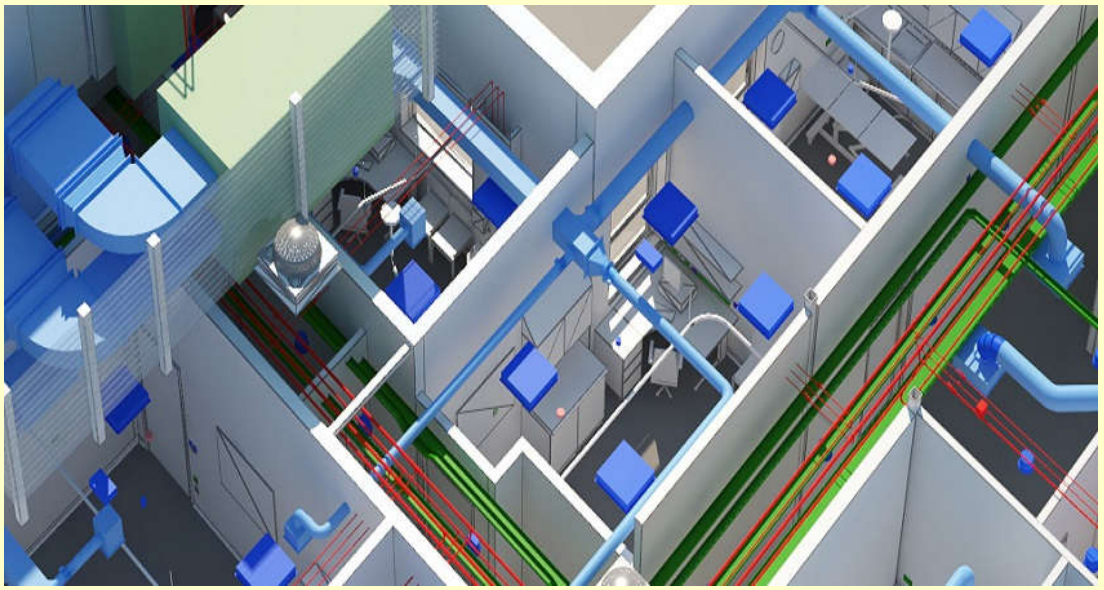
ARE 5.0 Study Series: Exploring MEP Considerations In Architectural Design, 4 Jul 2024 (Thu)



HVAC System Design

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Contents

- HVAC fundamentals
- Examples of HVAC systems
- HVAC sub-systems
- Air-side systems
- Ventilation systems
- Water-side systems
- Refrigeration systems

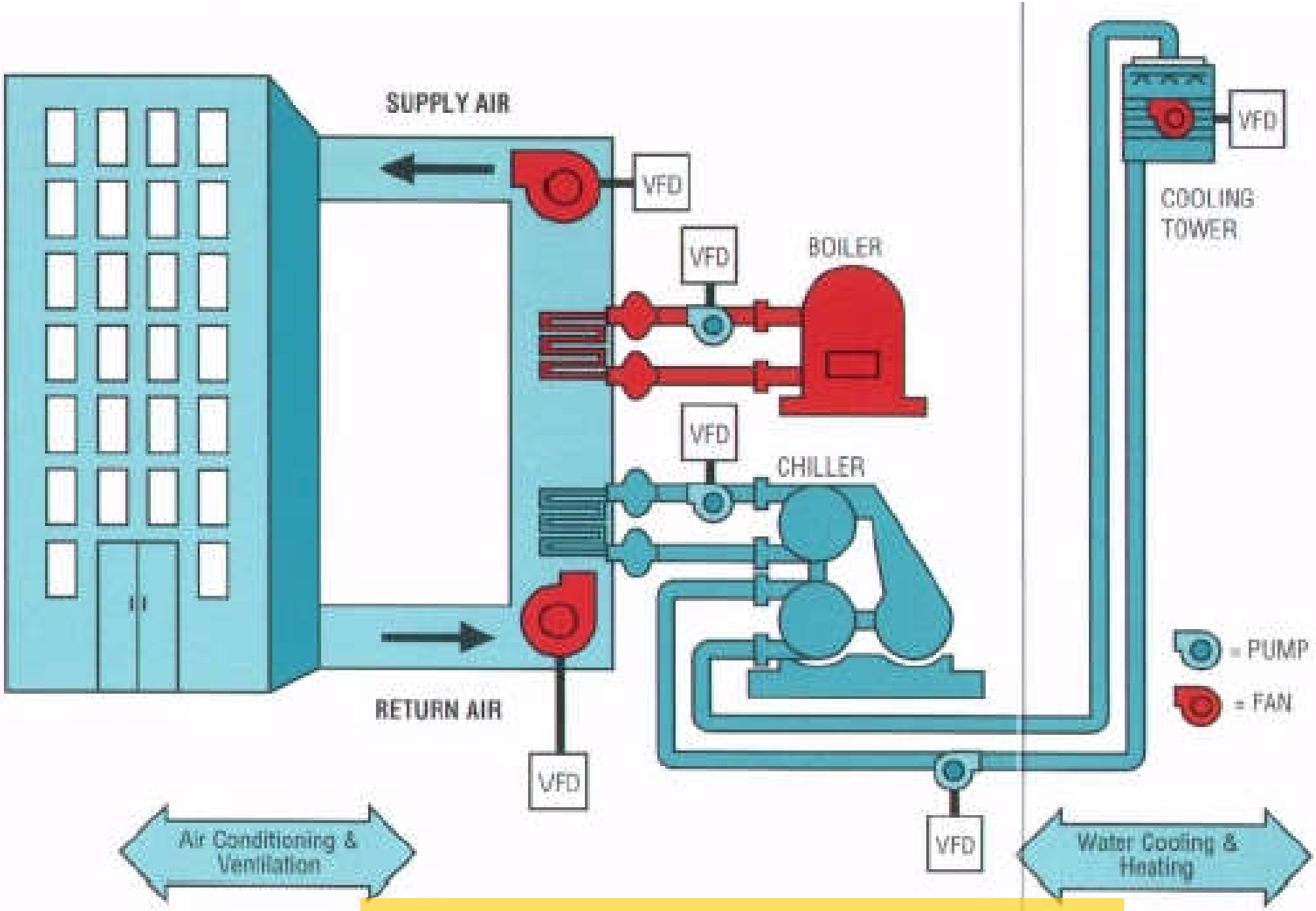
HVAC fundamentals

- 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 fundamentals

- 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)

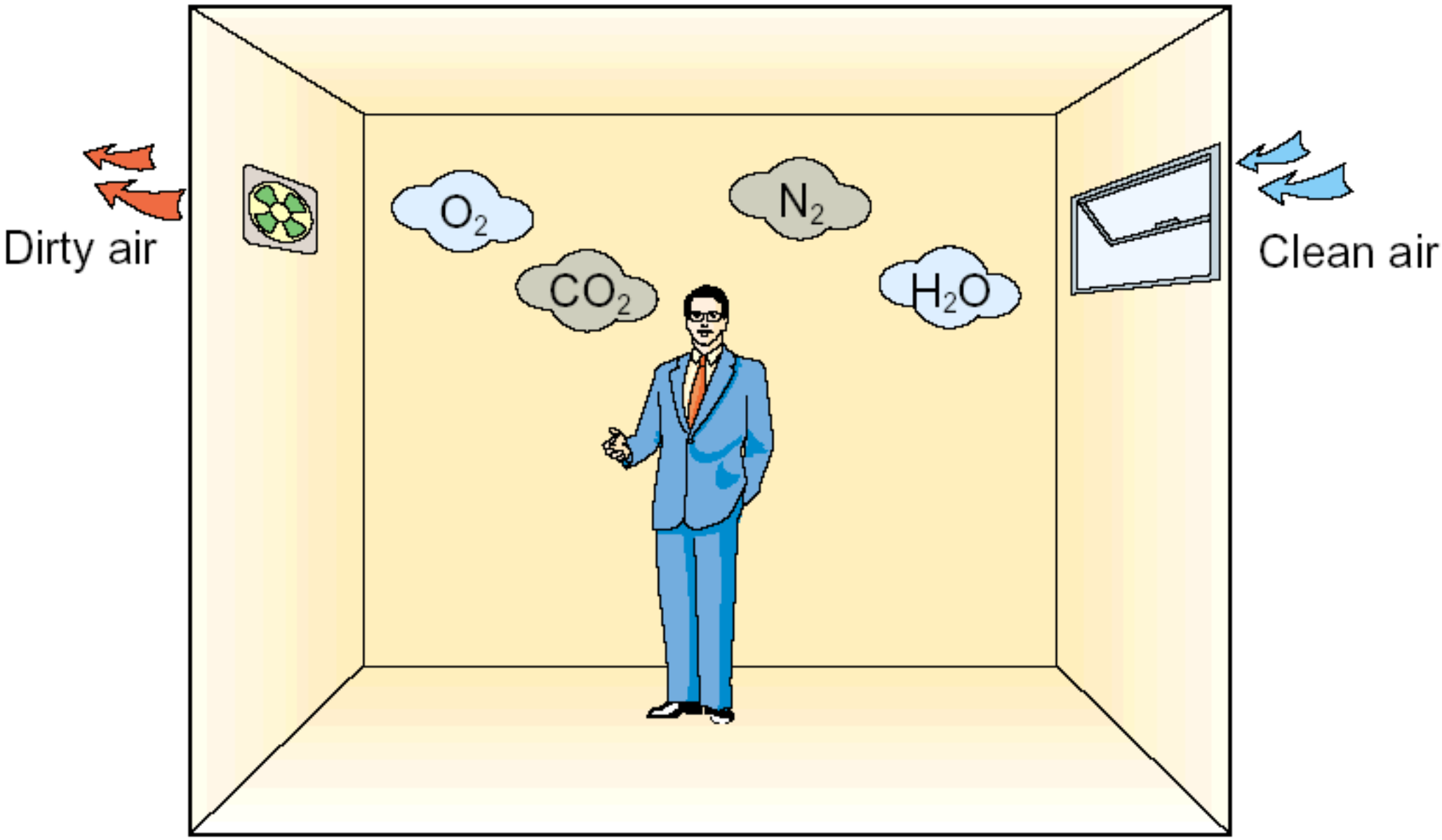
Example of a centralised HVAC system



Do you know the HVAC components?

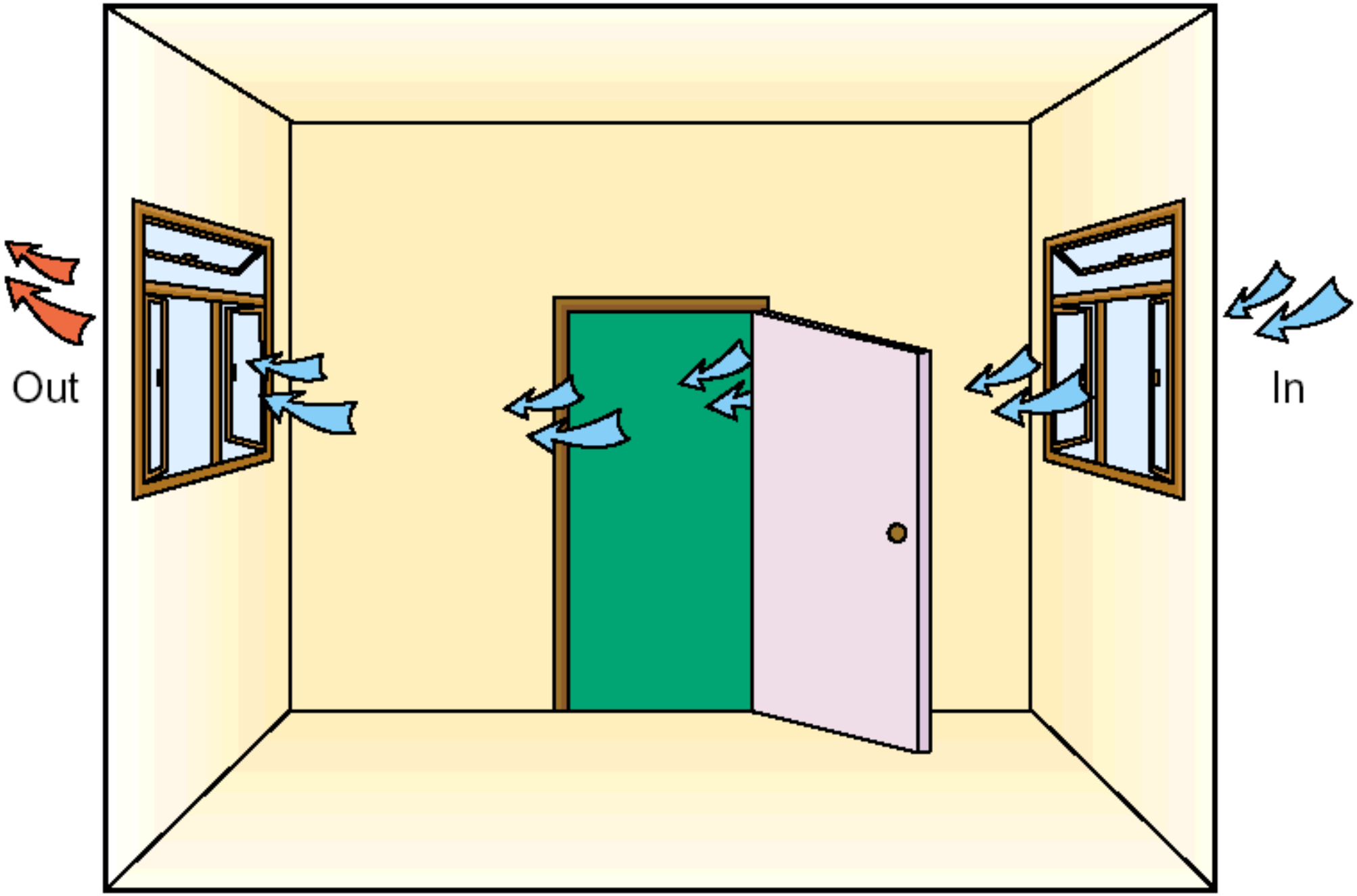
(Source: http://www.allhvacinfo.com/)

Simple ventilation design



(Source: www.iaq.hk)

Cross ventilation (natural)



(Source: www.iaq.hk)

Cross ventilation (mechanical assisted)

(Source: www.iaq.hk)

HVAC fundamentals

- 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”

(See also: Air conditioning http://en.wikipedia.org/wiki/Air_conditioning)

HVAC fundamentals

- 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.)

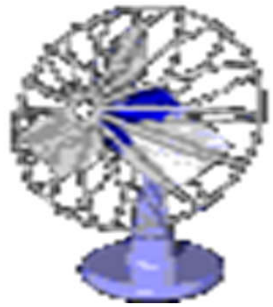
HVAC fundamentals

- 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)

HVAC fundamentals

- 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

Examples of HVAC systems



- 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

Is it feasible to use
Natural Ventilation?

If situation prevents this,
is it feasible to use
Mechanical Ventilation?

If situation prevents this,
is it feasible to use
Hybrid/Mixed Mode Ventilation?

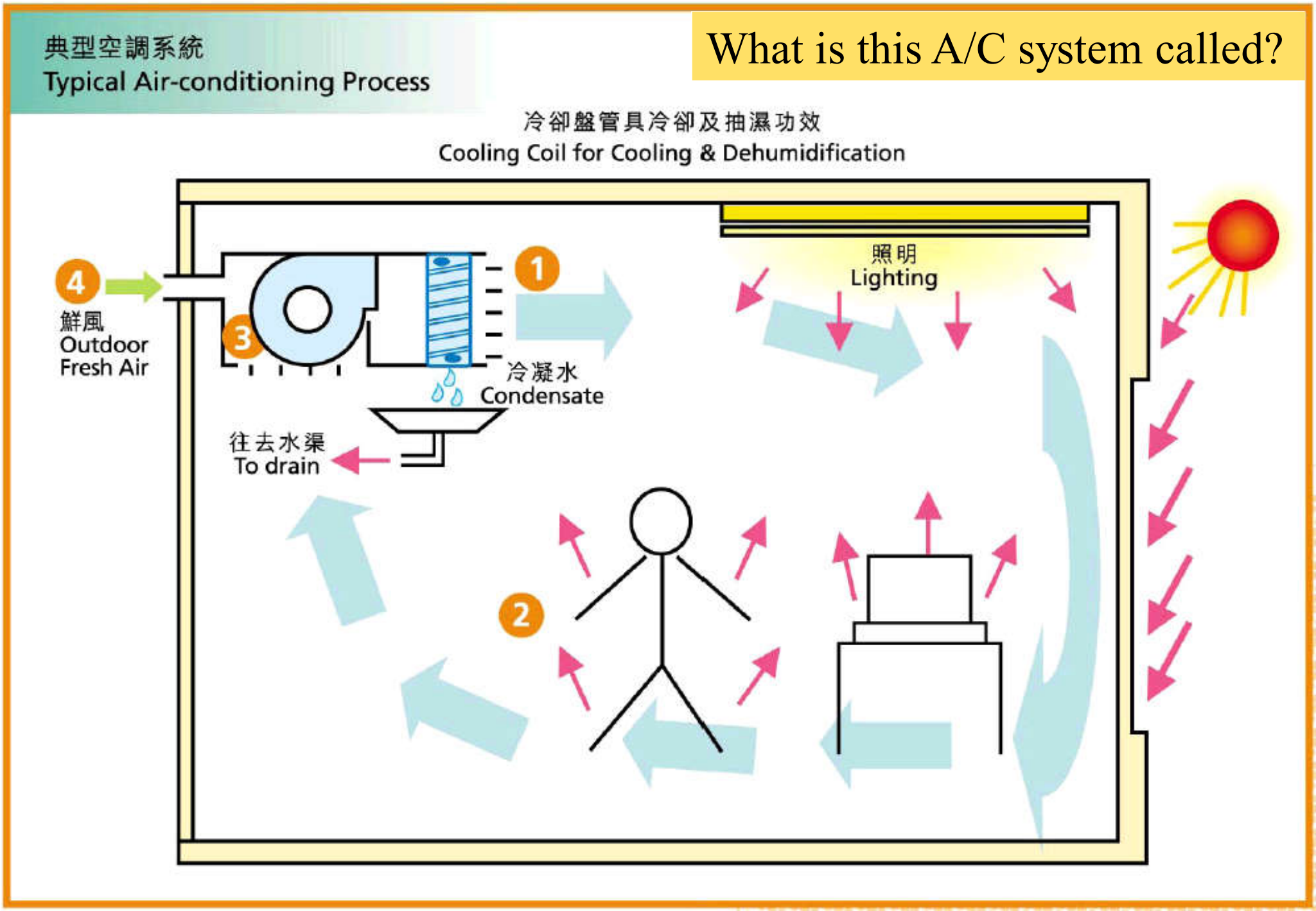
If situation prevents this,
is it feasible to use
Cooling and Heating
(without humidity control)?

If situation prevents this,
is it feasible to use
Full Air Conditioning
(with humidity control)?

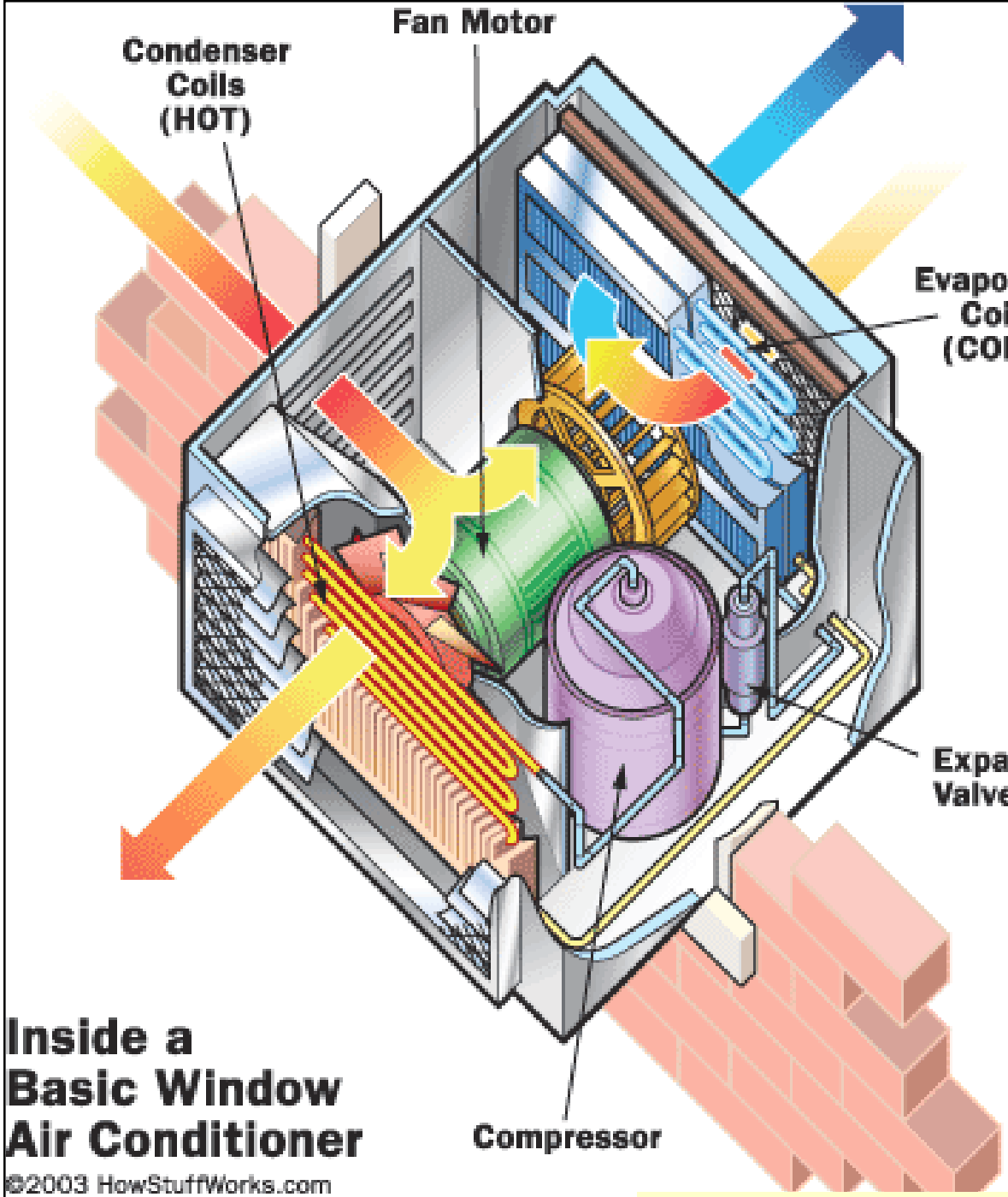
Ventilation design hierarchy

Increasing:
- energy consumption
- capital cost
- running costs
- maintenance
- complexity

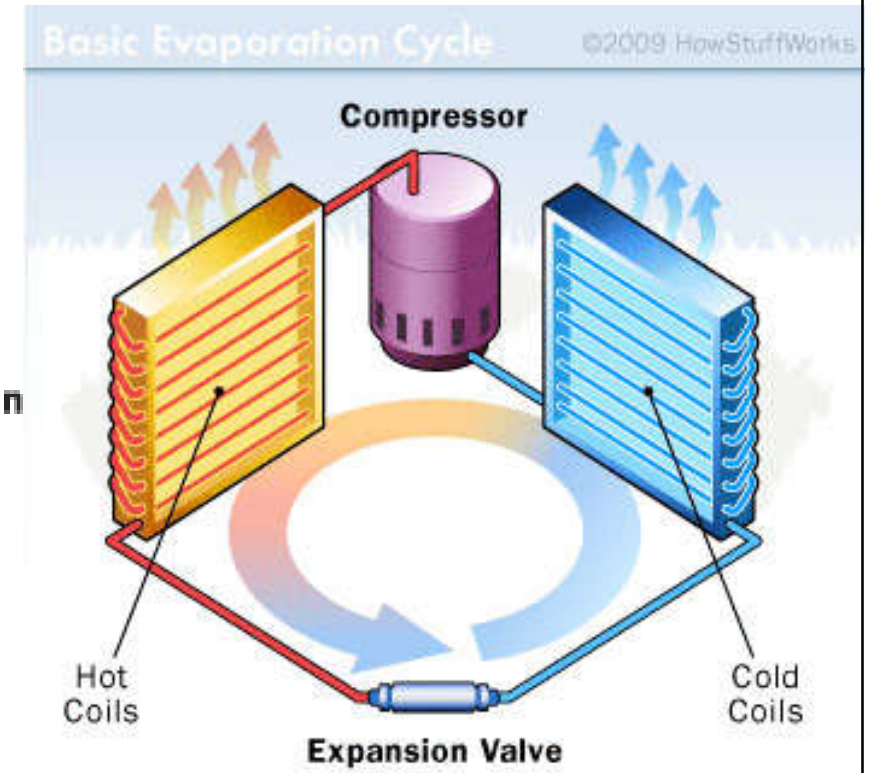
What is this A/C system called?



(Source: EnergyWitts newsletter, EMSD)



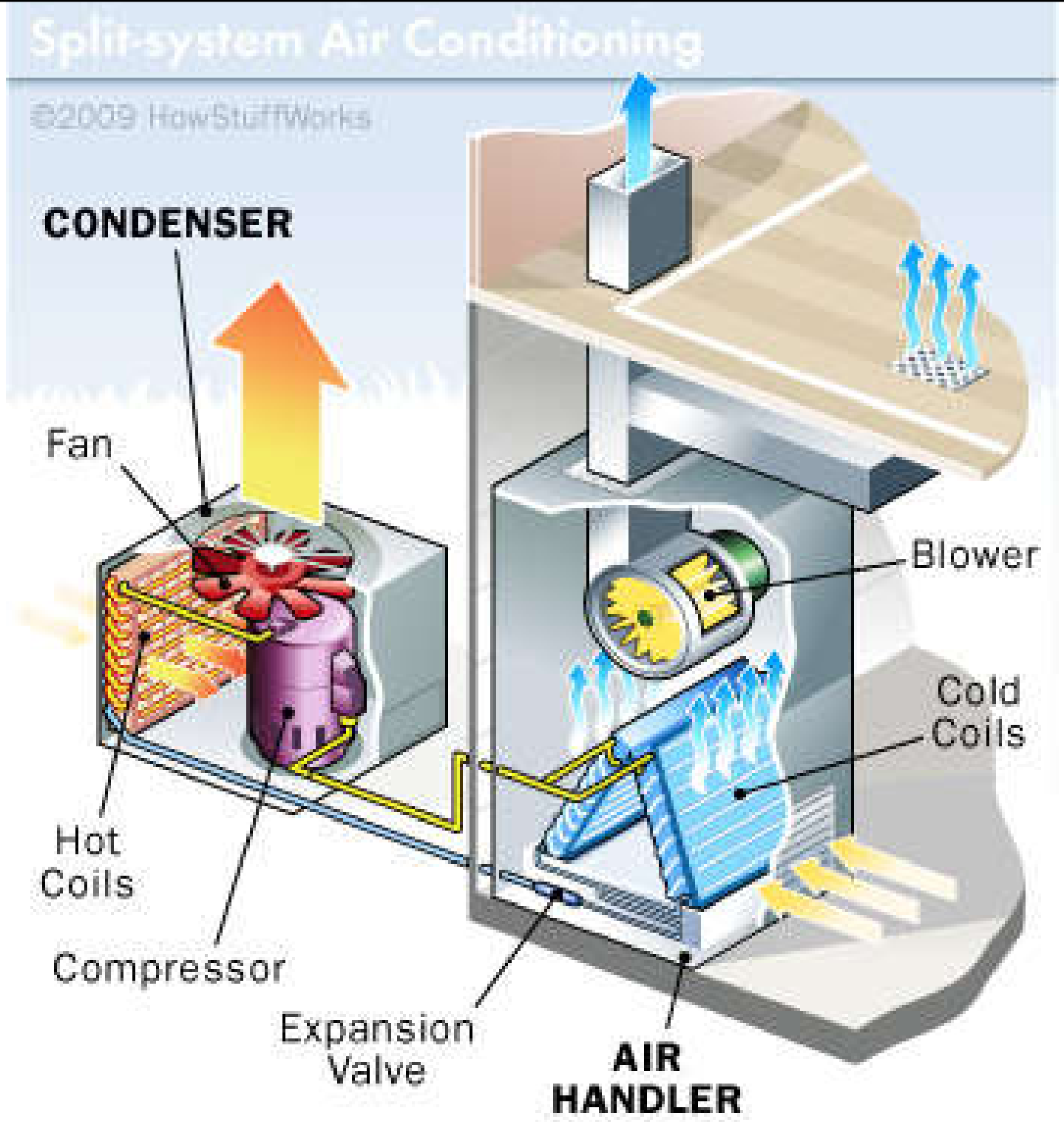
Window-type air conditioner



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

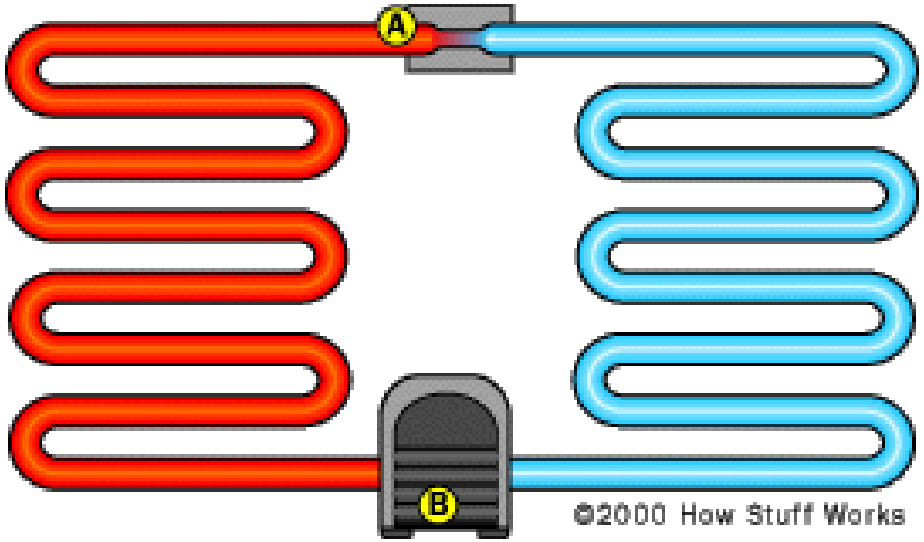
(Source: www.howstuffworks.com/ac.htm)

Split-type air conditioner



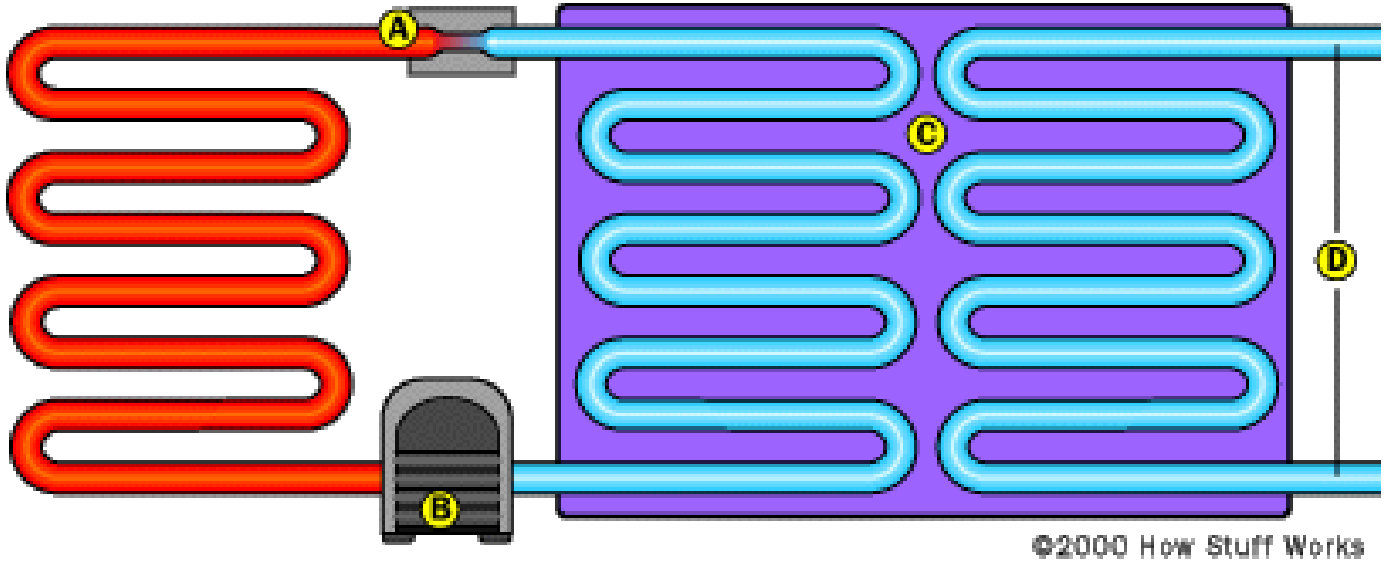
(Source: www.howstuffworks.com/ac.htm)

Refrigerant cycle



What are the major components?

A typical air conditioner



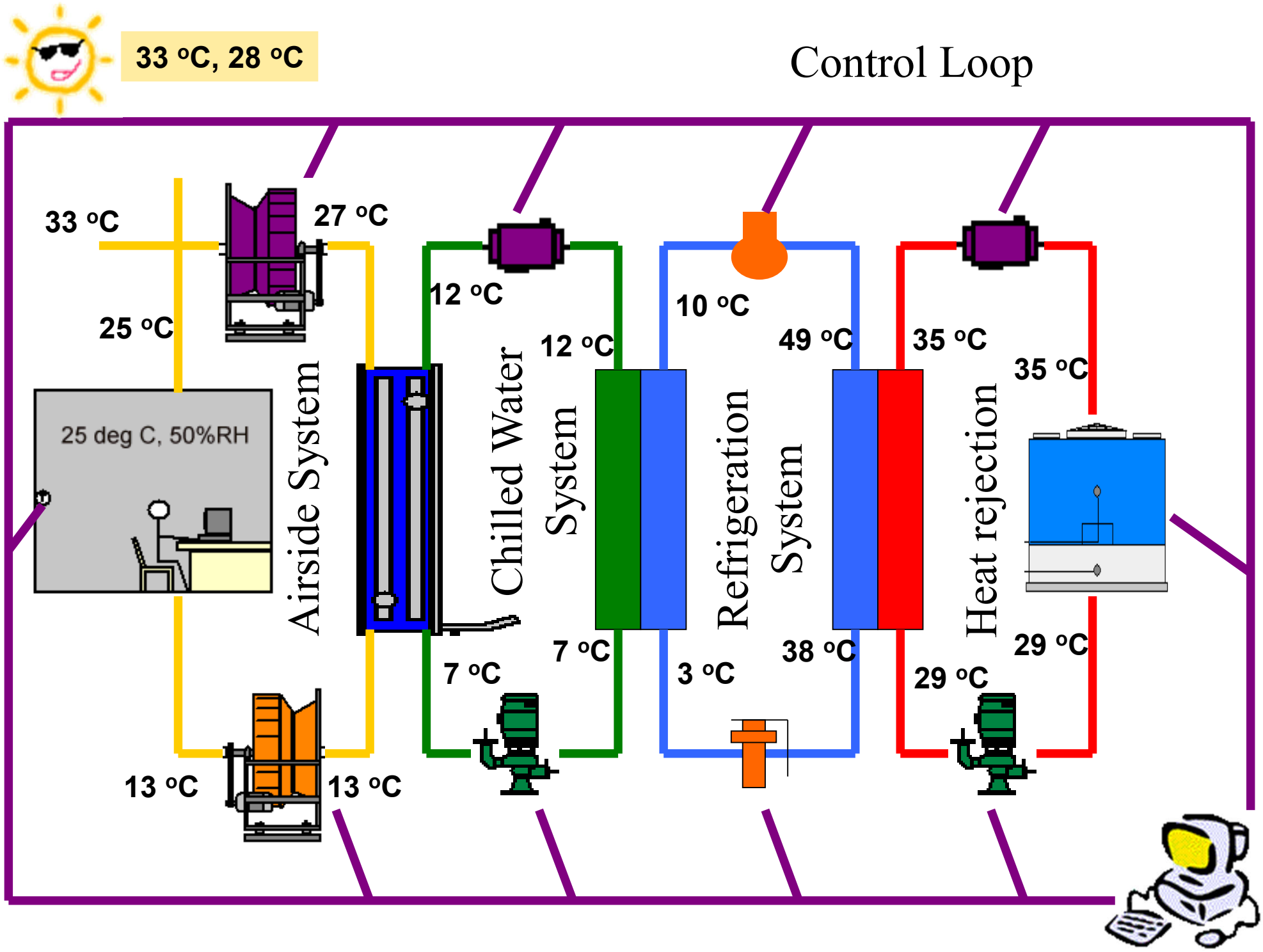
Chilled water system

Air conditioning with a chilled water system

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

HVAC sub-systems

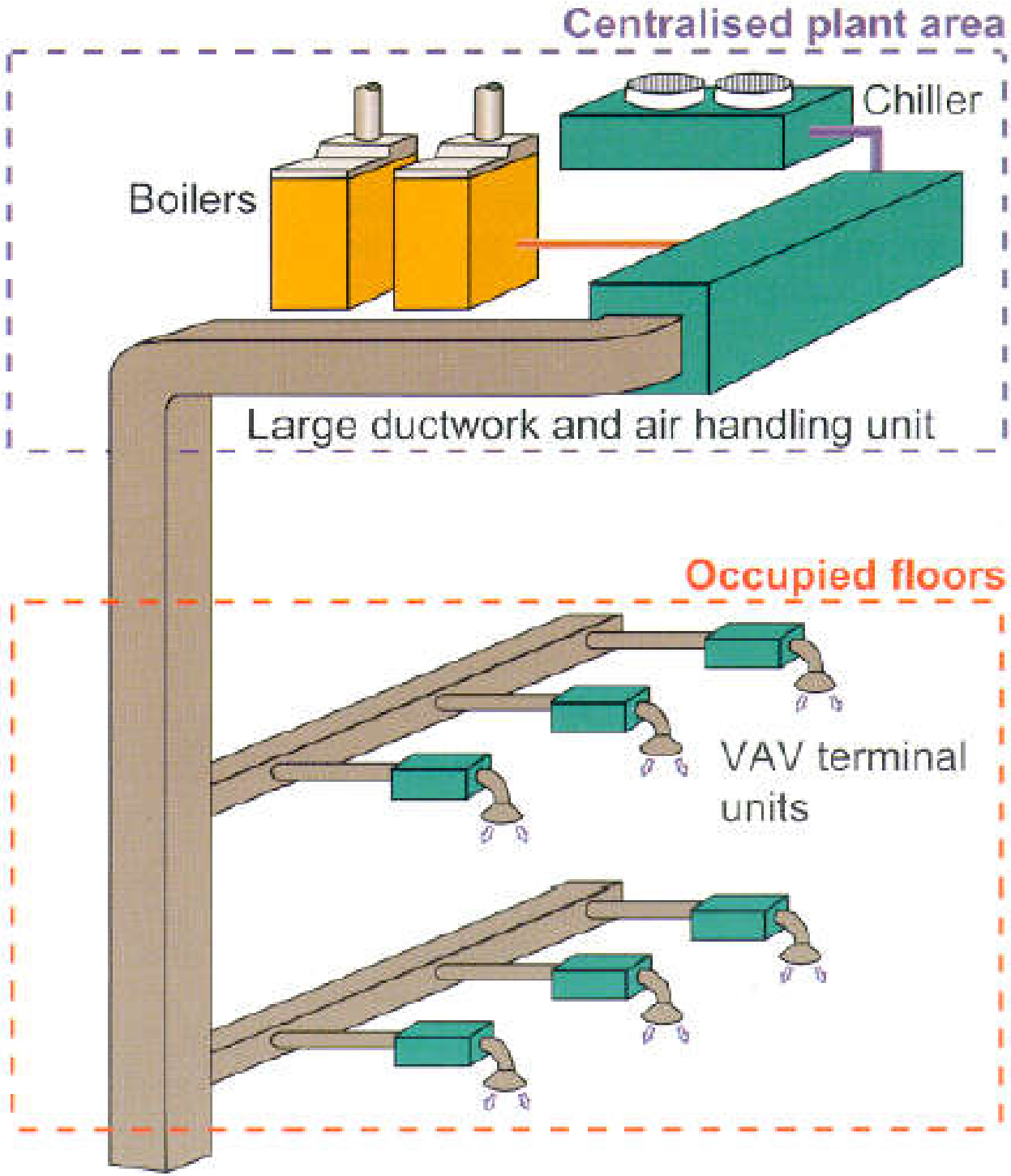
- To understand better, air conditioning system can be divided into five subsystems or loops:
  - 1. Air-side 空氣側
  - 2. Chilled water 冷凍水
  - 3. Refrigeration equipment 製冷設備
  - 4. Heat rejection 散熱
  - 5. Controls 控制


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

HVAC sub-systems

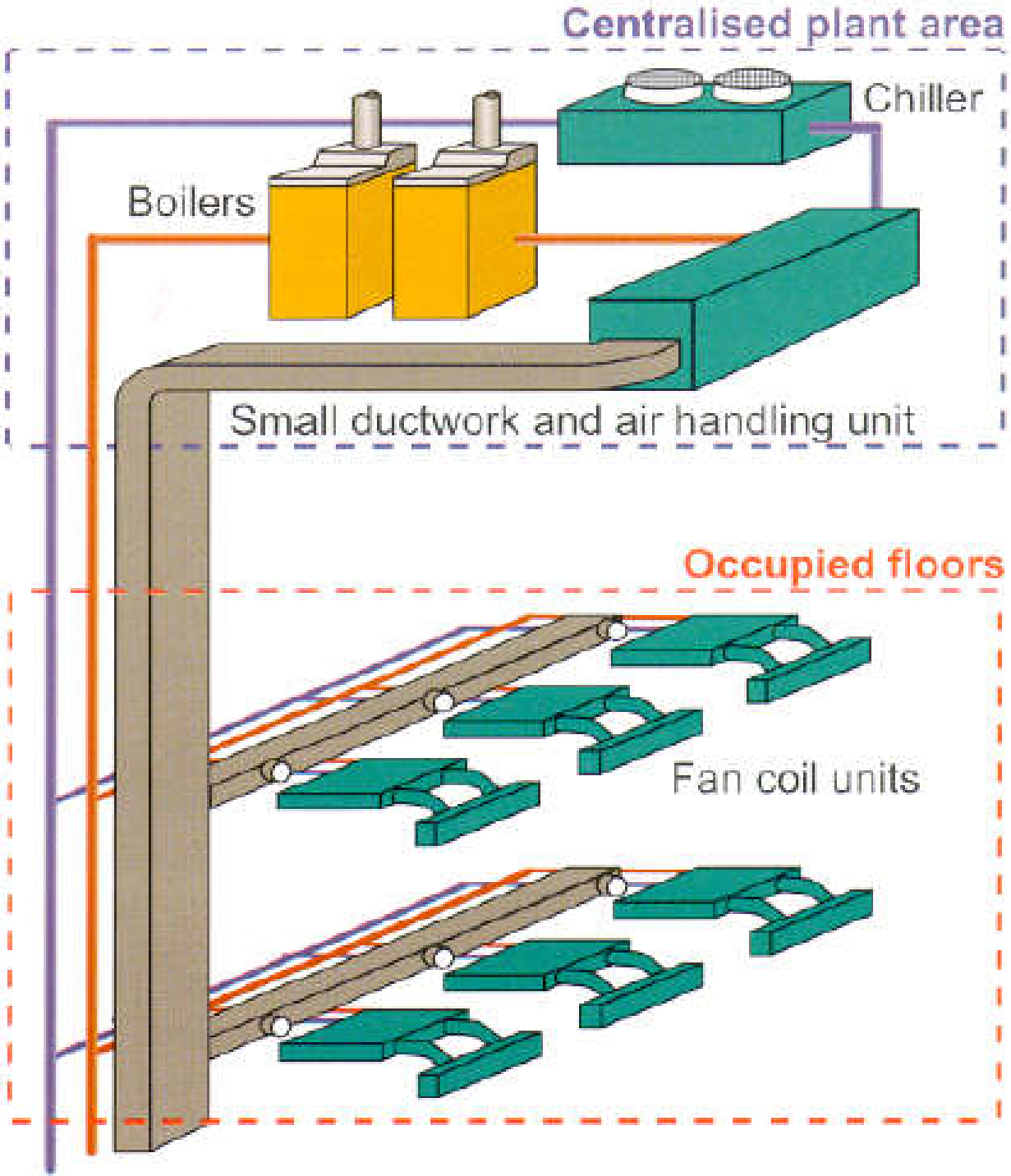
- Classification of HVAC systems -- three generic types of systems:
  - Centralised all air systems
    - Such as CAV (constant air volume), VAV (variable air volume), dual duct, multizone
  - Partially centralised air/water systems
    - Such as FCU (fan coil unit), induction units
  - Local systems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

Centralised air system *(VAV example)*

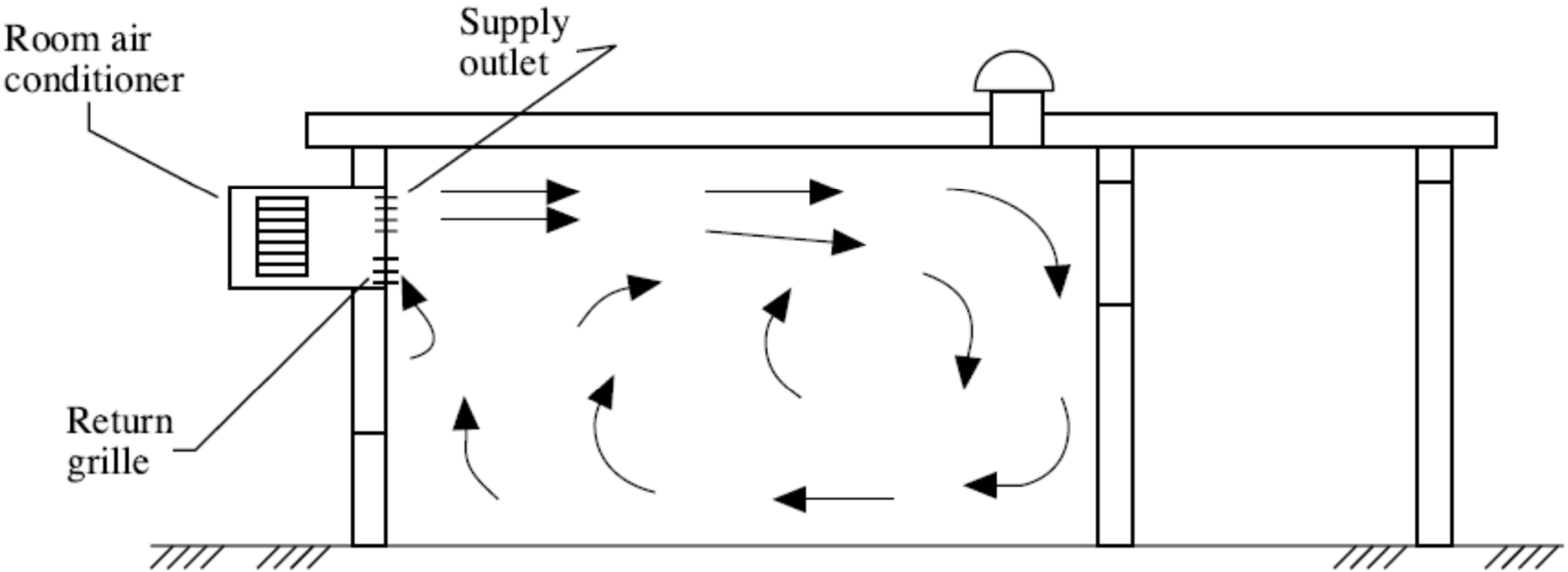


Partially centralised air/water system

(Fan coil example)

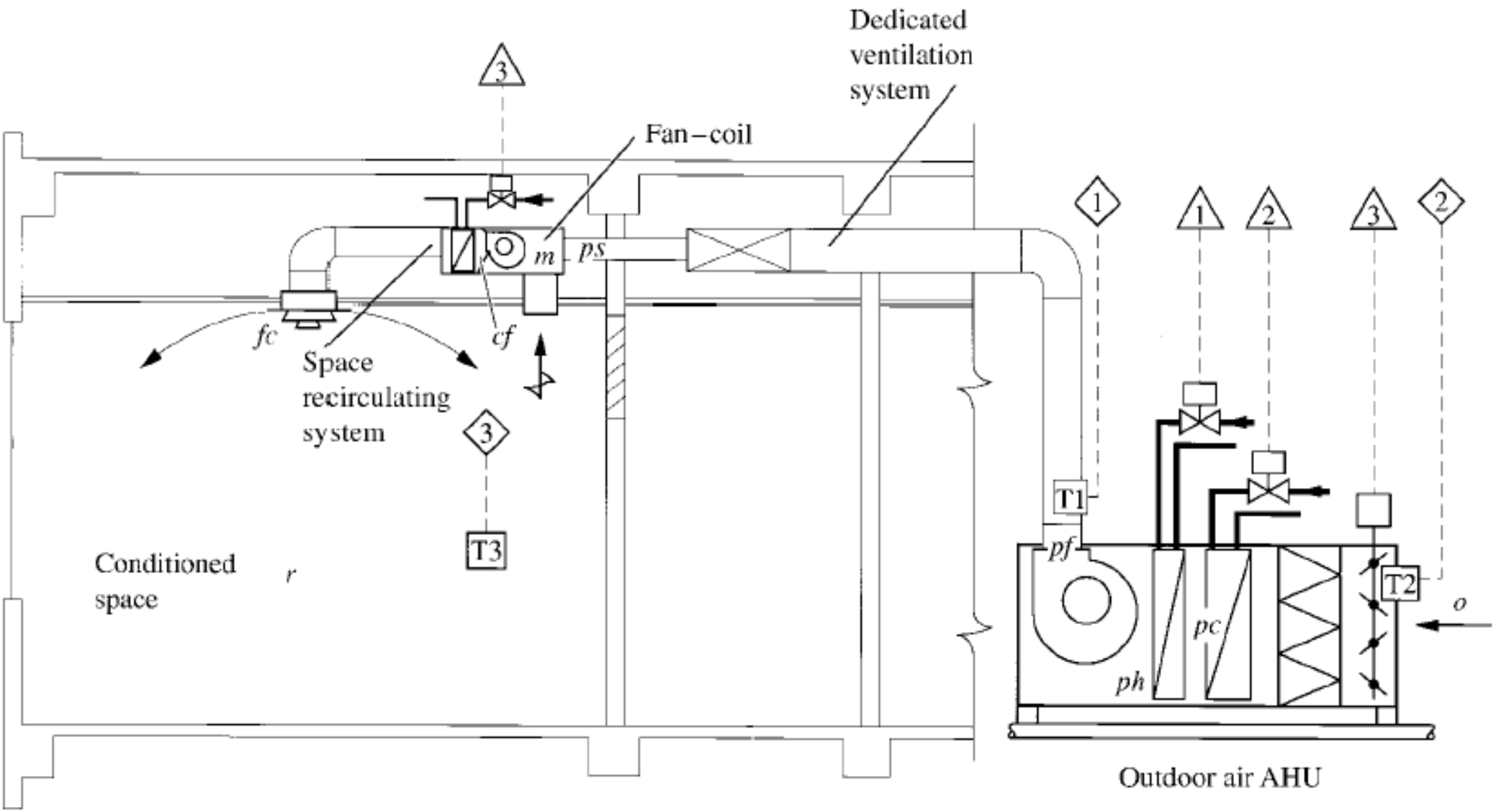


An individual room air-conditioning system



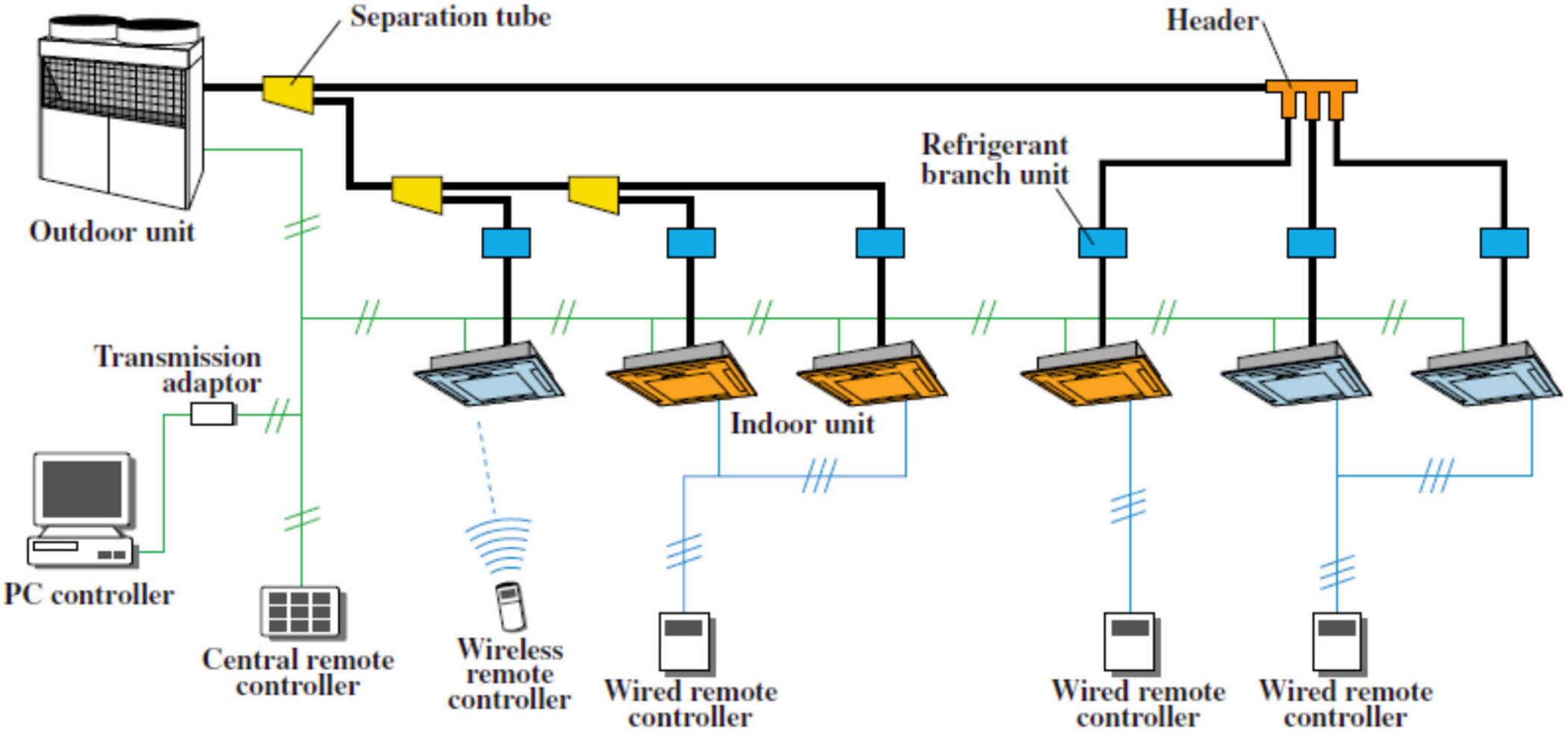
(Source: Wang, S. K., Lavan, Z. and Norton, P., 2000. *Air Conditioning and Refrigeration Engineering*)

Primary air fan coil unit (PA-FCU) system



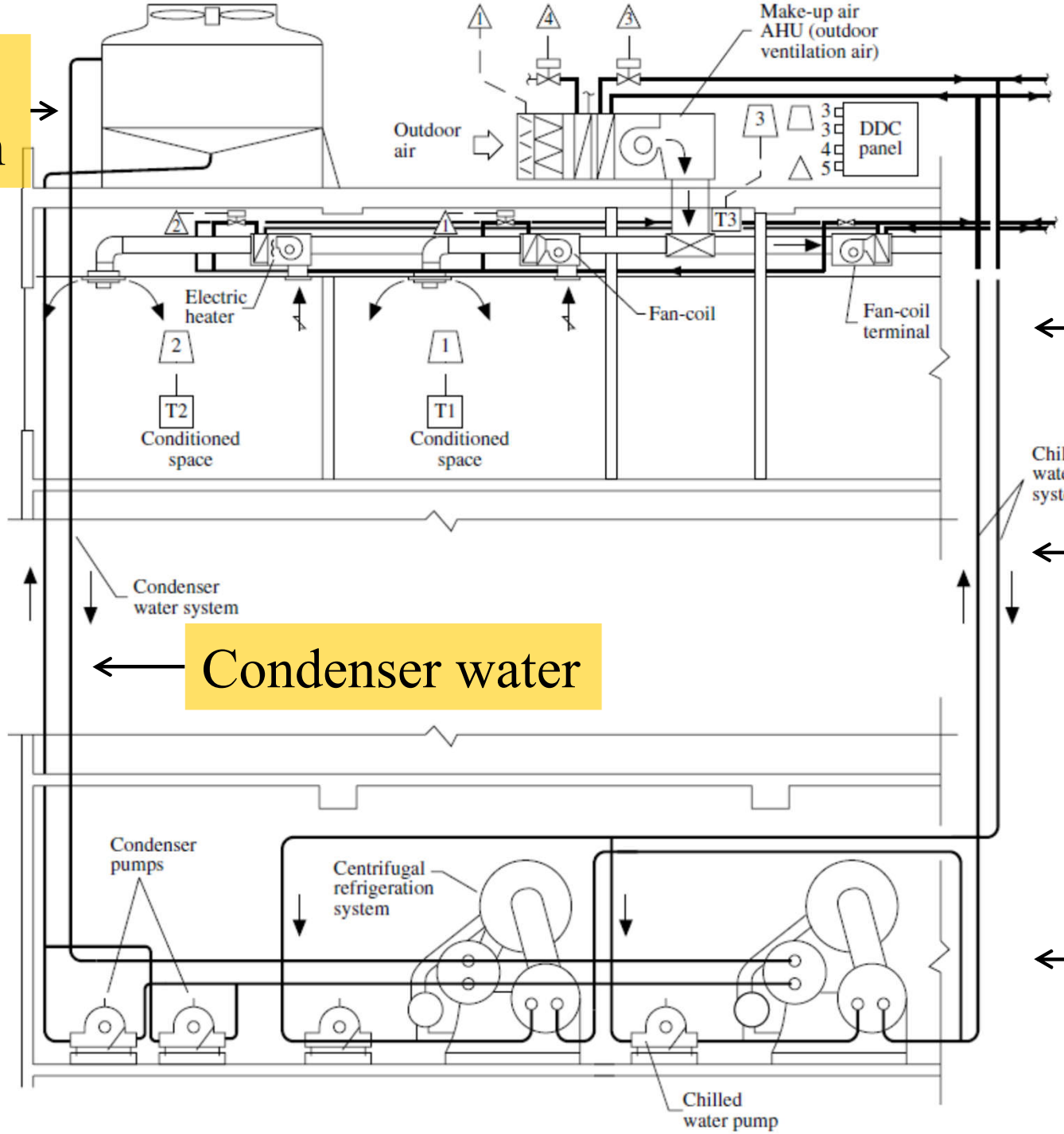
(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.)

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

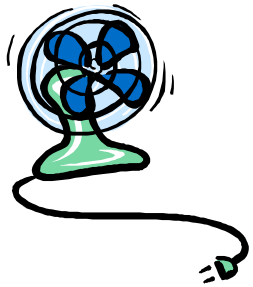
Chilled water

Condenser water

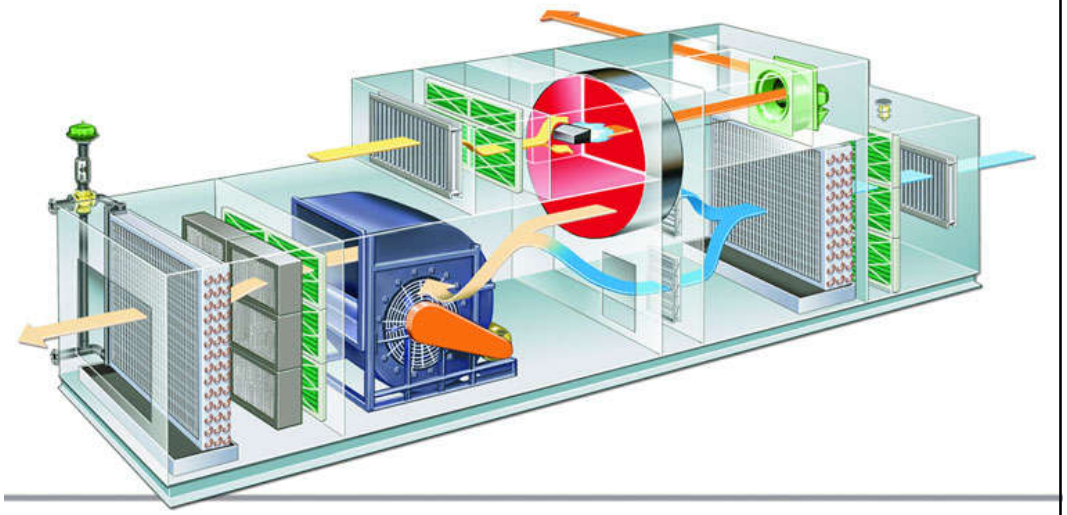
Refrigeration

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

Air-side systems

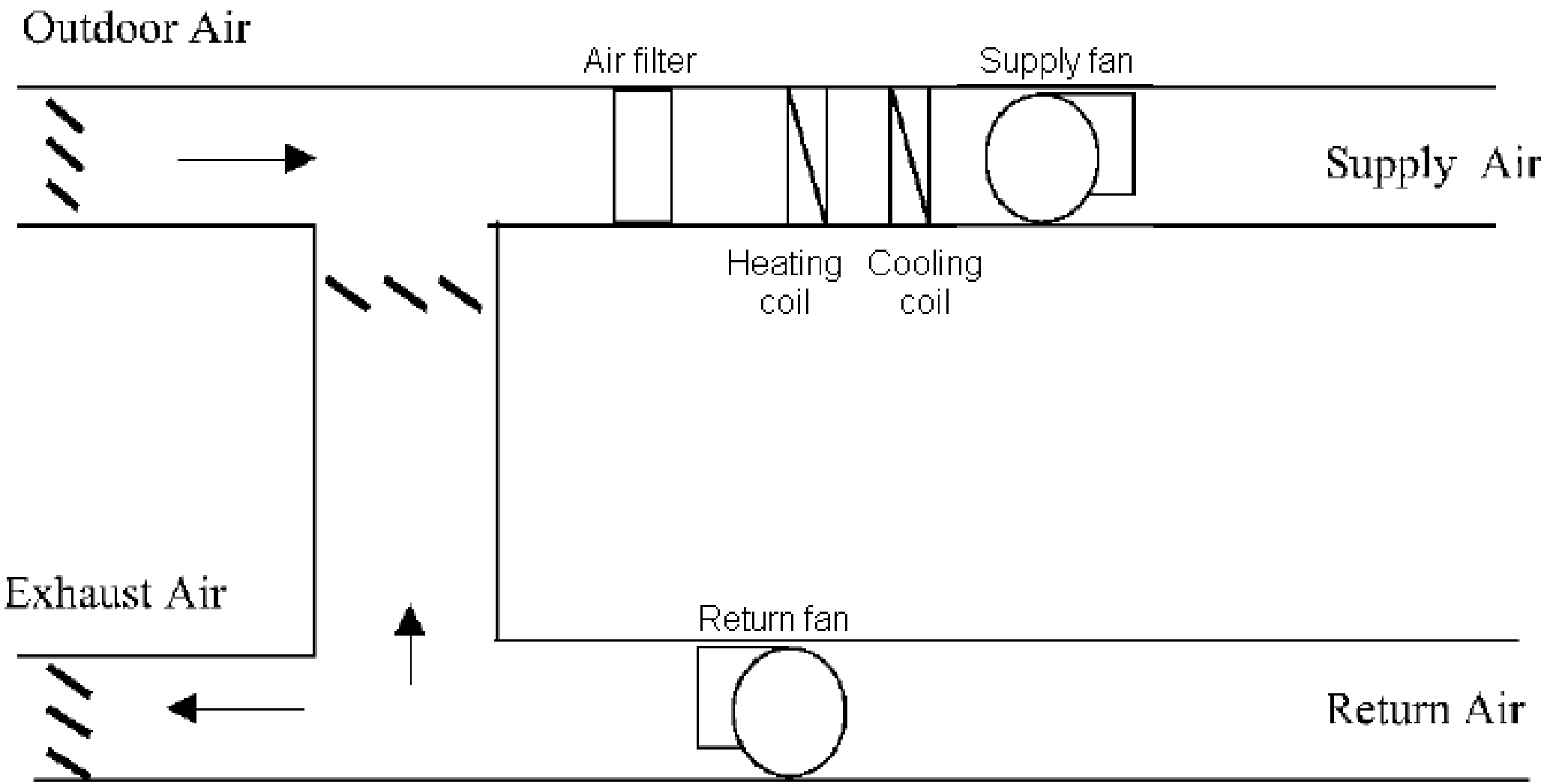


- Main components of air handling unit (AHU)
  - Casing
  - Fans
  - Coils
  - Filters
  - Humidifiers (optional)

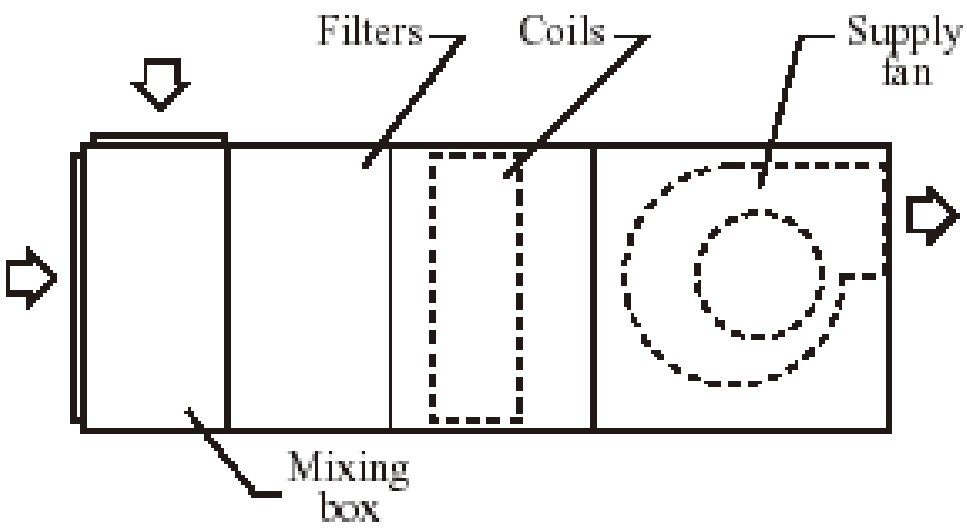


  - Outdoor air intake, mixing & exhaust section
  - Controls

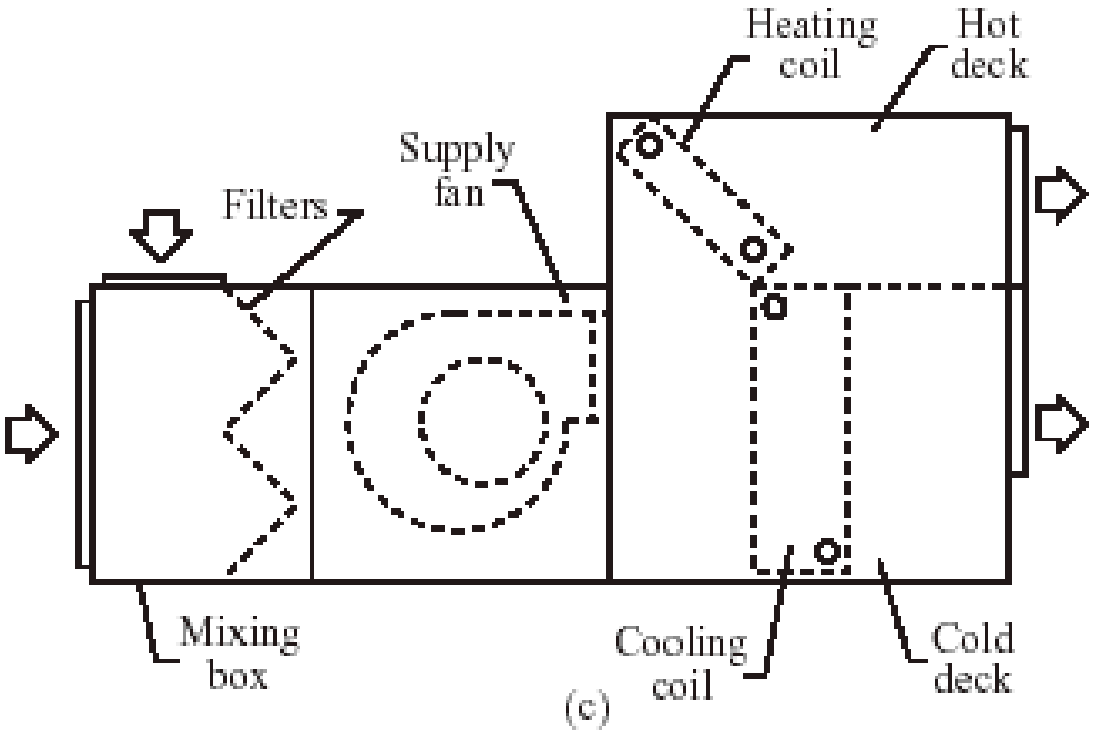
Simple air-handling unit (AHU)



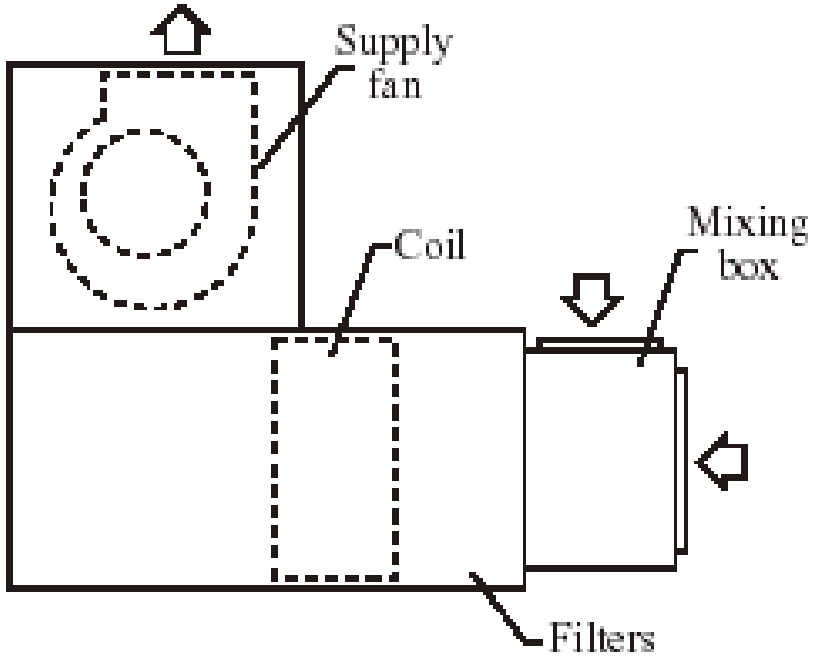
Example of an air-handling unit (modular type)



(a)



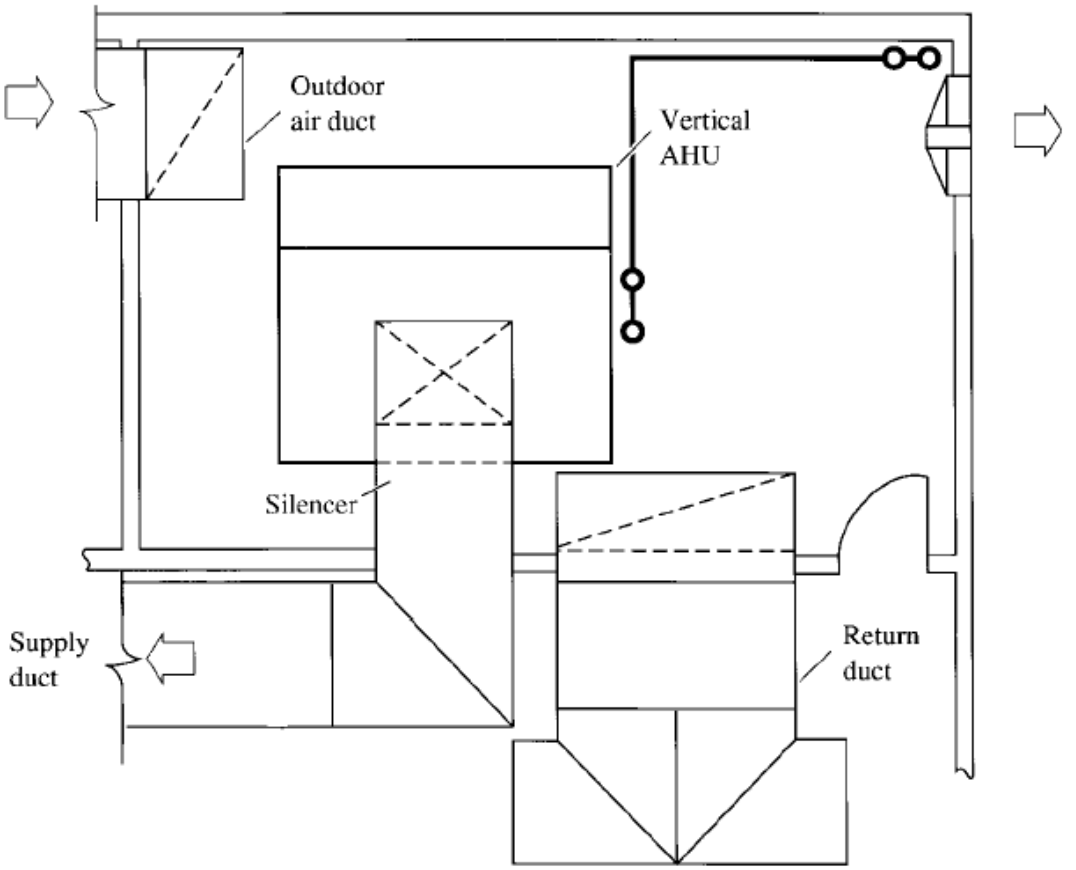
(c)

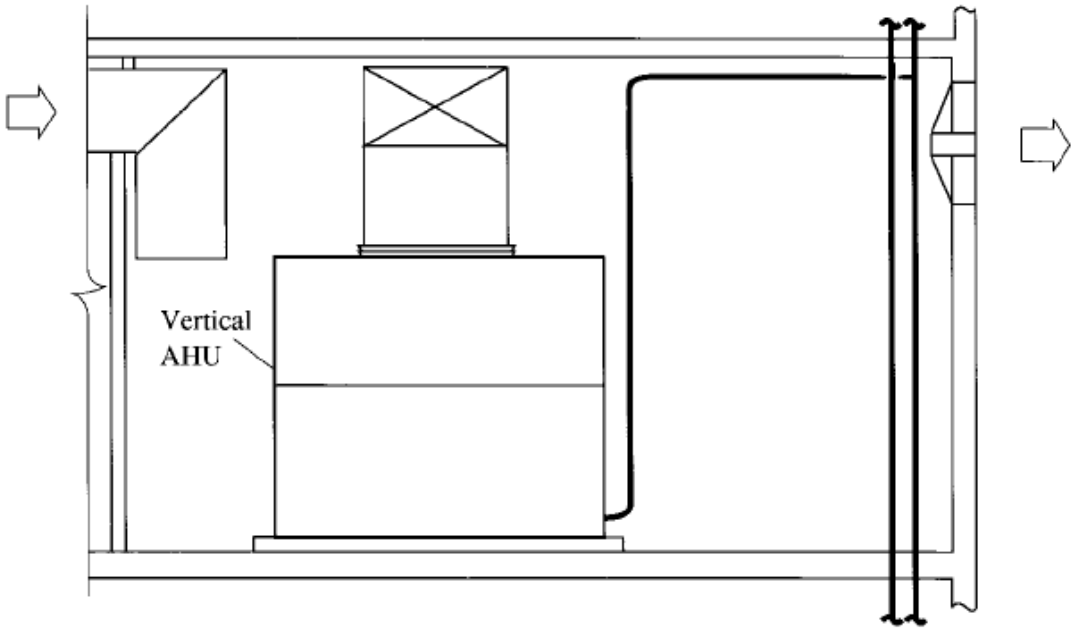


(b)

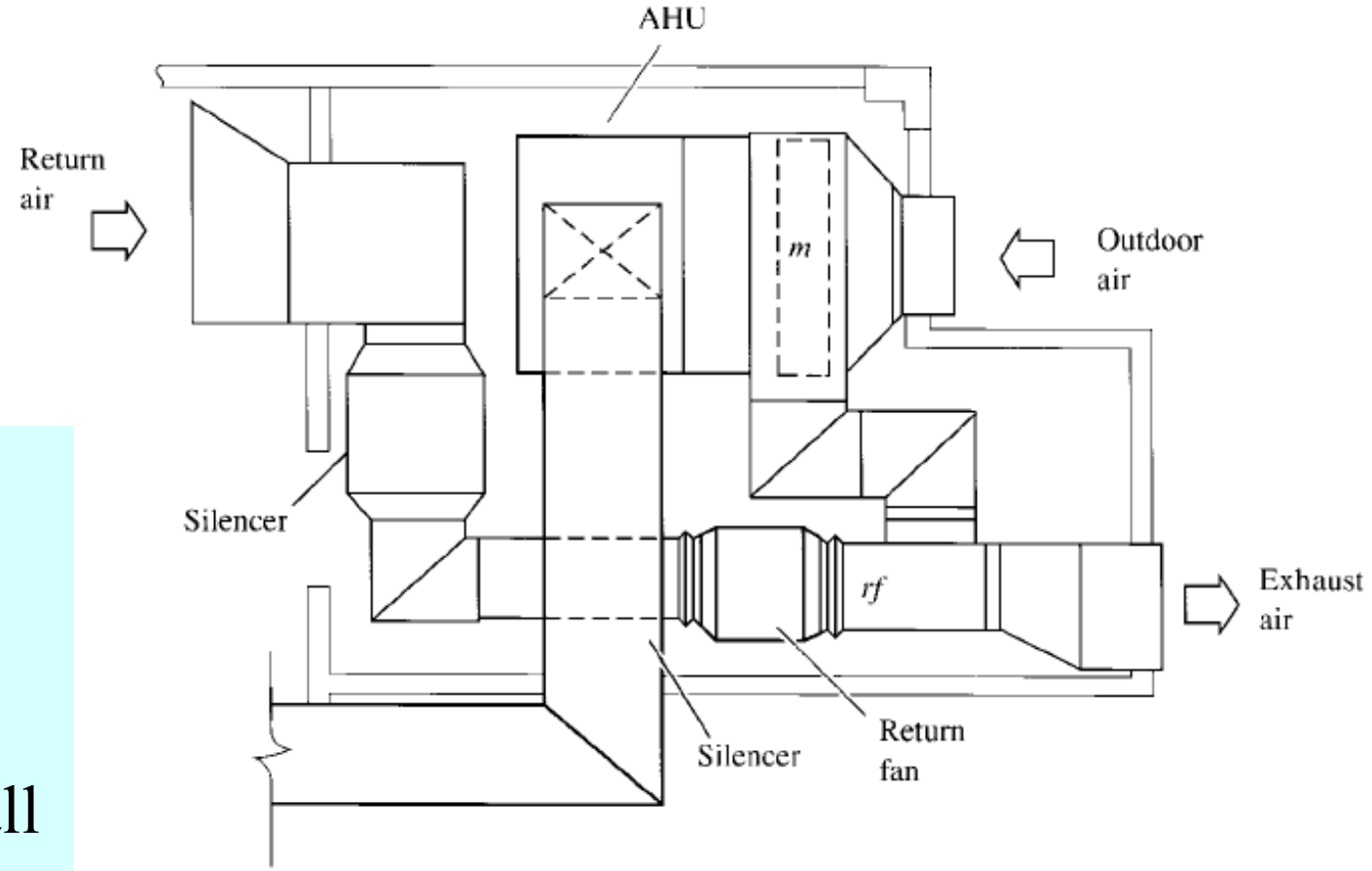
FIGURE 9.7.1 Type of air handling units: (a) horizontal draw-through unit, (b) vertical draw-through unit, and (c) multizone blow-through unit.

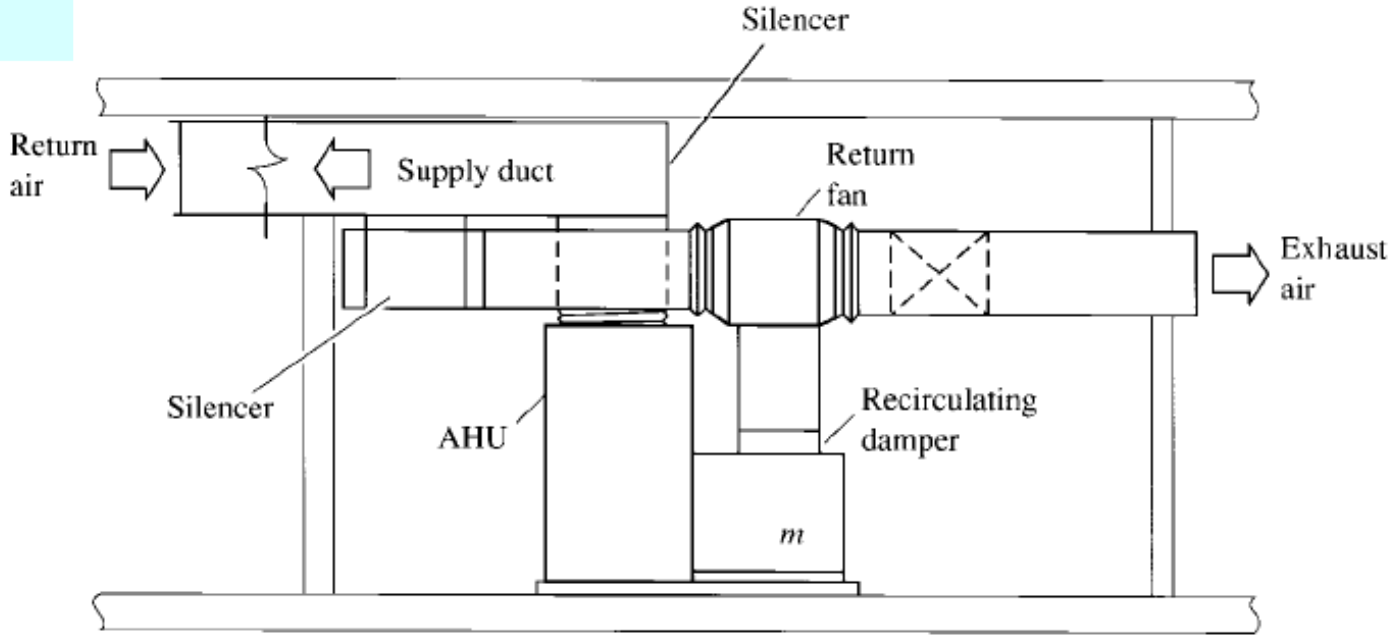
Open
Fan Room
(fan room become the mixing box)



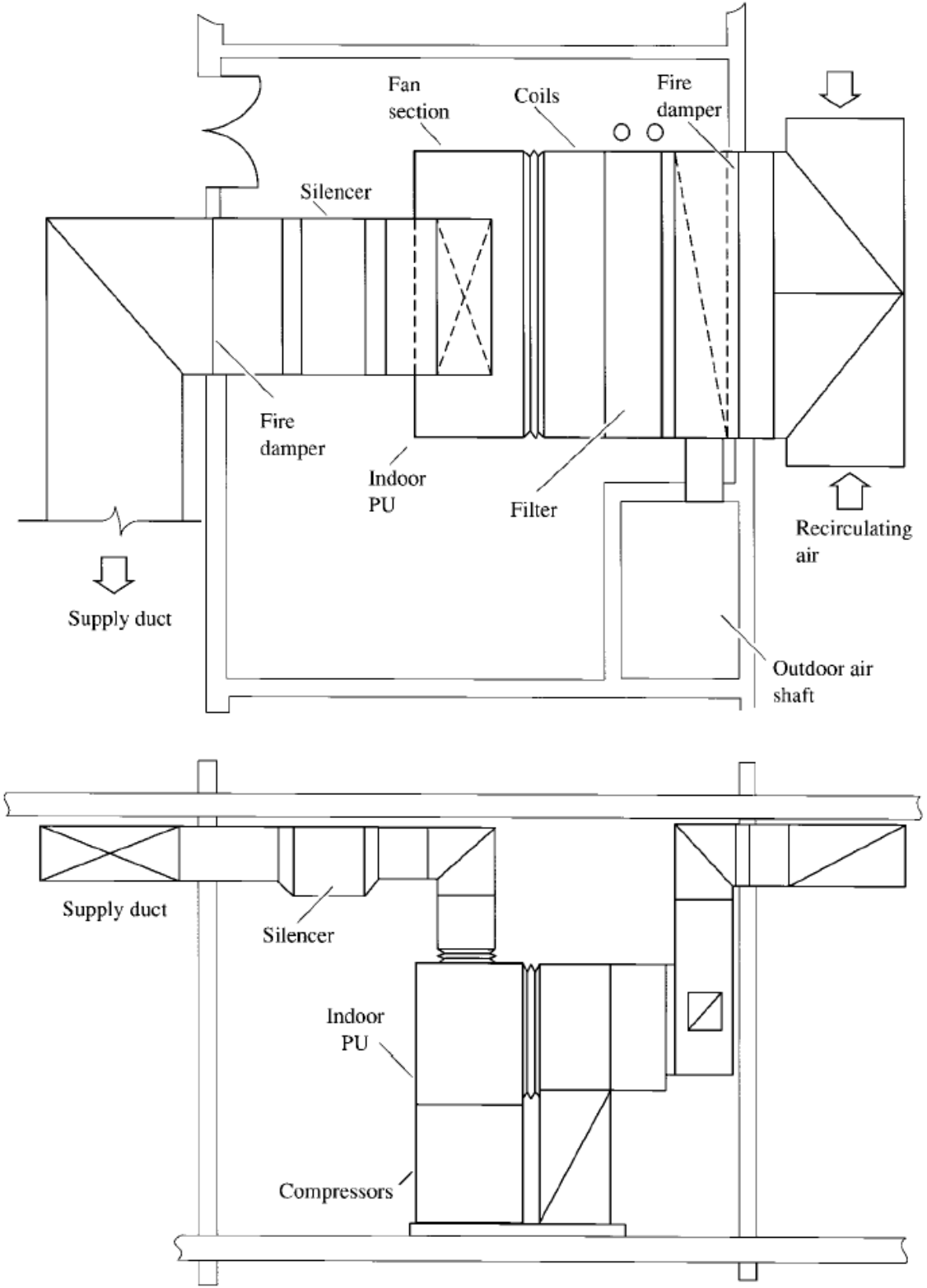


Isolated Fan Room
(outdoor air, return air & exhaust air are all in ductwork)

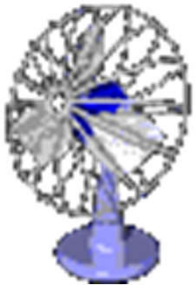




Interior Core Fan Room
(for an indoor package unit)

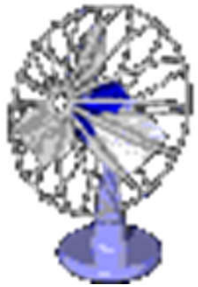


Ventilation systems



- Purposes of ventilation
  - Maintain human comfort and health
  - Provide sufficient air/oxygen for human/livestock
  - Provide sufficient air/oxygen for processes
  - Remove products of respiration and bodily odour
  - Remove contaminants or harmful chemicals
  - Remove heat generated indoor
  - Create air movement (feeling of freshness/comfort)

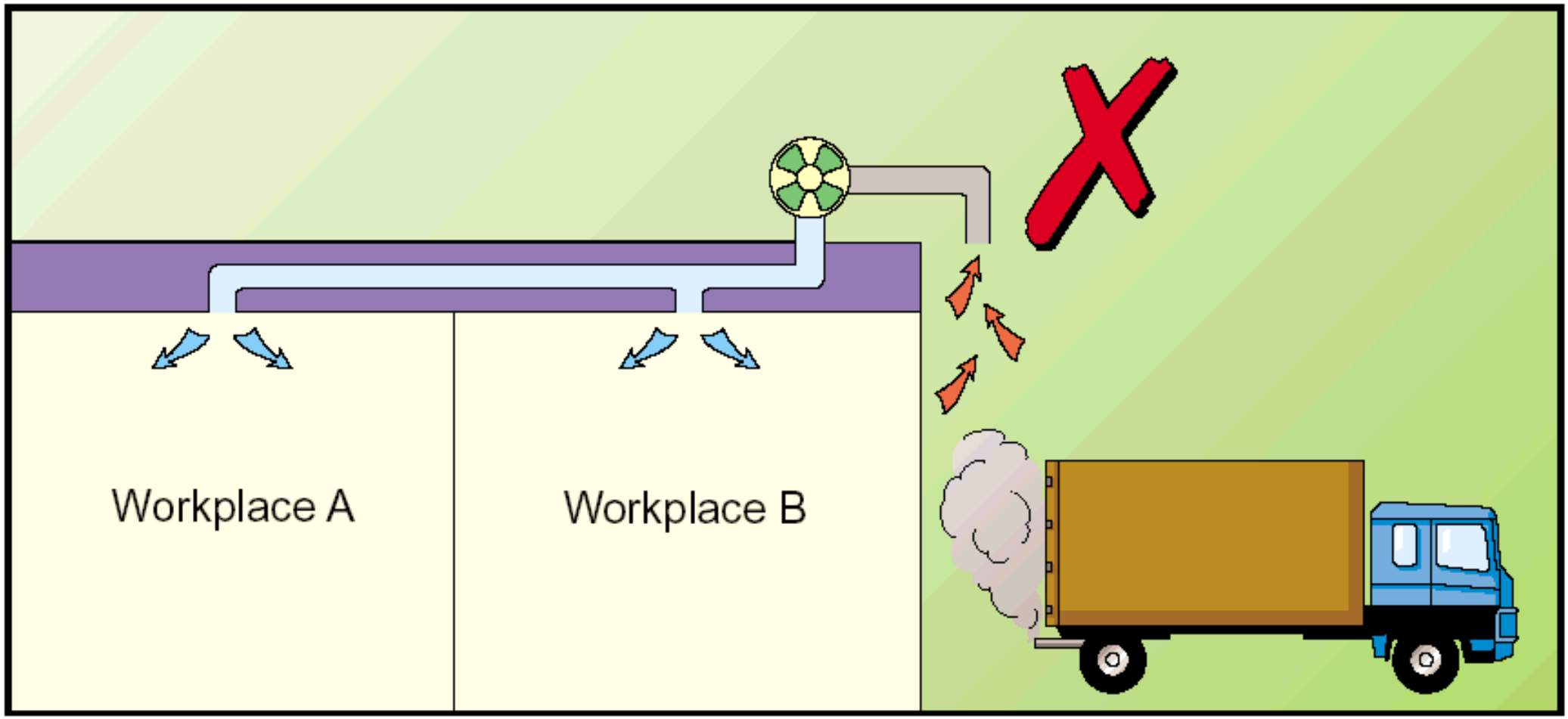
Ventilation systems



- For removal of indoor pollution
  - Estimate production rates of all known pollutants
  - Select the largest ventilation rate for design
- Standards & guides, e.g. ASHRAE Standard 62.1 and CIBSE Guide B2
  - Prescriptive procedure and analytical procedure
- In Hong Kong, the related building regulation
  - e.g. Building (Ventilating Systems) Regulations -- Chapter 123J

(See also: Ventilation Design http://www.arca53.dsl.pipex.com/index_files/vent7.htm)

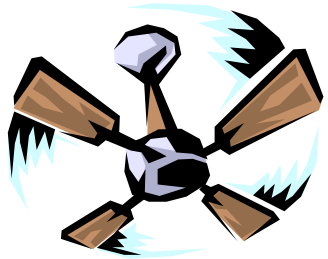
Ventilation system design should avoid intake of vehicle exhaust



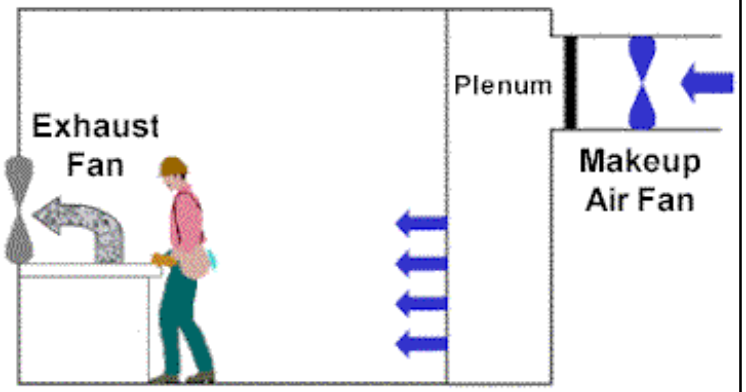
* Also ensure outdoor air intake is of adequate quality

(Source: Environmental Protection Department)

Ventilation systems

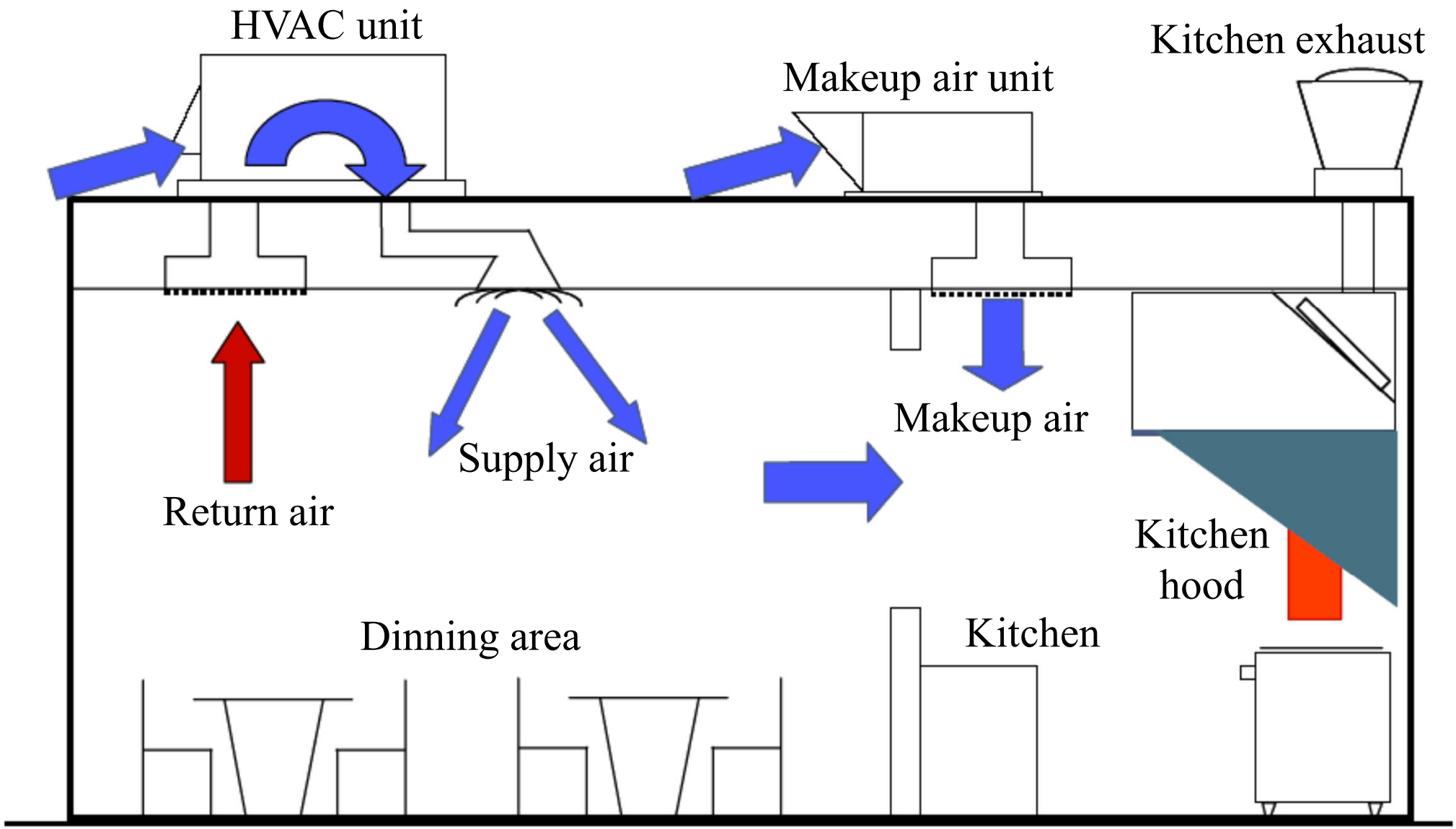


- Extract ventilation, e.g.
  - Commercial kitchens
  - Toilets and bathrooms
  - Underground carparks
  - Factories or industrial buildings
  - Localised industrial extraction

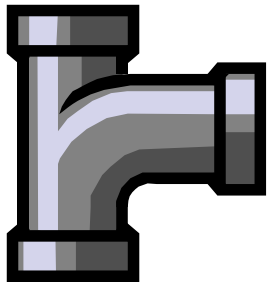


- Supply ventilation
  - Can be used to ensure adequate supply of outside air, e.g. in boiler house ventilation

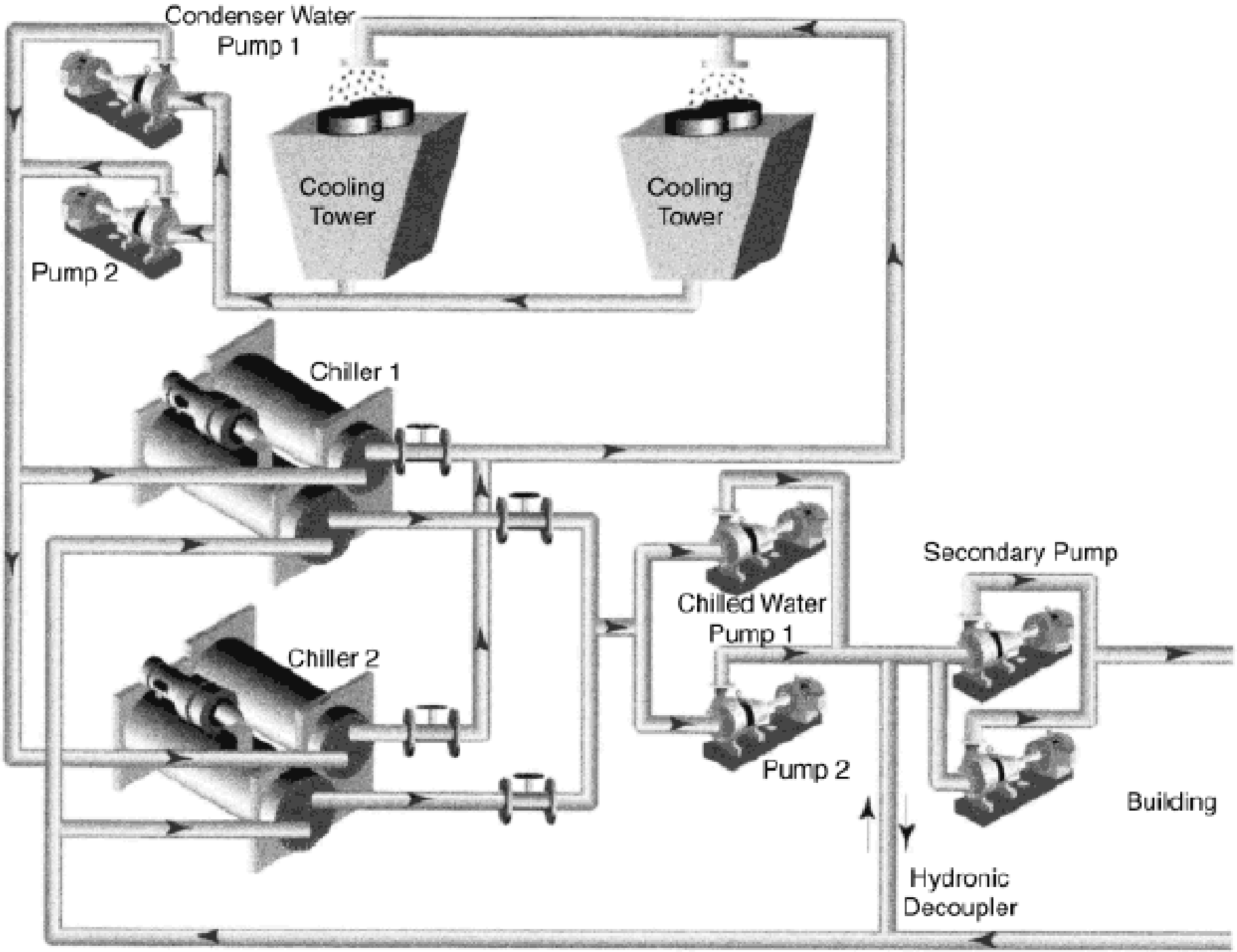
Example of kitchen ventilation system



Water-side systems



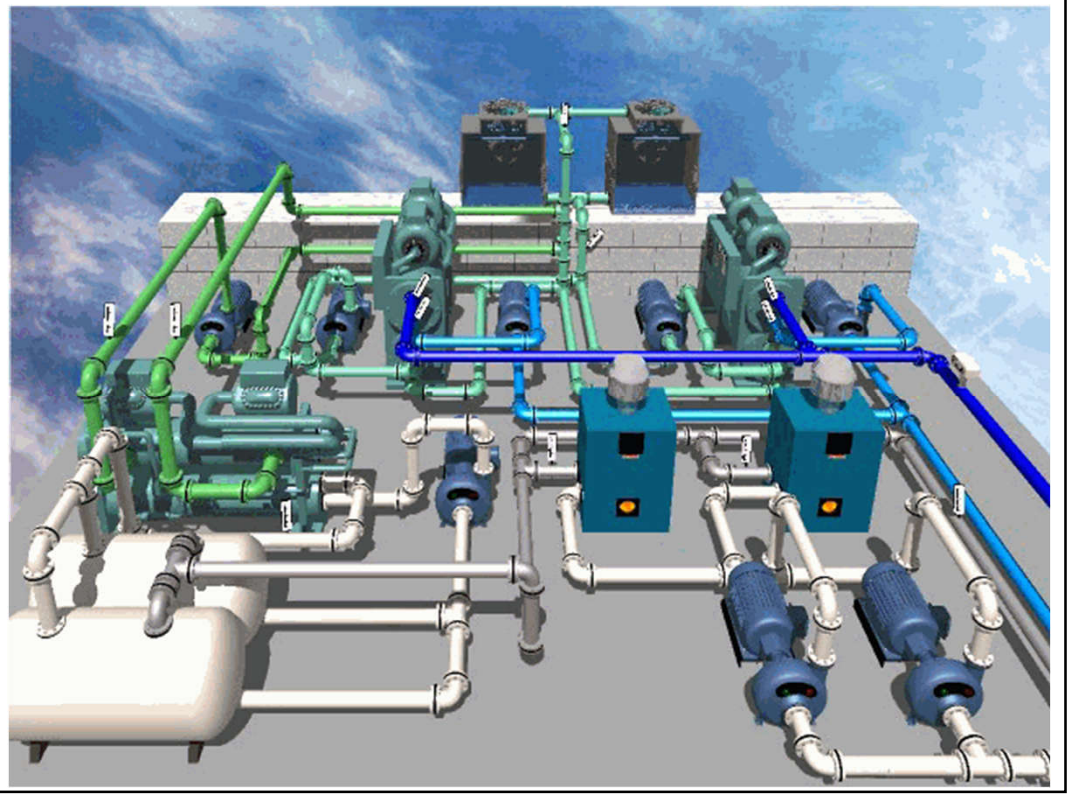
- Common types of HVAC piping systems
  - Chilled water (CHW) system
  - Condenser water (CW) system
  - Sea water system
  - Hot water supply system
  - Steam pipes, gas pipes
- Similar systems in other building services
  - Water supply & distribution (plumbing)



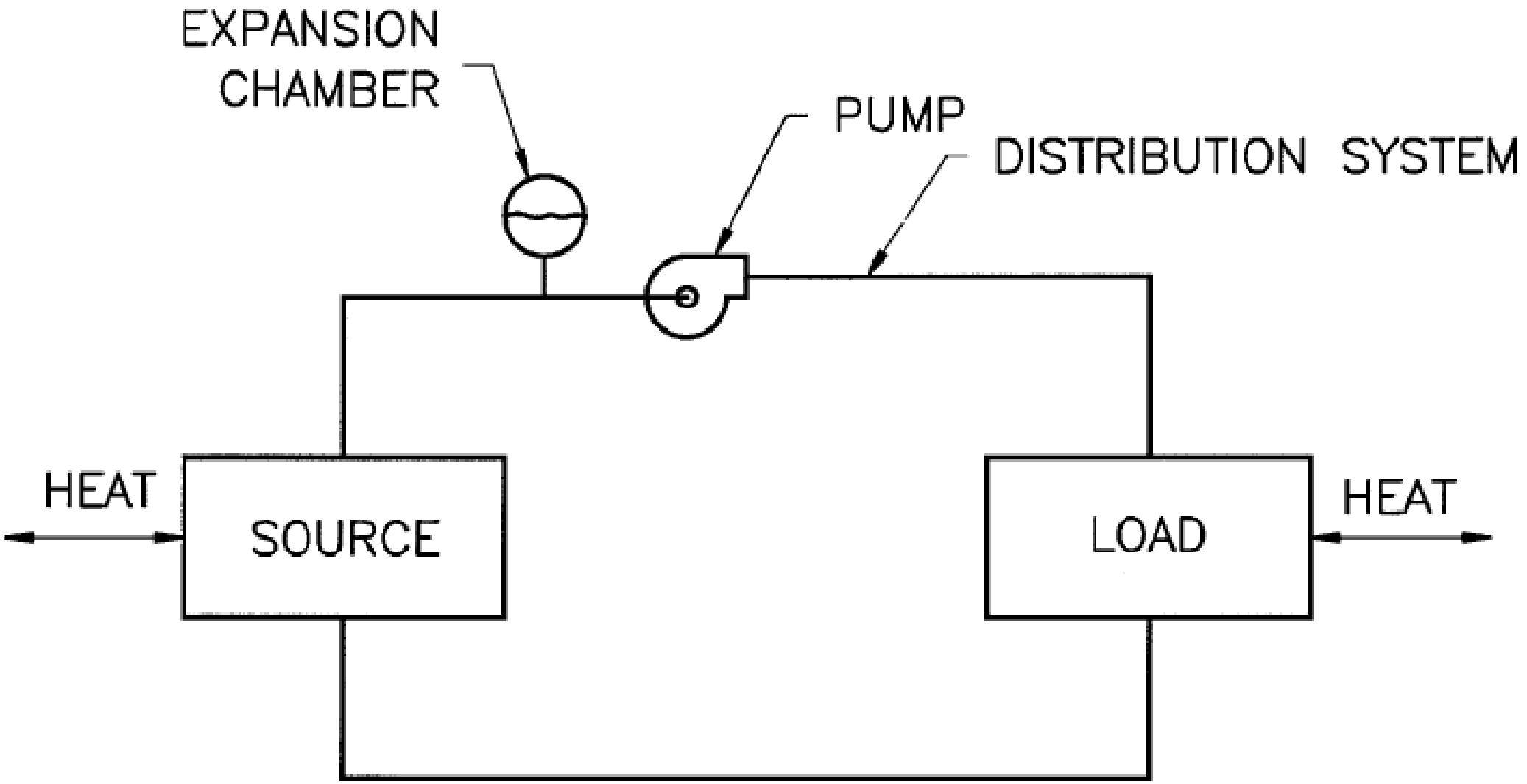
[Source: Kreider, K. F. (ed.), 2001. *Handbook of Heating, Ventilation, and Air Conditioning*, CRC Press, Boca Raton, FL.]

Water-side systems

- HVAC water systems can be classified by
  - Operating temperature
  - Flow generation
  - Pressurization
  - Piping arrangement
  - Pumping arrangement

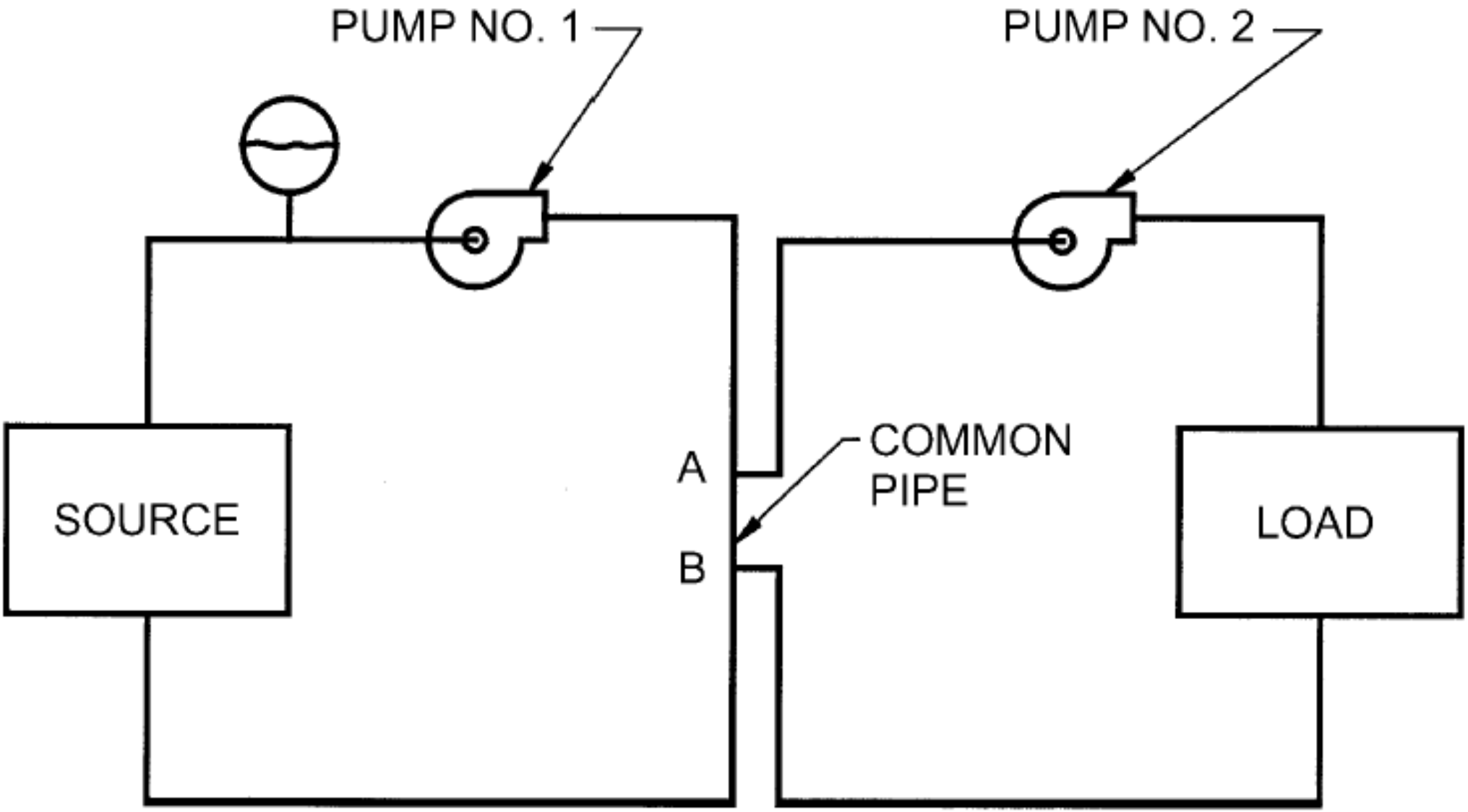


Basic components of water (hydronic) system



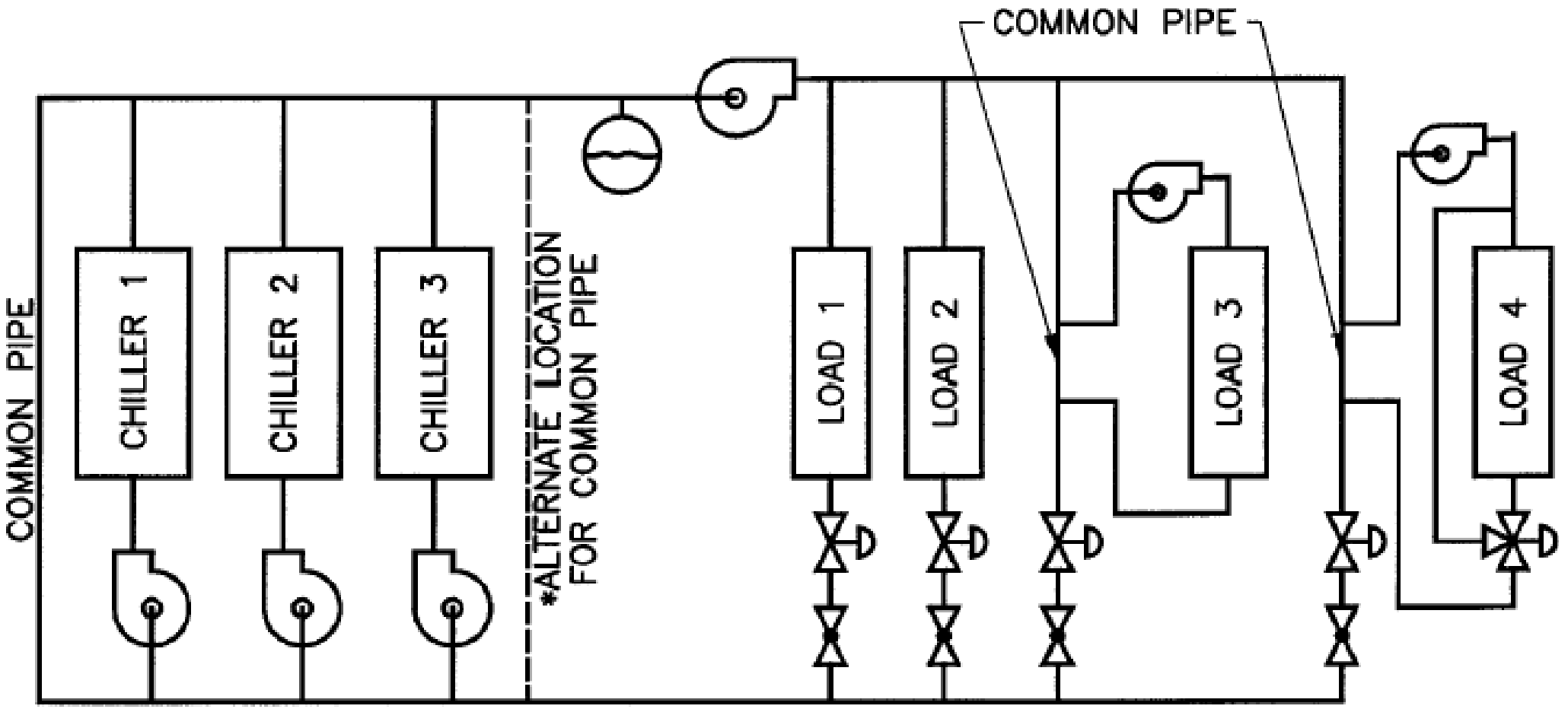
(Source: *ASHRAE HVAC Systems and Equipment Handbook 2004*)

Primary-secondary loop and pumping



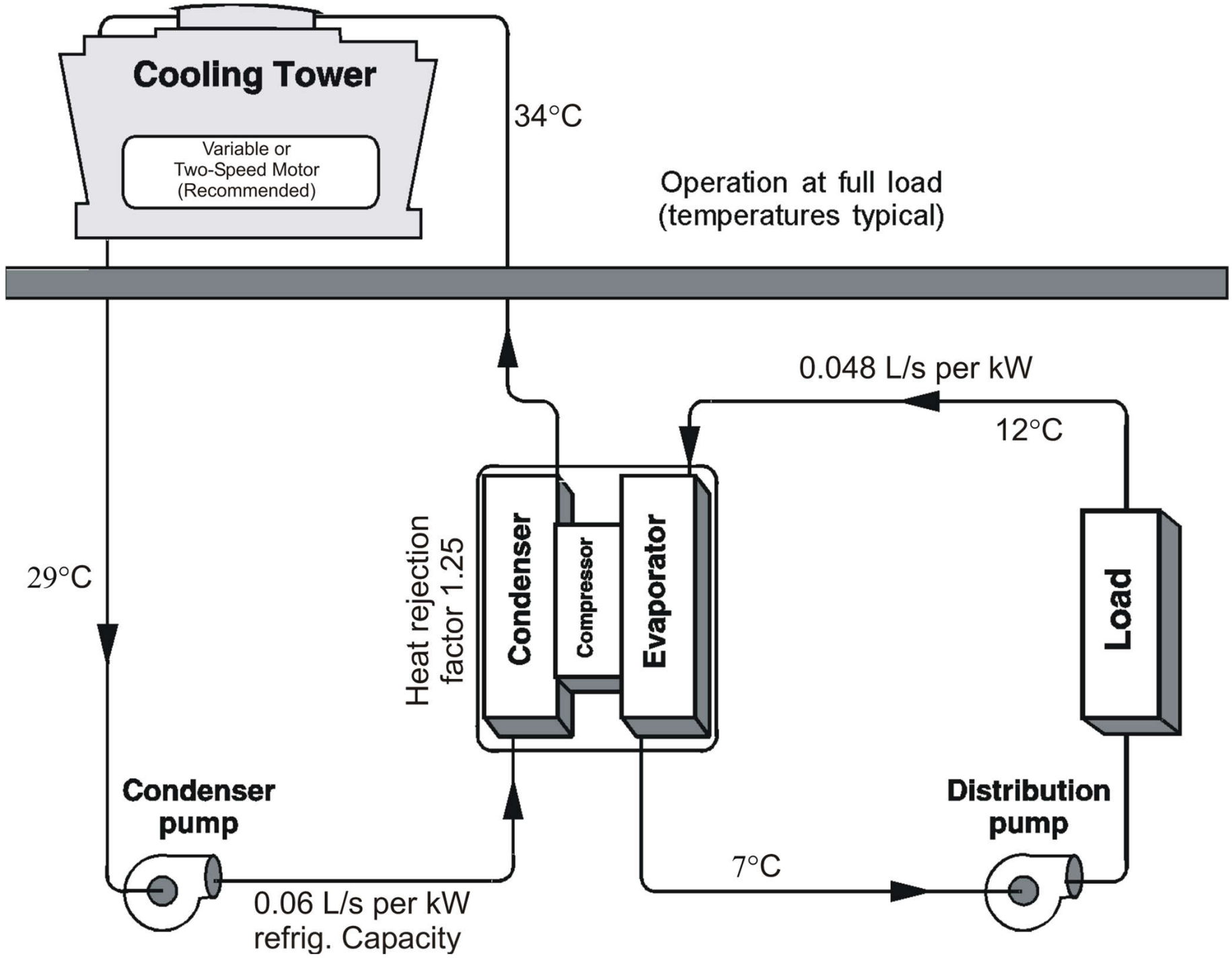
(Source: *ASHRAE HVAC Systems and Equipment Handbook 2004*)

Multiple chiller variable flow chilled water system



(Source: *ASHRAE HVAC Systems and Equipment Handbook 2004*)

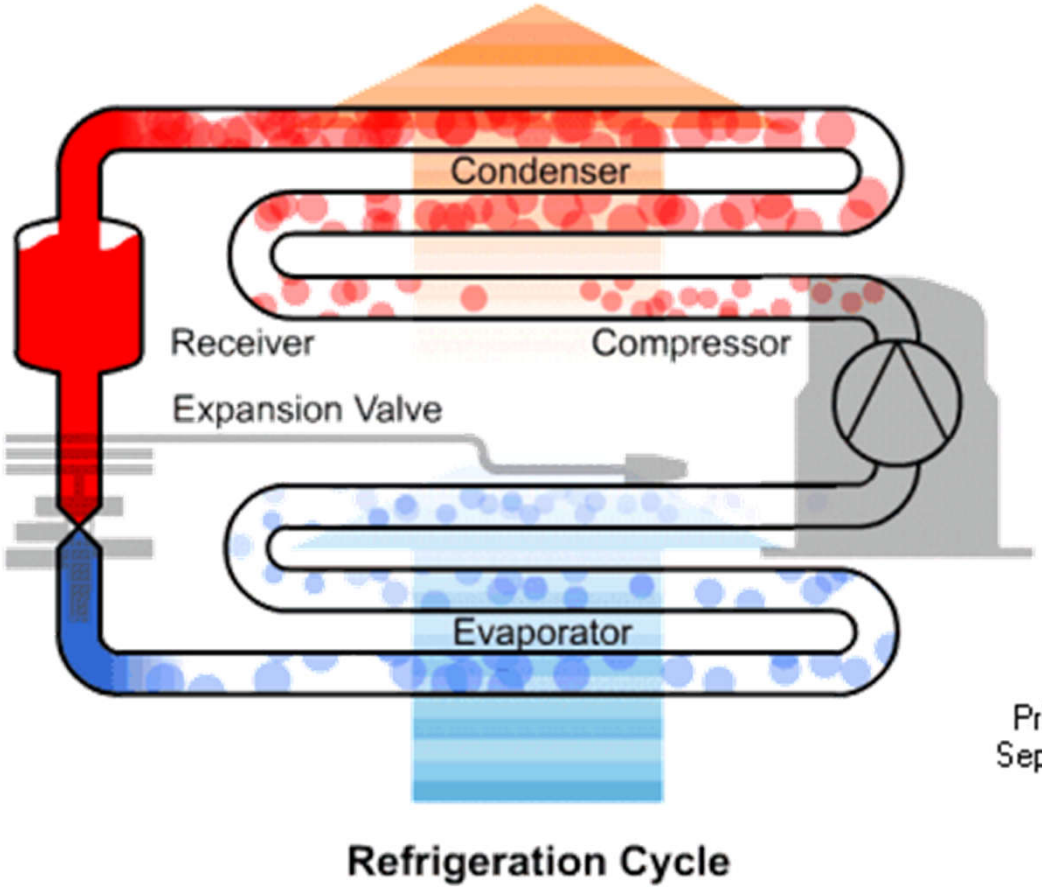
Cooling tower pumping system



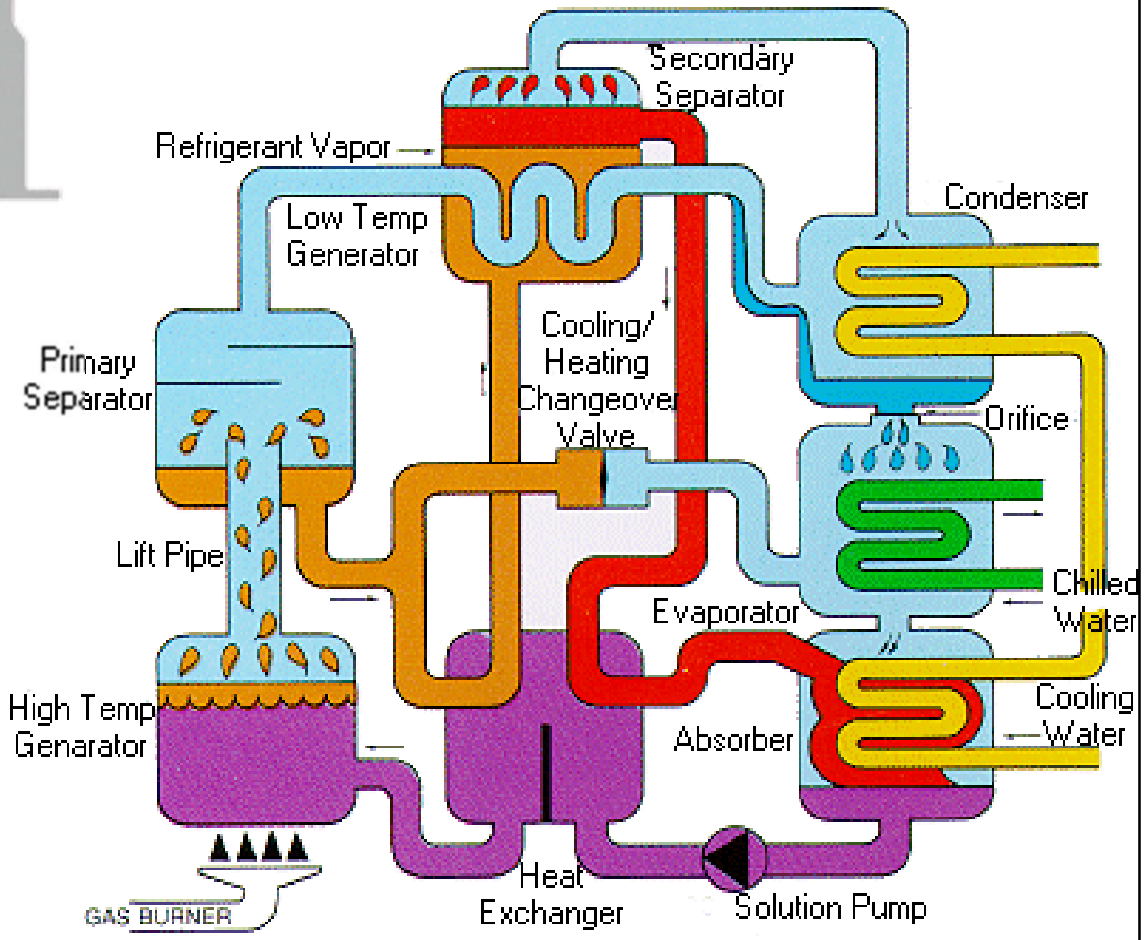
(Source: *Fundamentals of Water System Design*)

Refrigeration systems

- Common refrigeration systems in HVAC
  - Direct expansion (DX) systems & heat pumps
  - Centrifugal chillers
  - Screw chillers
  - Absorption systems
- Either single-stage or multistage
- Compressor lubrication
  - Use mineral or synthetic oil
  - Use magnetic bearings (oil-free chiller/compressor)

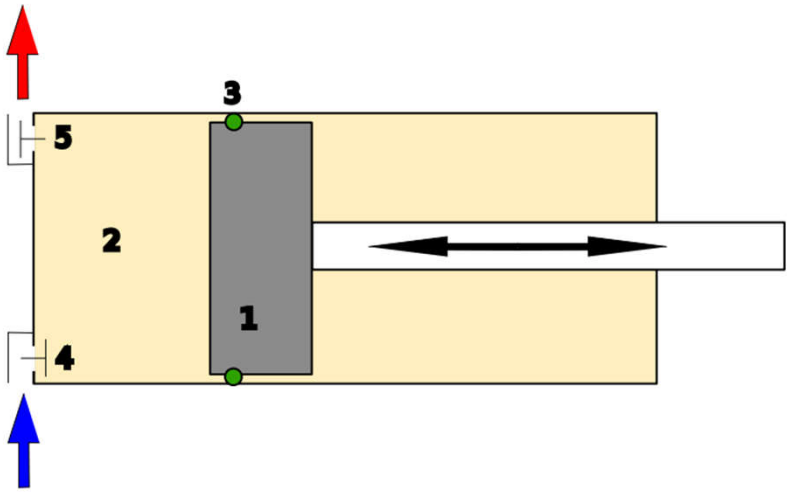


Vapour compression system



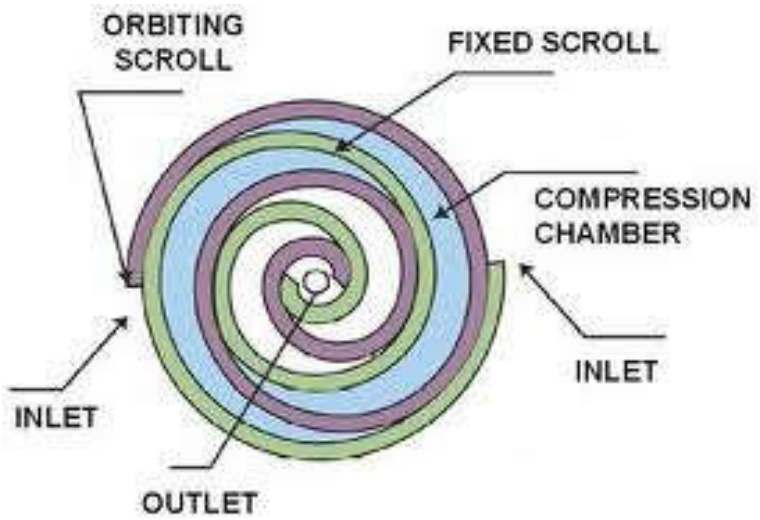
Absorption system

Common types of compressors used in chillers

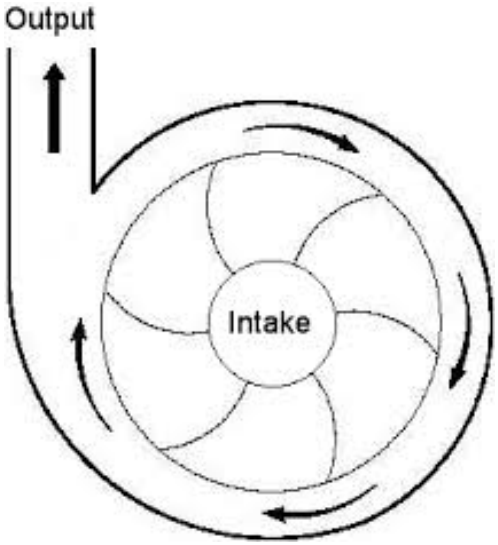


Reciprocating

Rotary screw



Scroll

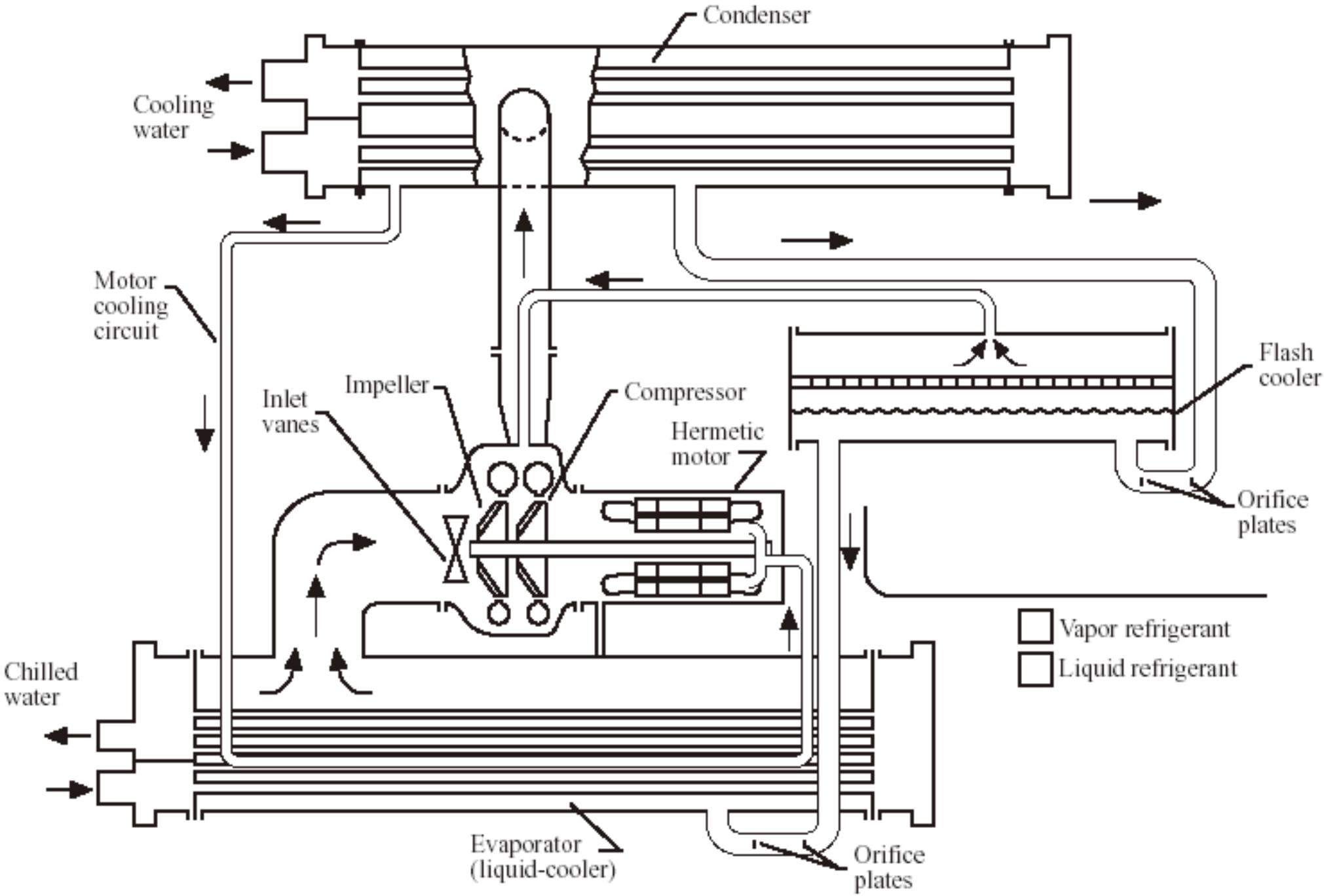


Centrifugal

Refrigeration systems

- Centrifugal chillers 離心式冷水機
  - Chiller = a refrigeration machine using a liquid cooler as an evaporator to produce chilled water
  - R-11, R-12, R-22 were used
    - R-11 replaced by R-123
    - R-12 replaced by R-134a
  - System components
    - Centrifugal compressor, evaporator, condenser, flash cooler, orifice plates & float valves, purge unit (optional)

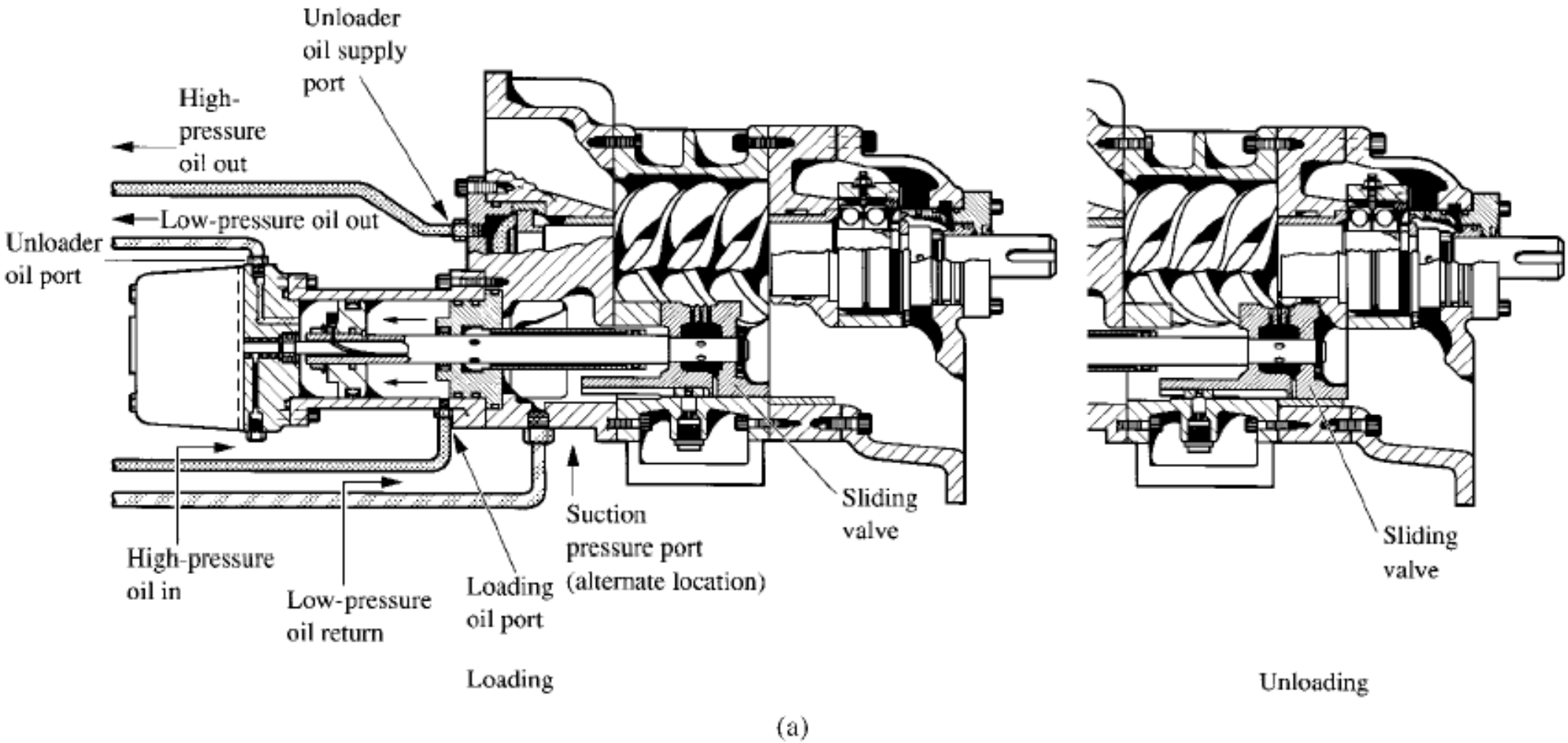
Two-stage water-cooled centrifugal chiller



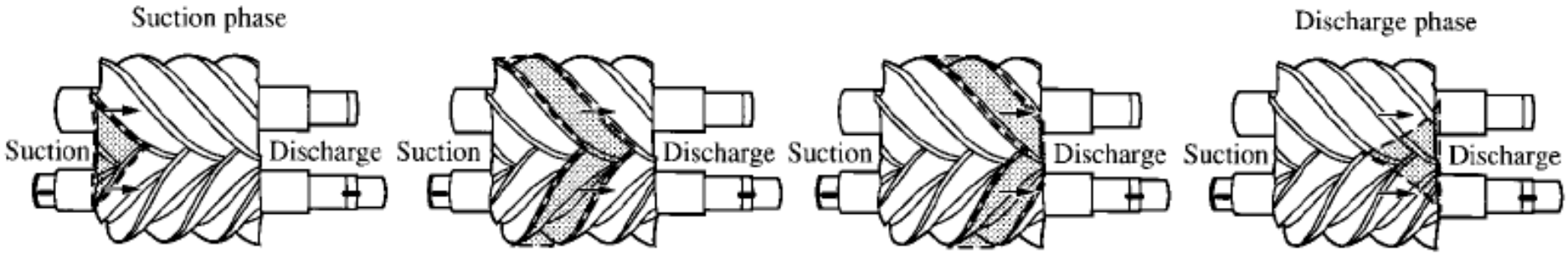
Refrigeration systems

- Screw chillers 螺桿式冷水機
  - Helical rotary chiller: use screw compressor
    - Twin-screw compressors are widely used
    - Capacity 100 to 1000 TR
  - Variable volume ratio
  - Economizer
    - Similar to a two-stage compound system w/ flash cooler
  - Oil separation, oil cooling and oil injection
    - Oil slugging is not a problem

Twin-screw compressor



(a)



(b)

Refrigeration systems

- Heat pumps 熱泵
  - Three types:
    - Air-source (air-to-air)
      - R-22 often used, range 1.5 to 40 TR
    - Water-source
    - Ground-coupled
  - Extract energy from ground, water, or ambient air
  - Cooling and heating mode operartion
    - Winter may require defrosting
  - High COP & EER (energy efficiency ratio)