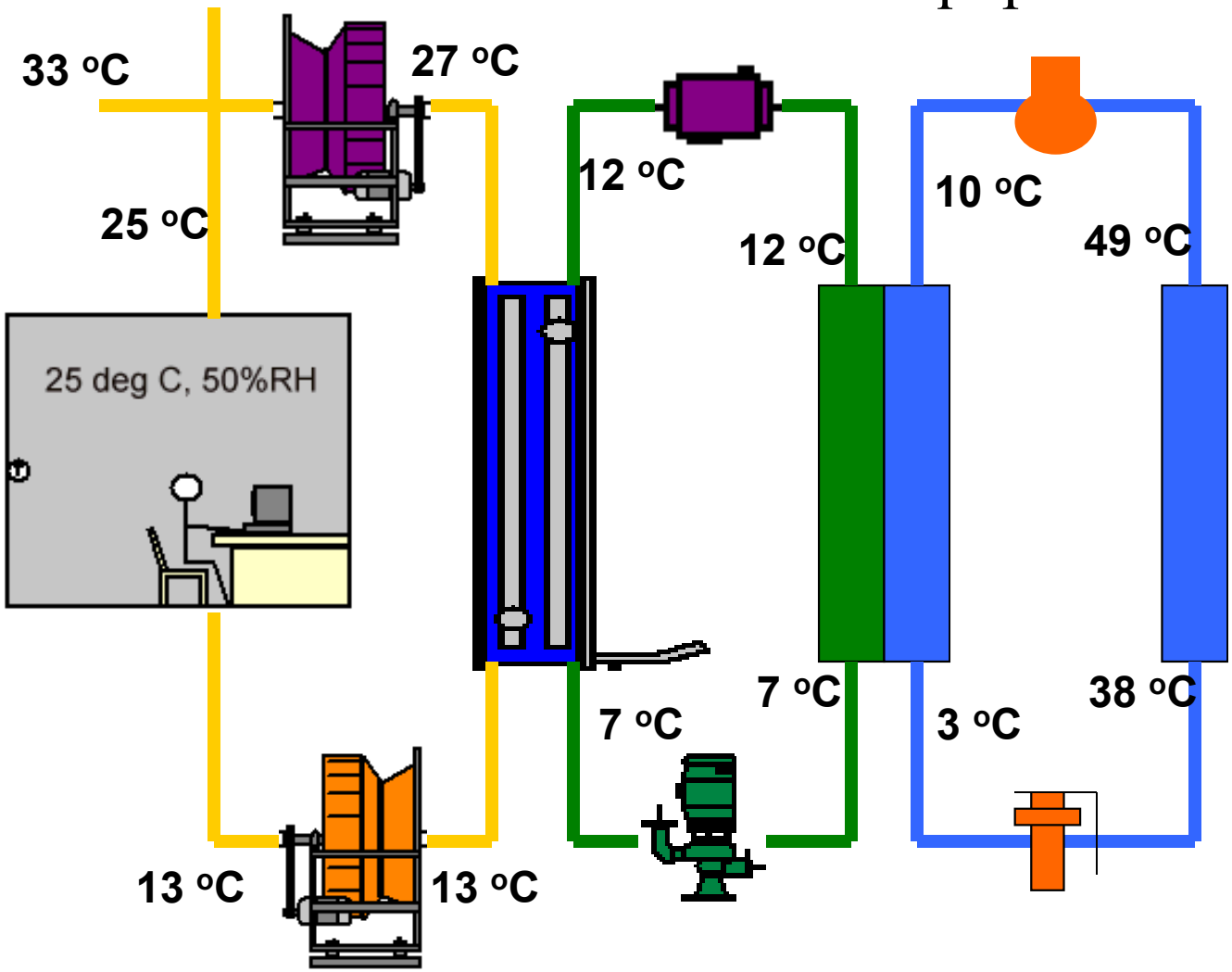
33 °C, 28 °C

Chilled water system



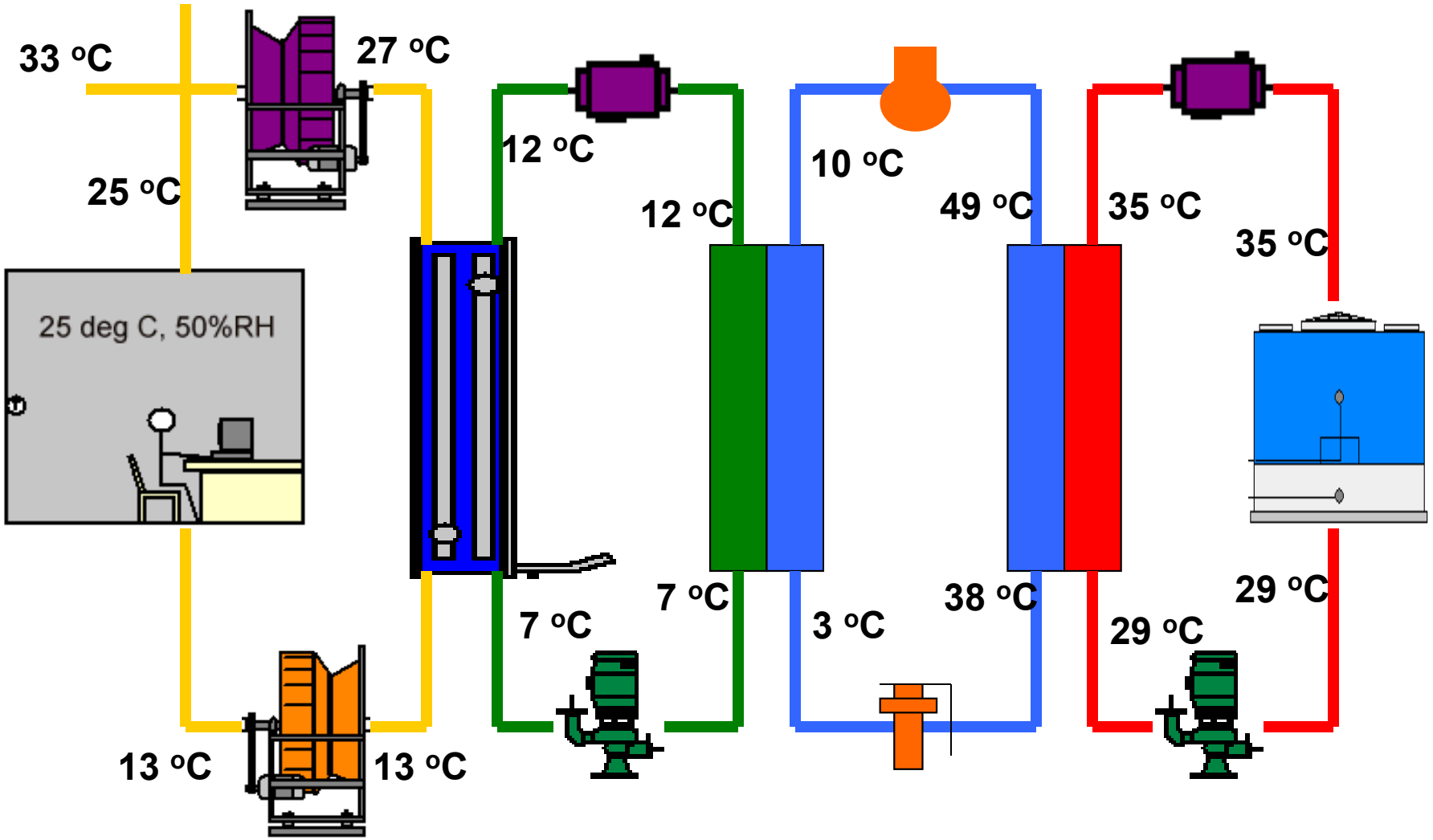
33 °C, 28 °C

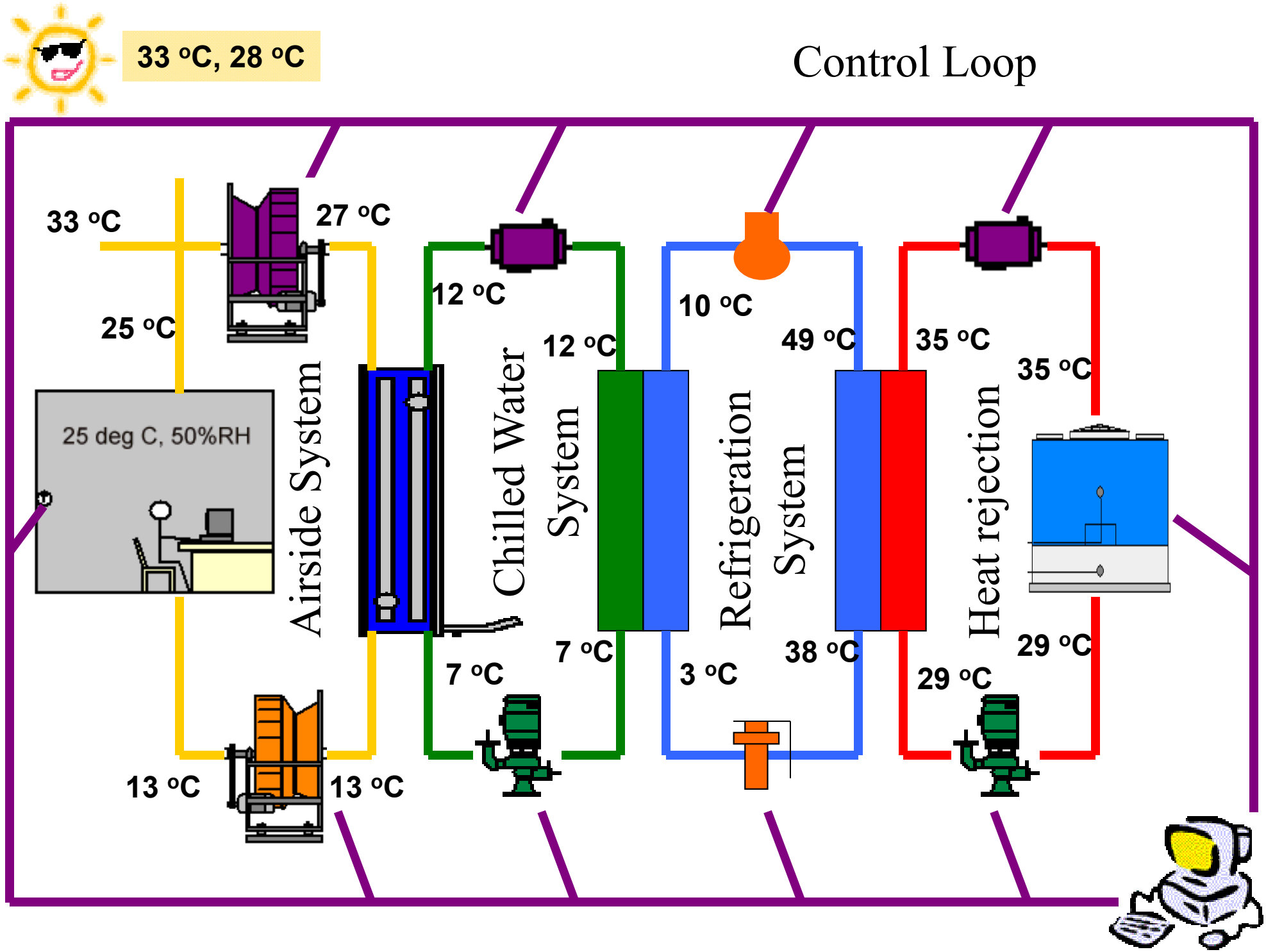
Refrigeration equipment



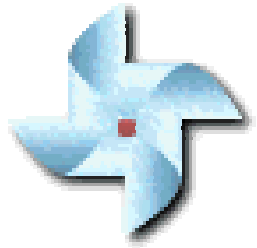
33 °C, 28 °C

Heat rejection



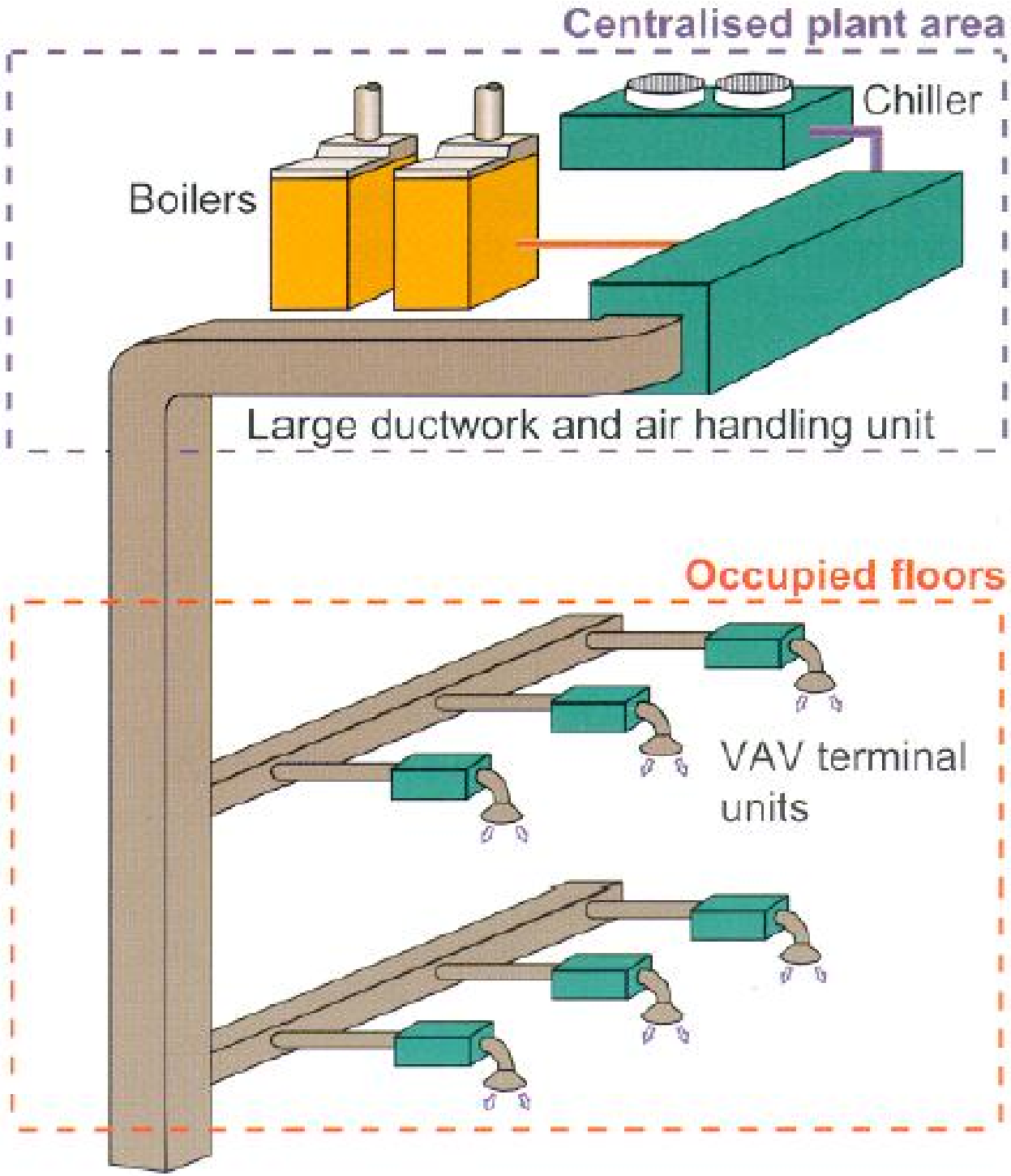

33 °C, 28 °C
Control Loop
33 °C
27 °C
25 °C
25 deg C, 50%RH
Airside System
13 °C
13 °C
12 °C
7 °C
Chilled Water System
12 °C
7 °C
10 °C
3 °C
Refrigeration System
49 °C
38 °C
35 °C
29 °C
Heat rejection
35 °C
29 °C

Design of HVAC Systems



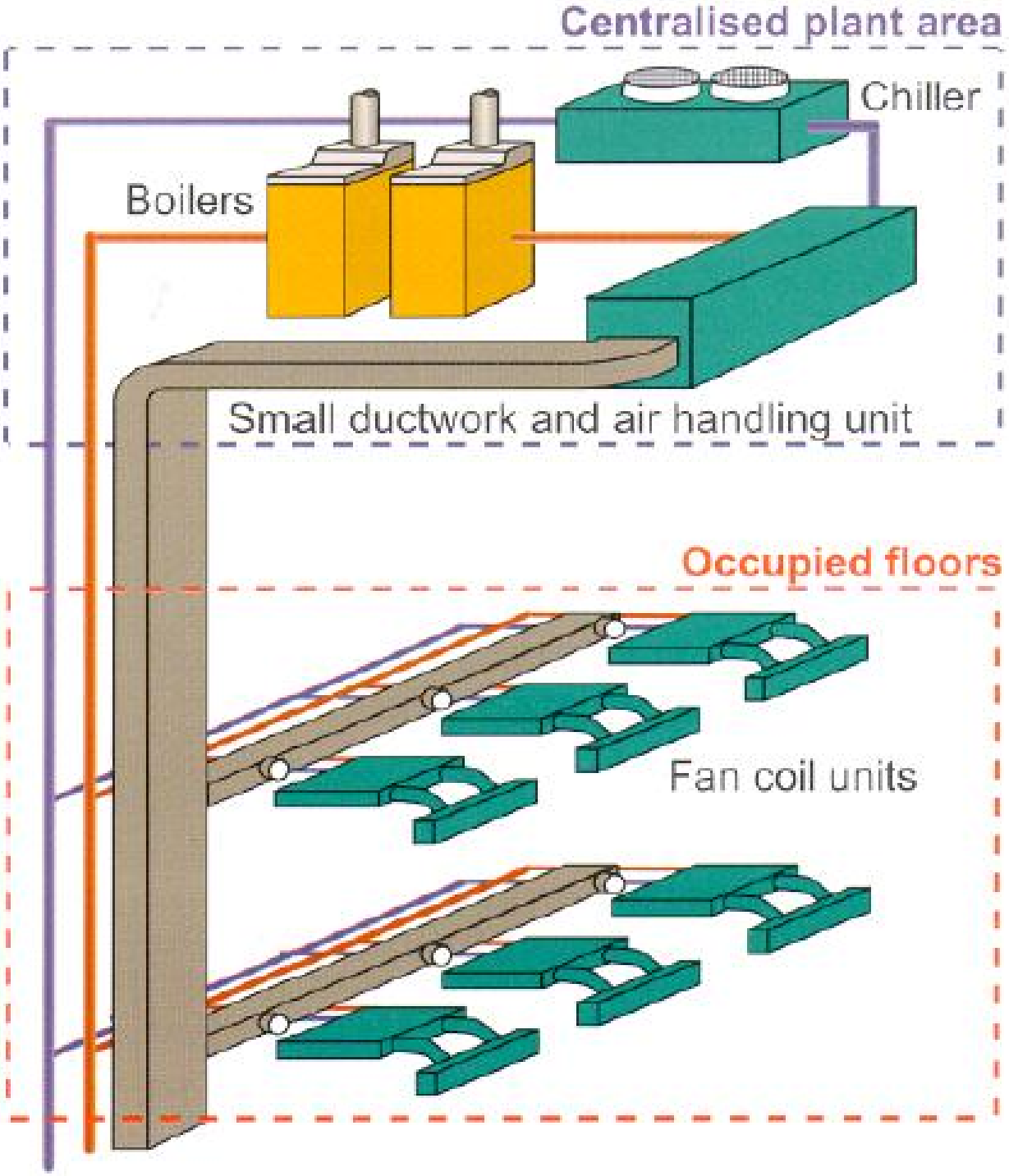
- Classification of HVAC systems -- three generic types of systems:
  - Centralised all air systems
    - Such as CAV (constant air volume), VAV (variable air volume), dual duct, multizone
  - Partially centralised air/water systems
    - Such as FCU (fan coil unit), induction units
  - Local systems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

Centralised air system *(VAV example)*

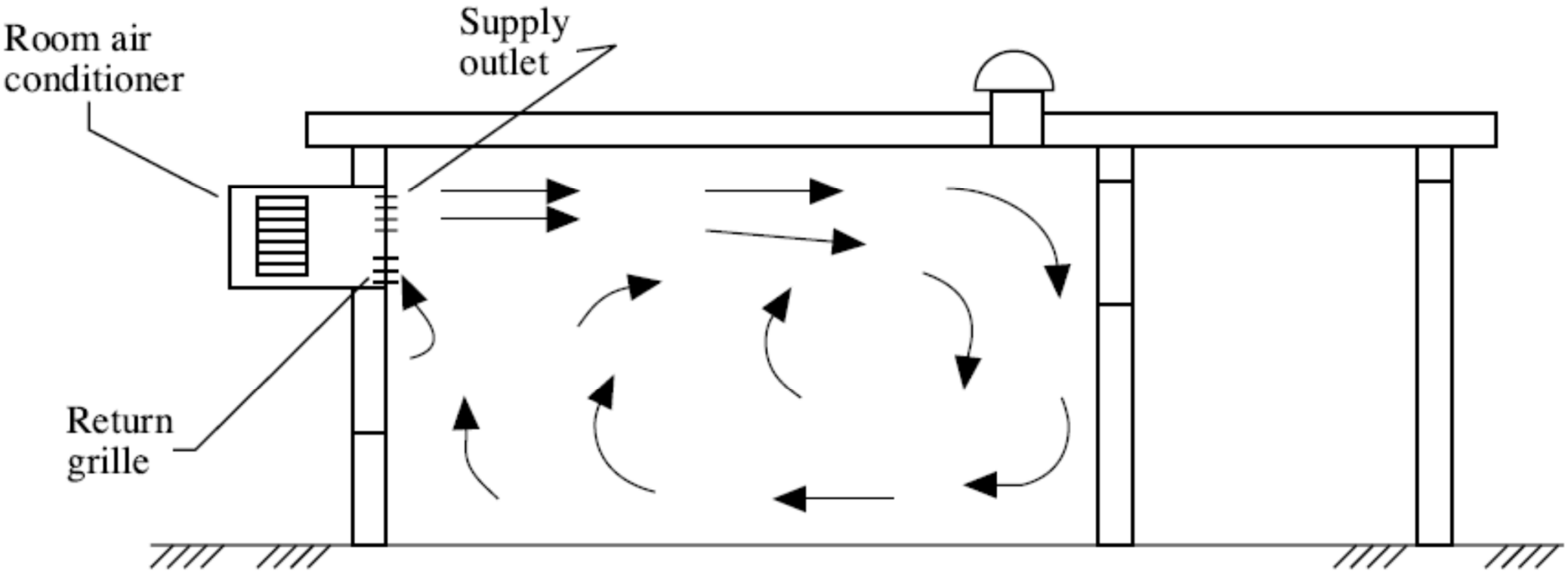


Partially centralised air/water system

(Fan coil example)

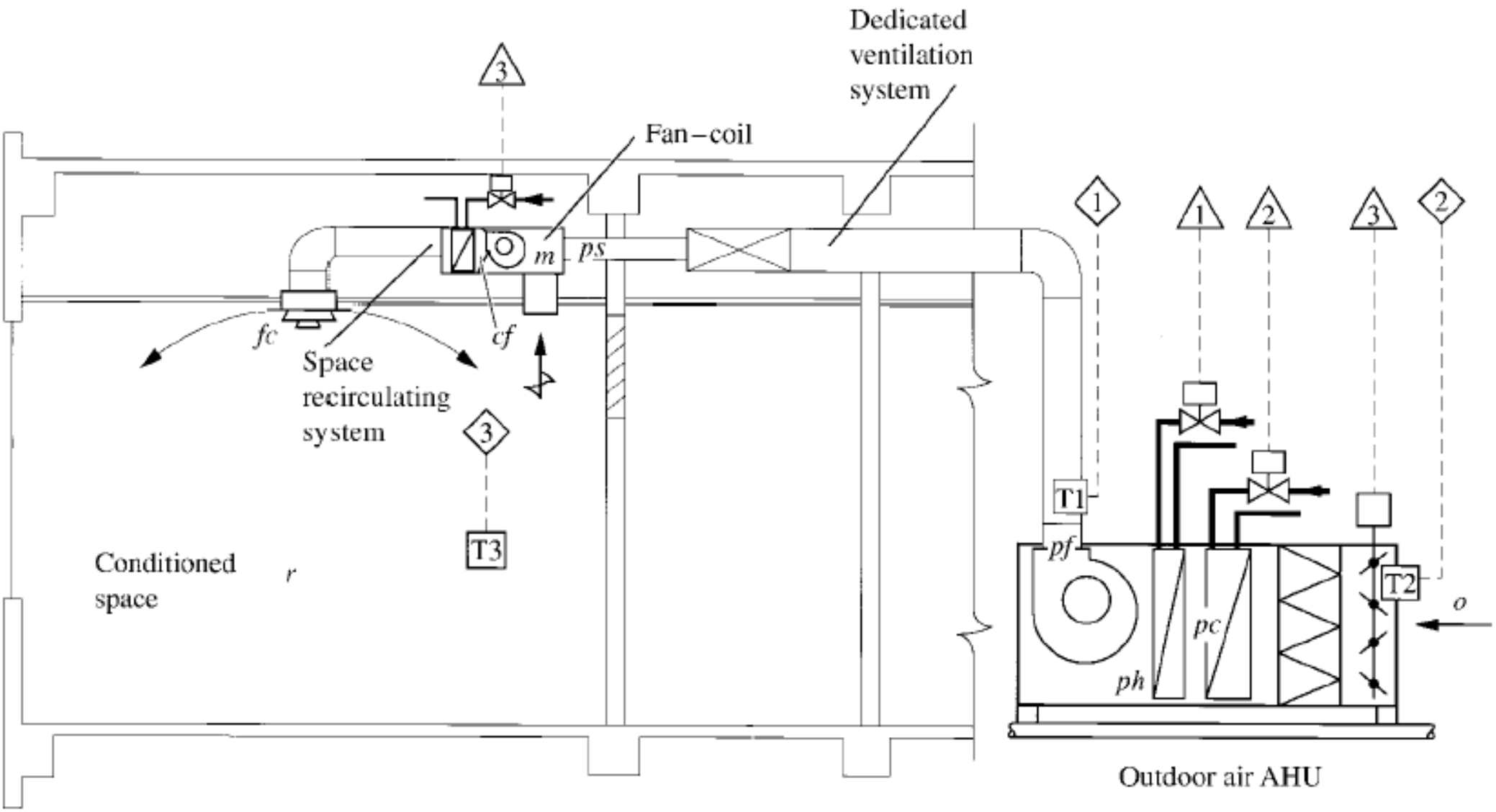


An individual room air-conditioning system



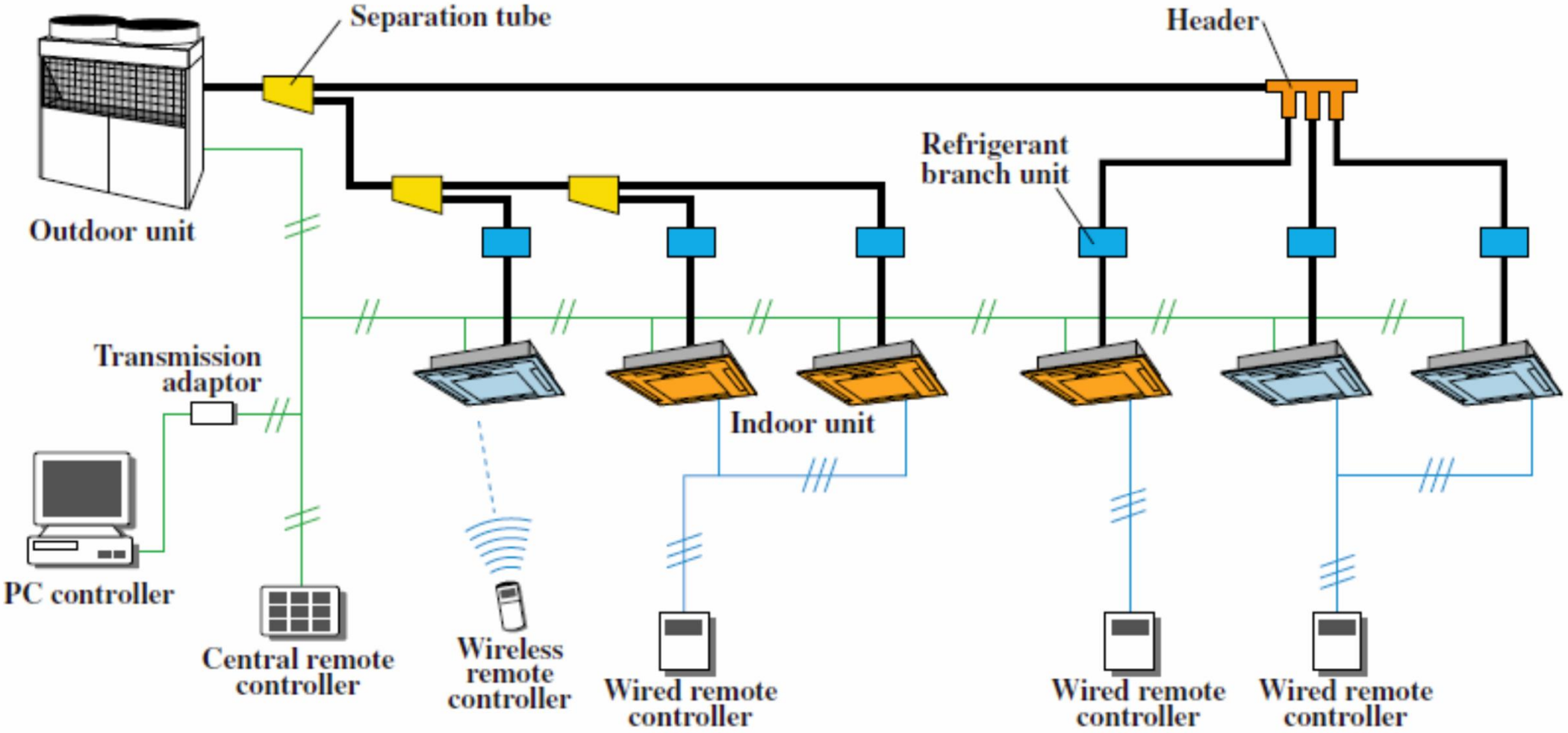
(Source: Wang, S. K., Lavan, Z. and Norton, P., 2000. *Air Conditioning and Refrigeration Engineering*)

Primary air fan coil unit (PA-FCU) system



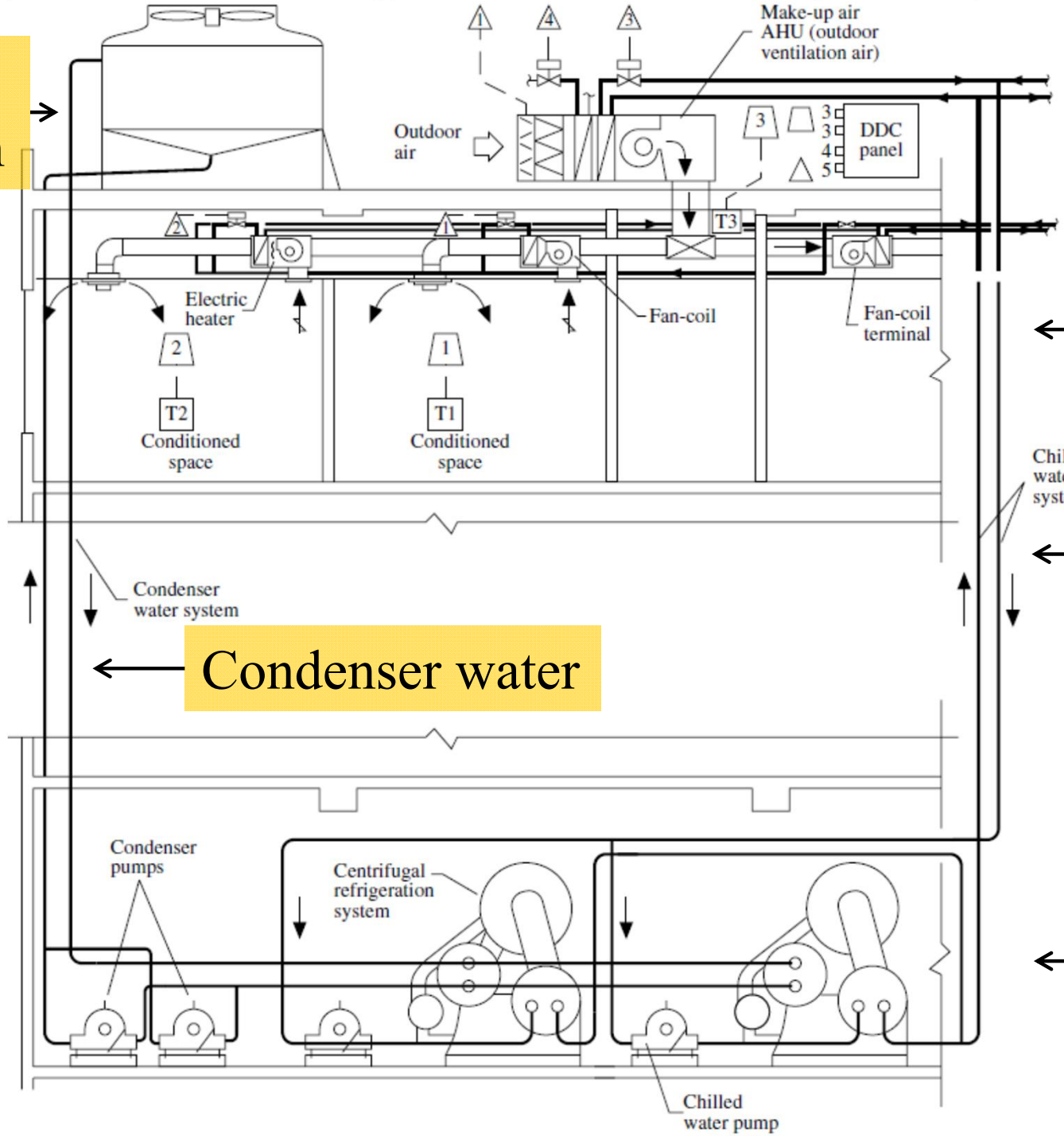
(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.)

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

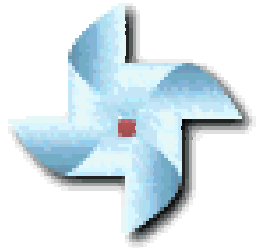
Chilled water

Condenser water

Refrigeration

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

Design of HVAC Systems

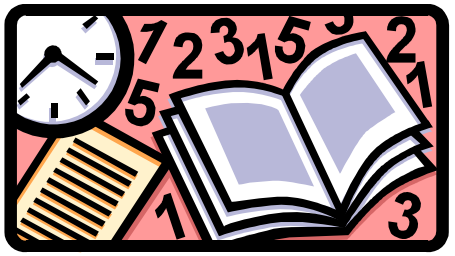


- Design of an HVAC system includes:
  - 1. Calculation of the maximum cooling and heating loads for the spaces to be served
  - 2. Selection of the type of system to be used
  - 3. Calculation of piping and/or duct sizes
  - 4. Selection of the type and size of equipment (chillers, boilers, fans, air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

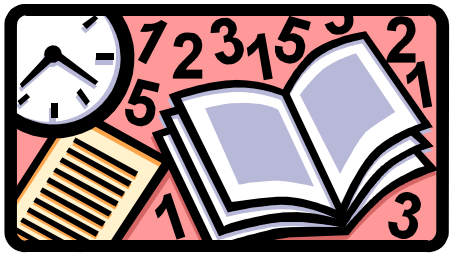
Hong Kong International Airport

Further Reading



- Introduction to Air Conditioning
  - www.arca53.dsl.pipex.com/index_files/ac1.htm
- 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

References



- Useful HVAC references:
  - 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.
  - Jones, W. P., 2001. *Air Conditioning Engineering*, 5th ed., Butterworth-Heinemann, Oxford & Boston.
  - Mcdowall, R., 2007. *Fundamentals of HVAC Systems*, SI edition, American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc., Atlanta, GA.
- Further reading and learning materials: (online)
  - NPTEL E-learning course -- Refrigeration and Air Conditioning http://nptel.ac.in/courses/112105129/