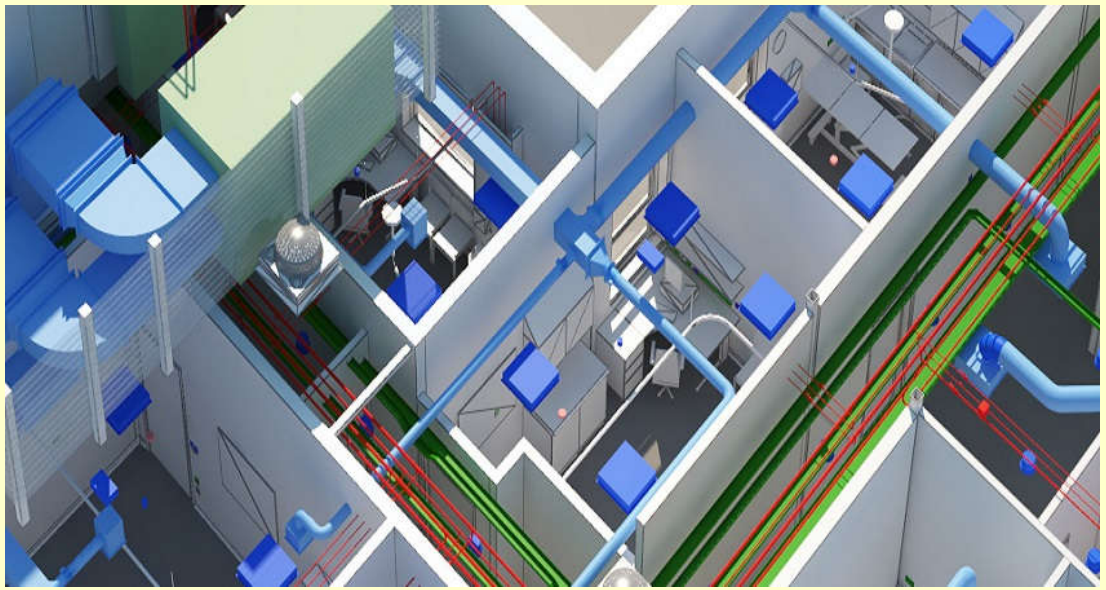

5. HVAC Part 1

5.2 HVAC systems and equipment

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May 2021

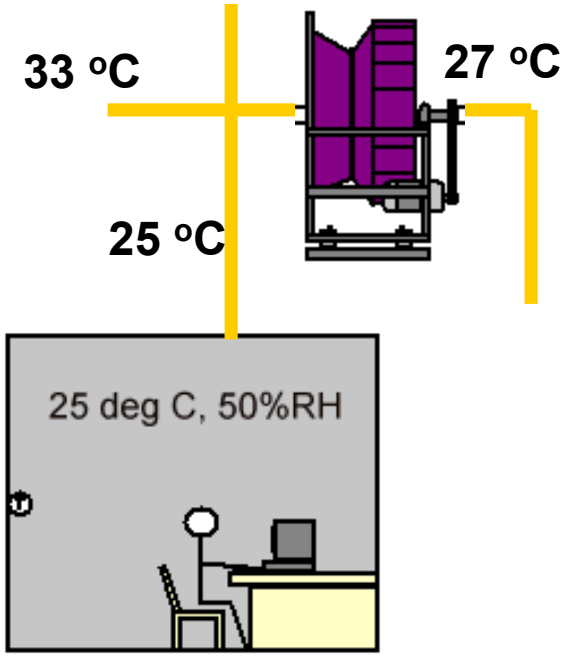
Contents 內容

- HVAC sub-systems 暖通空調子系統
- Air-side systems 空氣側系統
- Ventilation systems 通風系統
- Water-side systems 水側系統
- Refrigeration systems 製冷系統

HVAC sub-systems

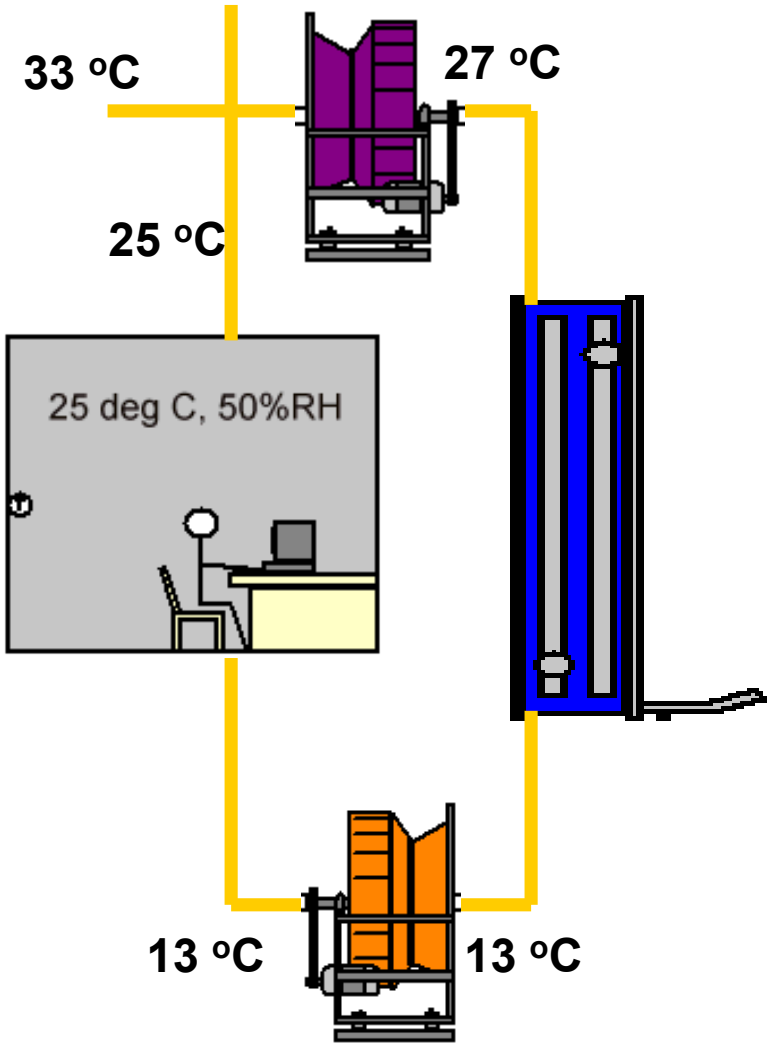
- To understand better, air conditioning system can be divided into five subsystems or loops:
  - 1. Air-side 空氣側
  - 2. Chilled water 冷凍水
  - 3. Refrigeration equipment 製冷設備
  - 4. Heat rejection 散熱
  - 5. Controls 控制

33 °C, 28 °C



Conditioned space

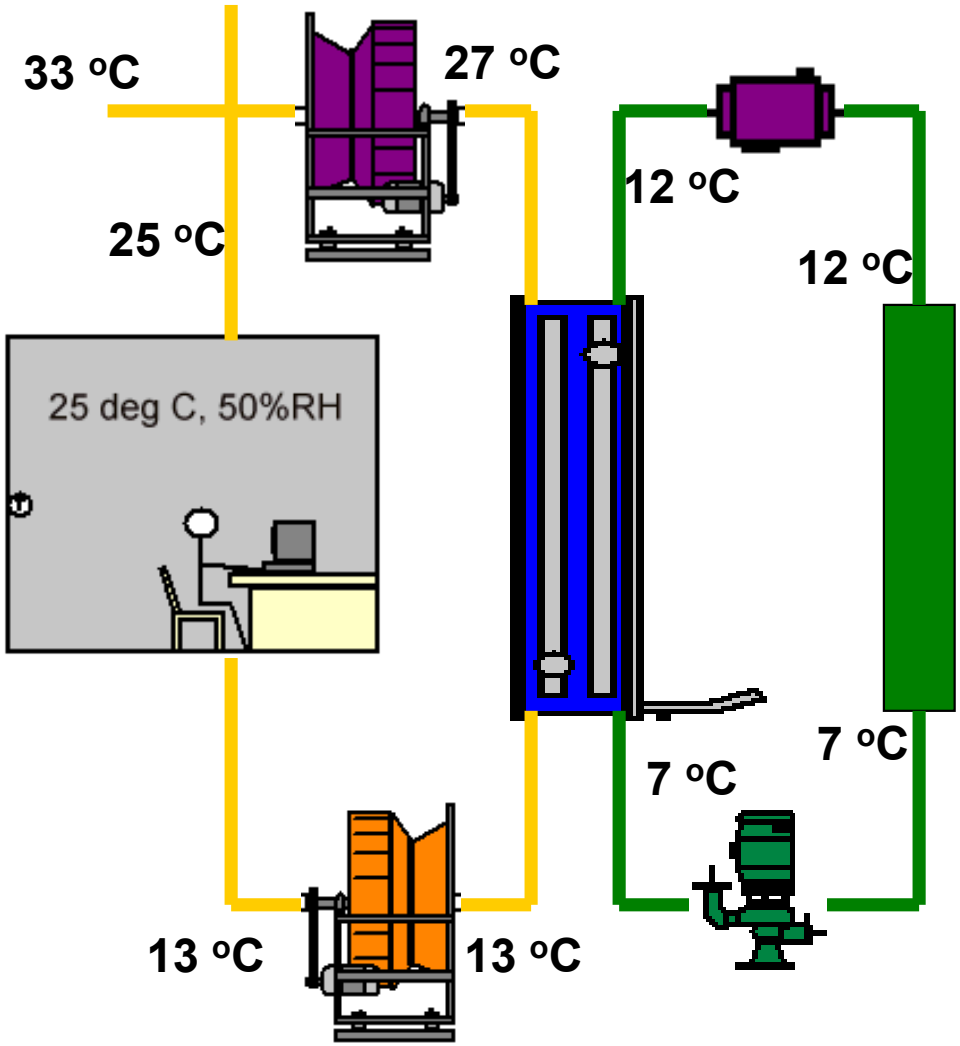
33 °C, 28 °C



Air side system

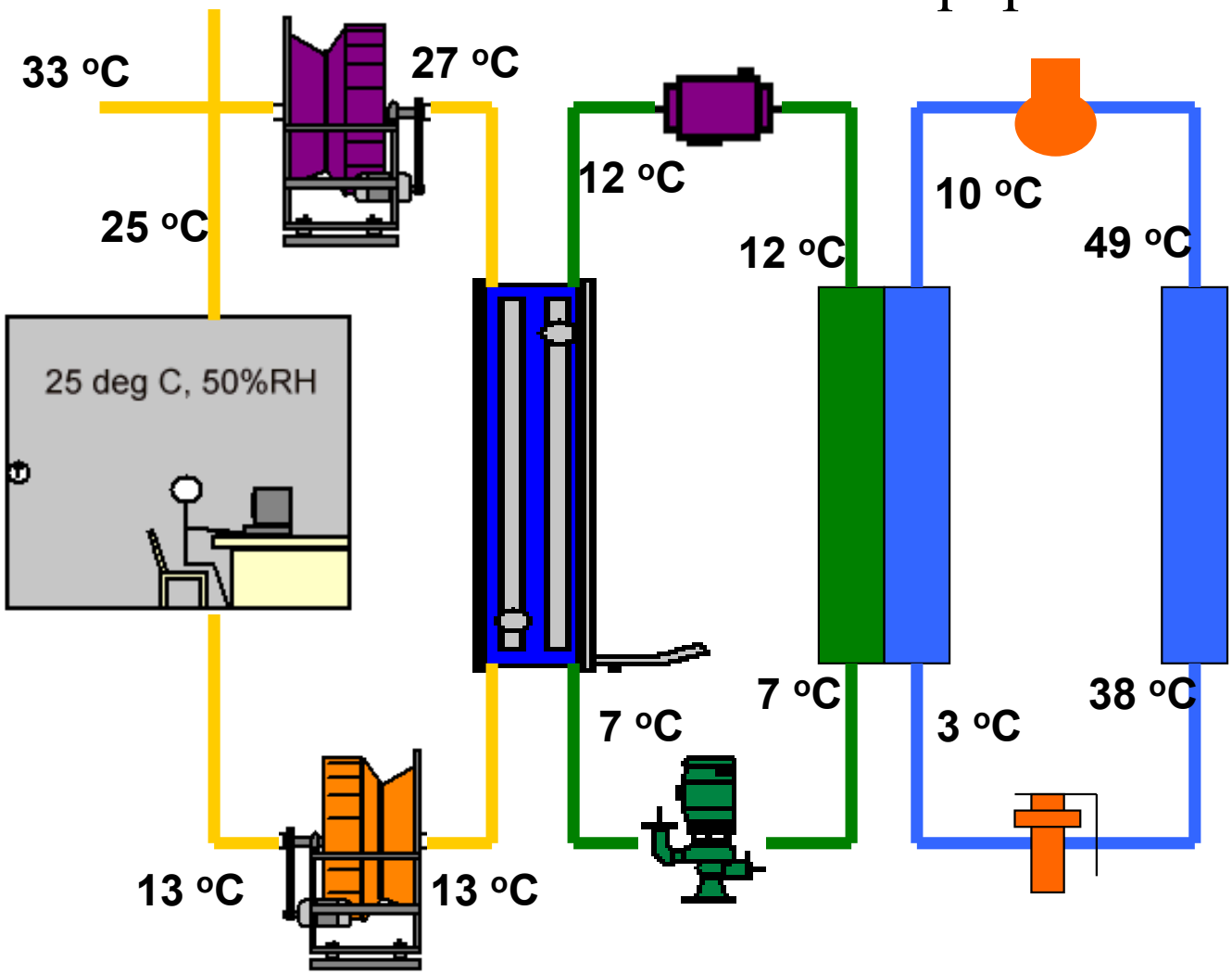
33 °C, 28 °C

Chilled water system



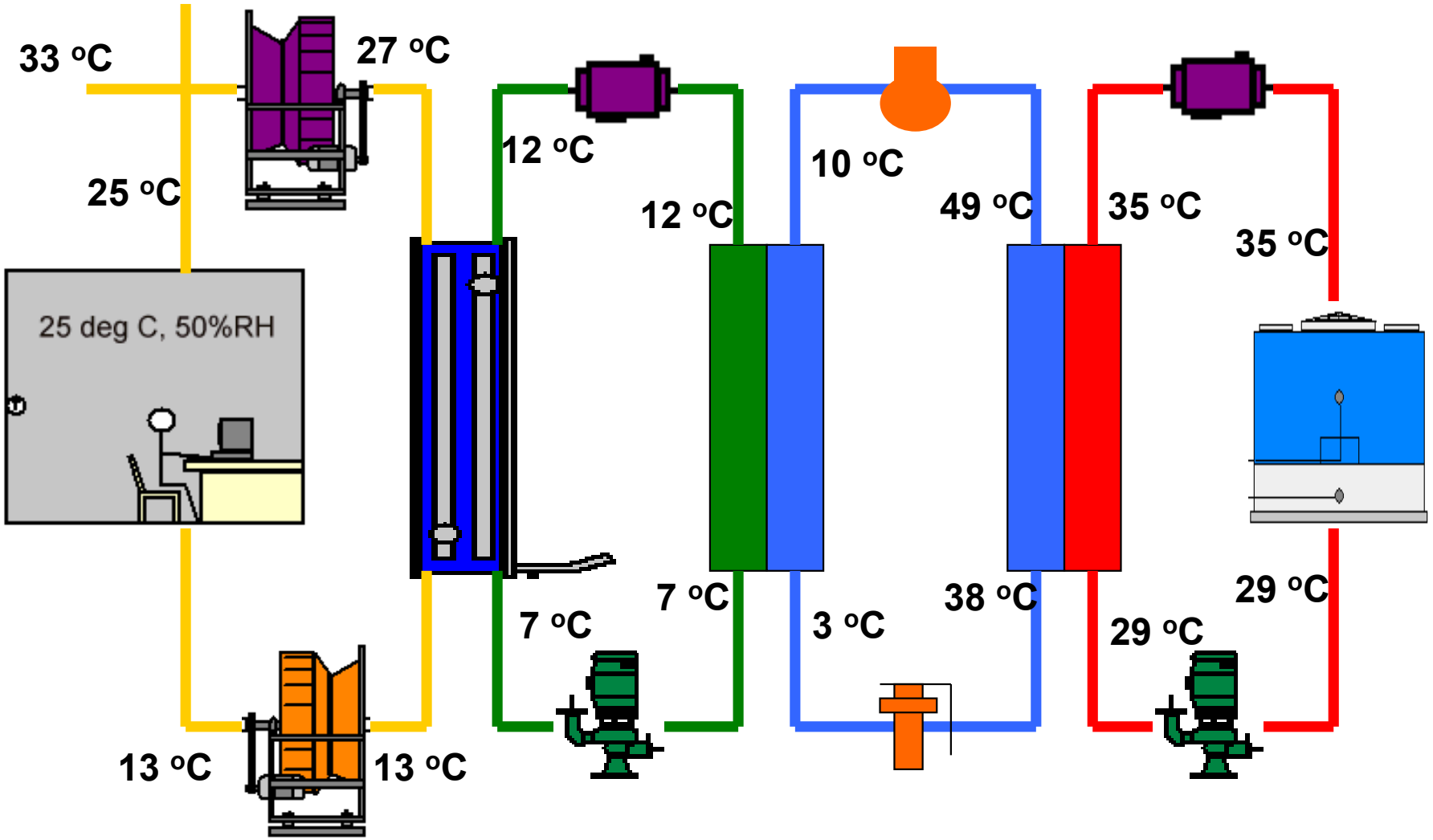
33 °C, 28 °C

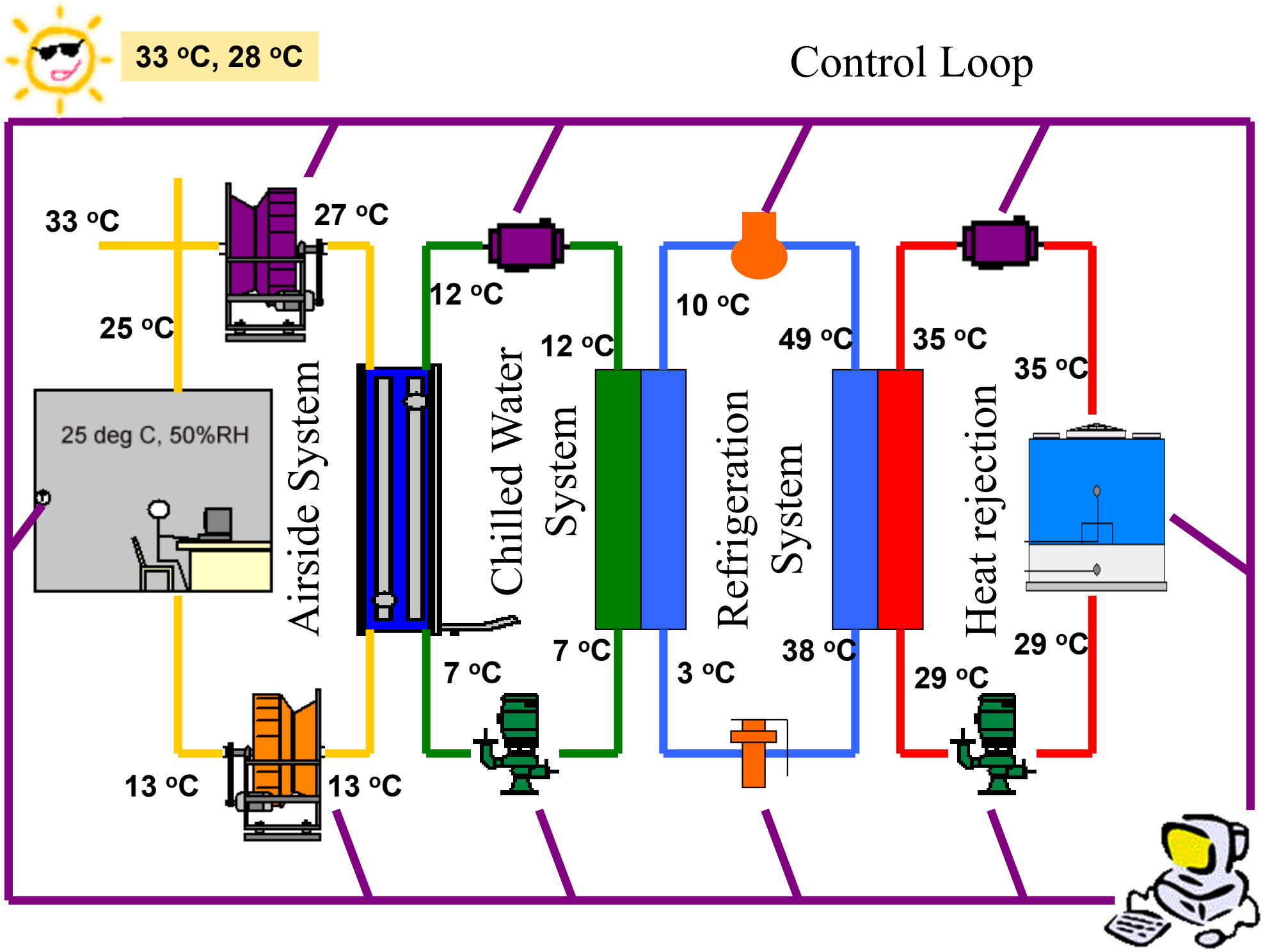
Refrigeration equipment



33 °C, 28 °C

Heat rejection

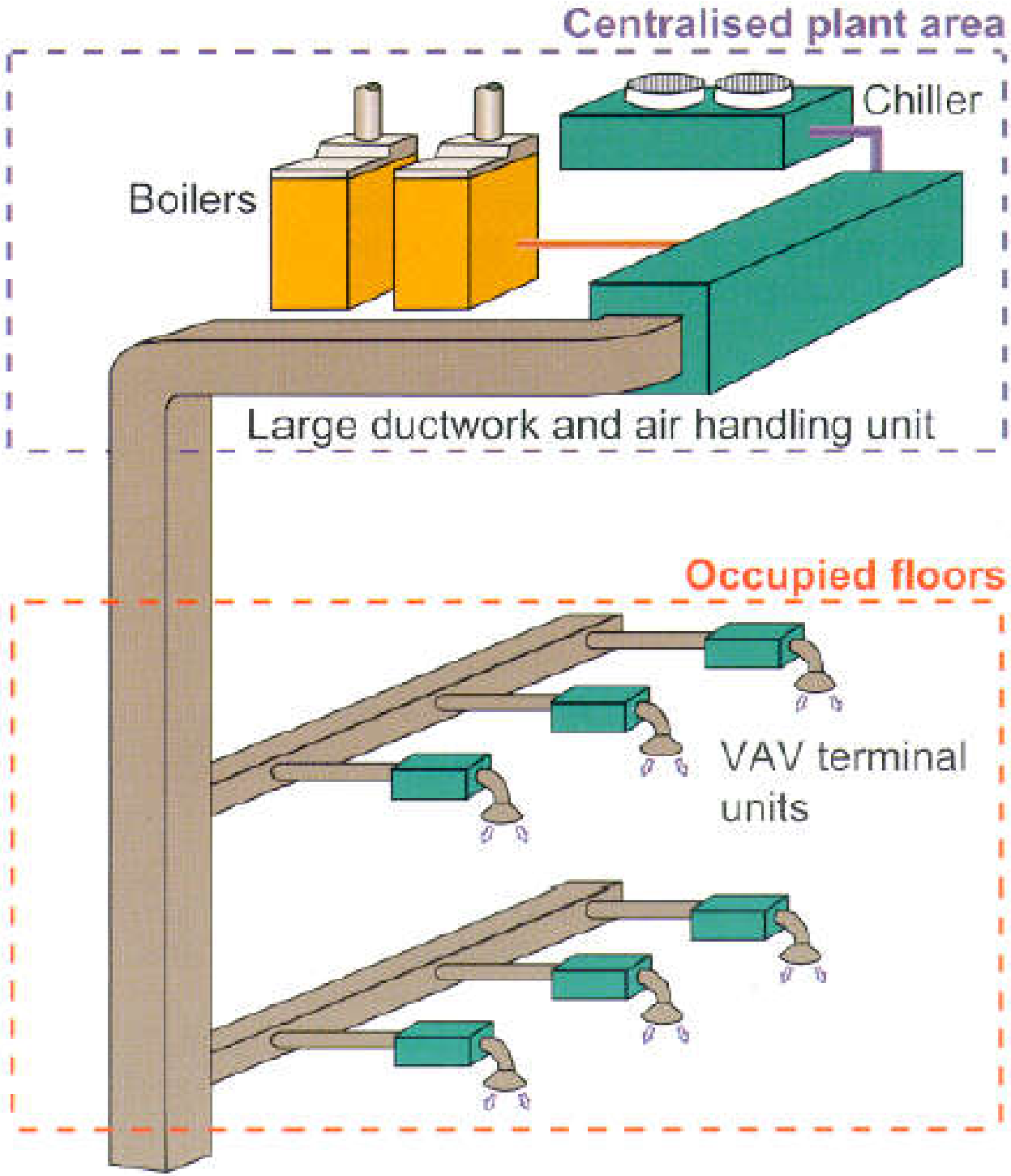



33 °C, 28 °C
Control Loop
33 °C
27 °C
25 °C
25 deg C, 50%RH
Airside System
13 °C
13 °C
12 °C
7 °C
Chilled Water System
12 °C
7 °C
10 °C
3 °C
Refrigeration System
49 °C
38 °C
35 °C
29 °C
Heat rejection
35 °C
29 °C

HVAC sub-systems

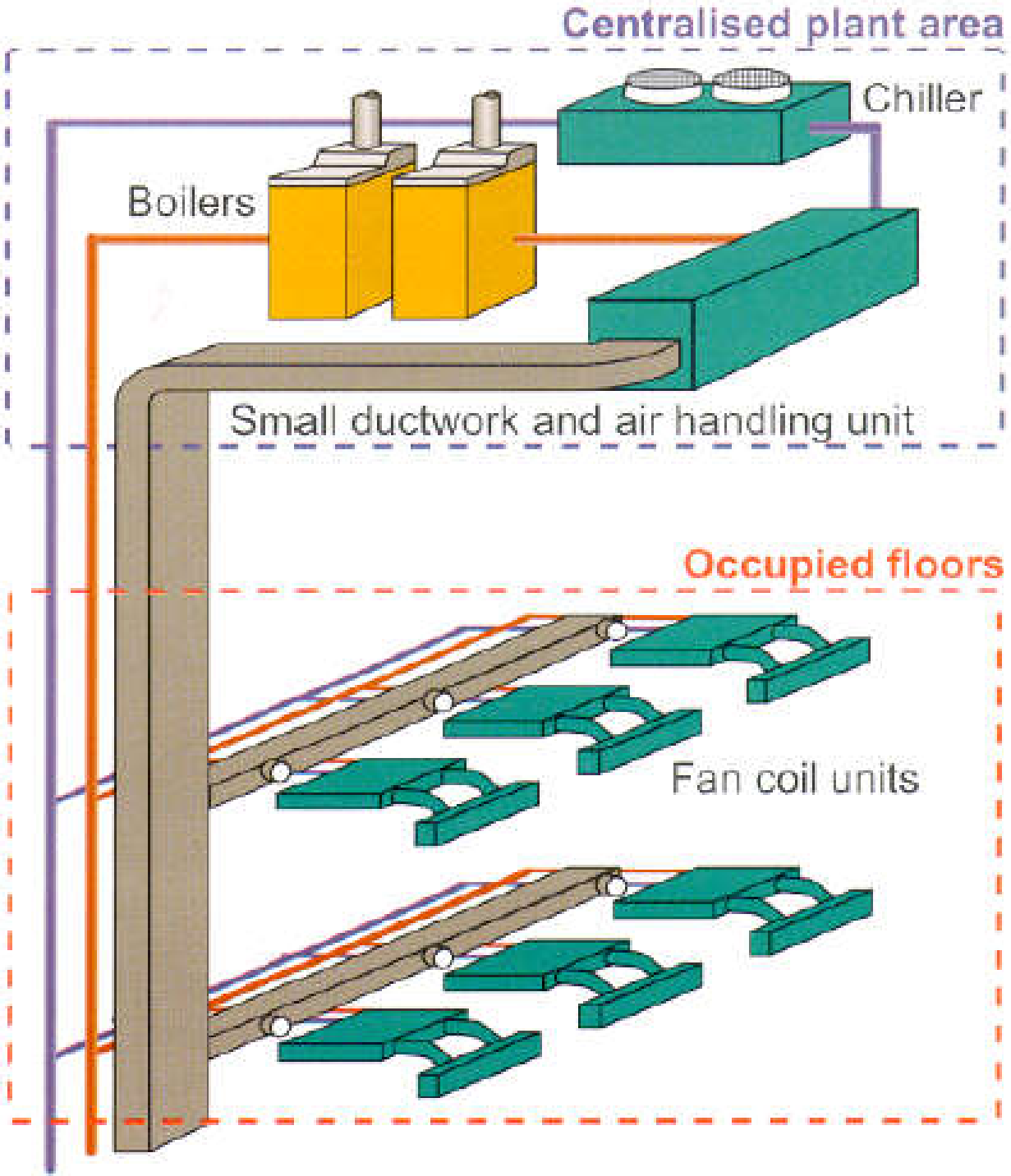
- Classification of HVAC systems -- three generic types of systems:
  - Centralised all air systems
    - Such as CAV (constant air volume), VAV (variable air volume), dual duct, multizone
  - Partially centralised air/water systems
    - Such as FCU (fan coil unit), induction units
  - Local systems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

Centralised air system *(VAV example)*

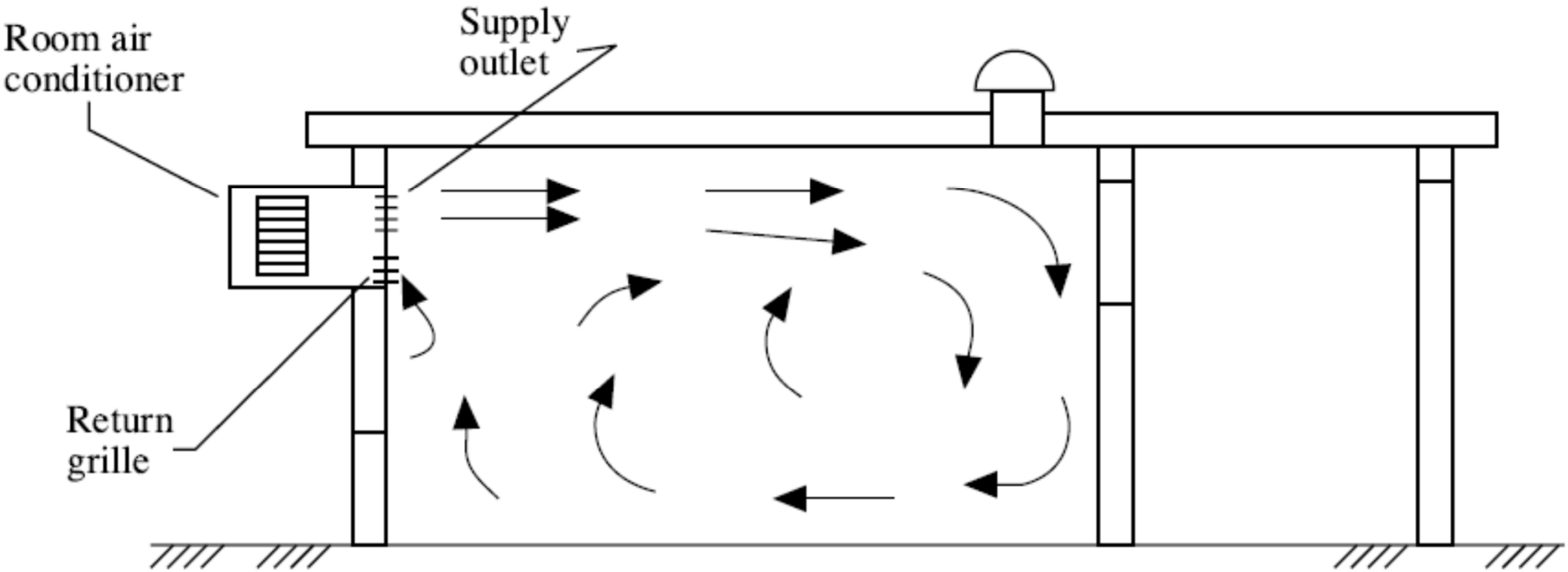


Partially centralised air/water system

(Fan coil example)

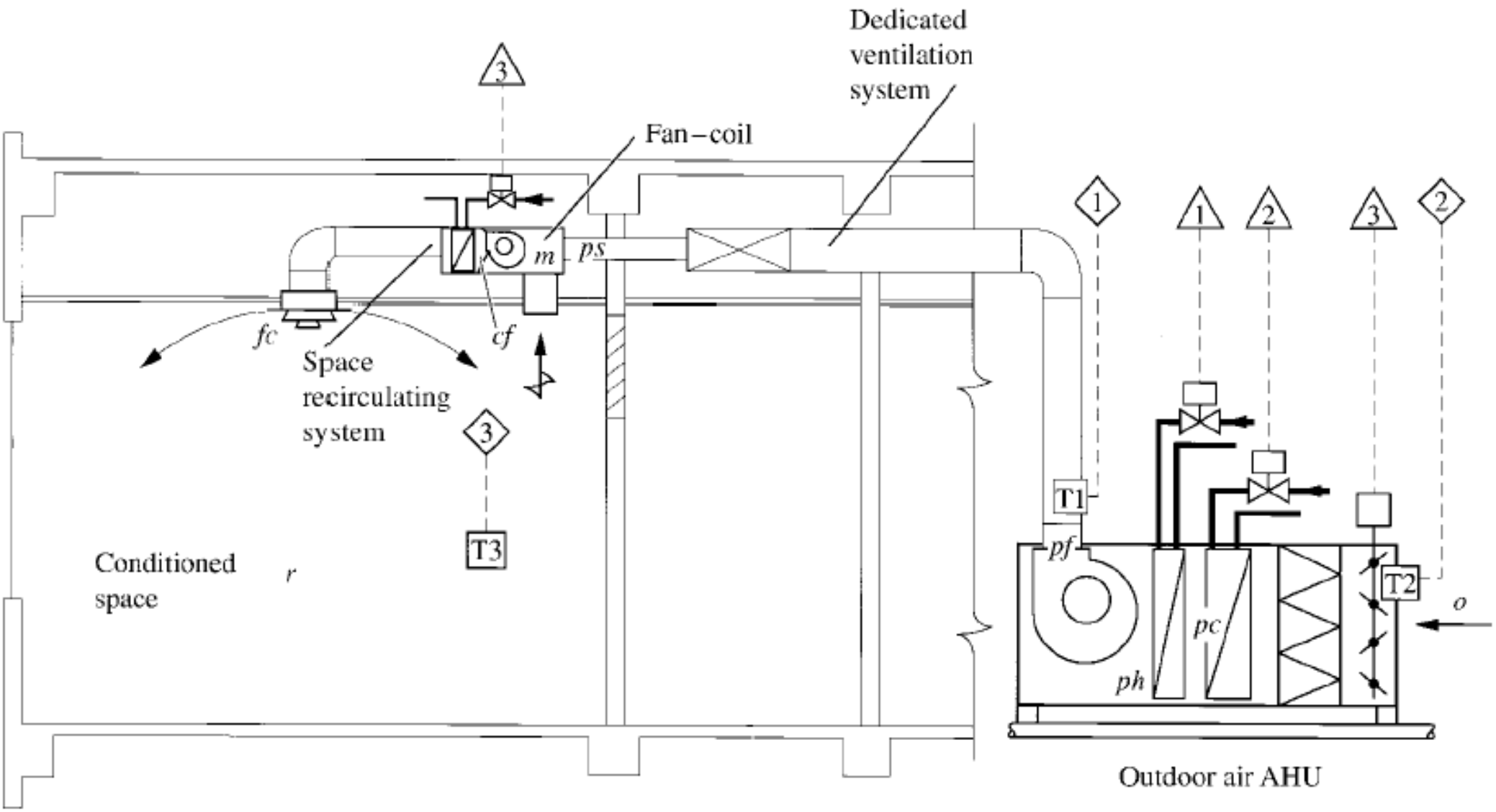


An individual room air-conditioning system



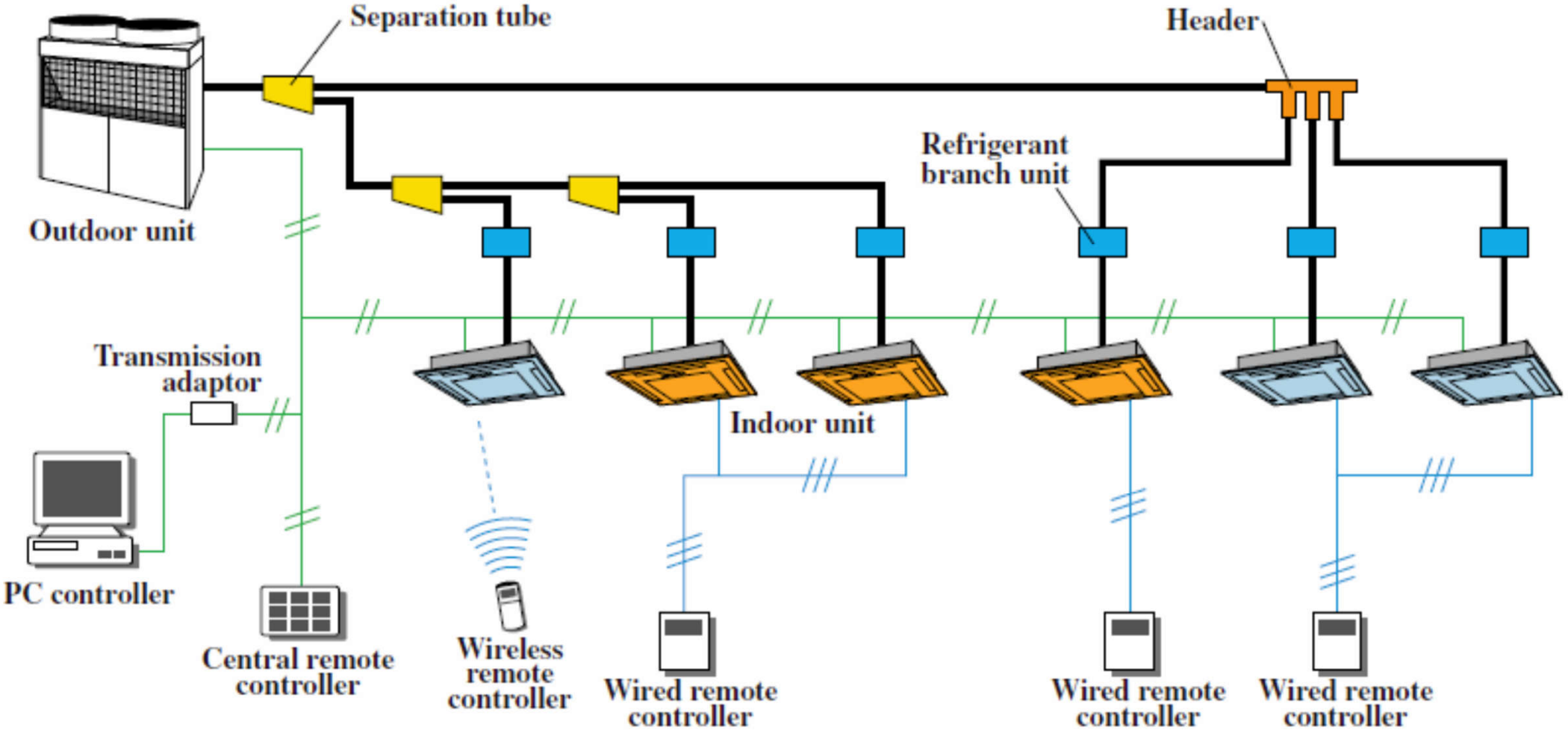
(Source: Wang, S. K., Lavan, Z. and Norton, P., 2000. *Air Conditioning and Refrigeration Engineering*)

Primary air fan coil unit (PA-FCU) system



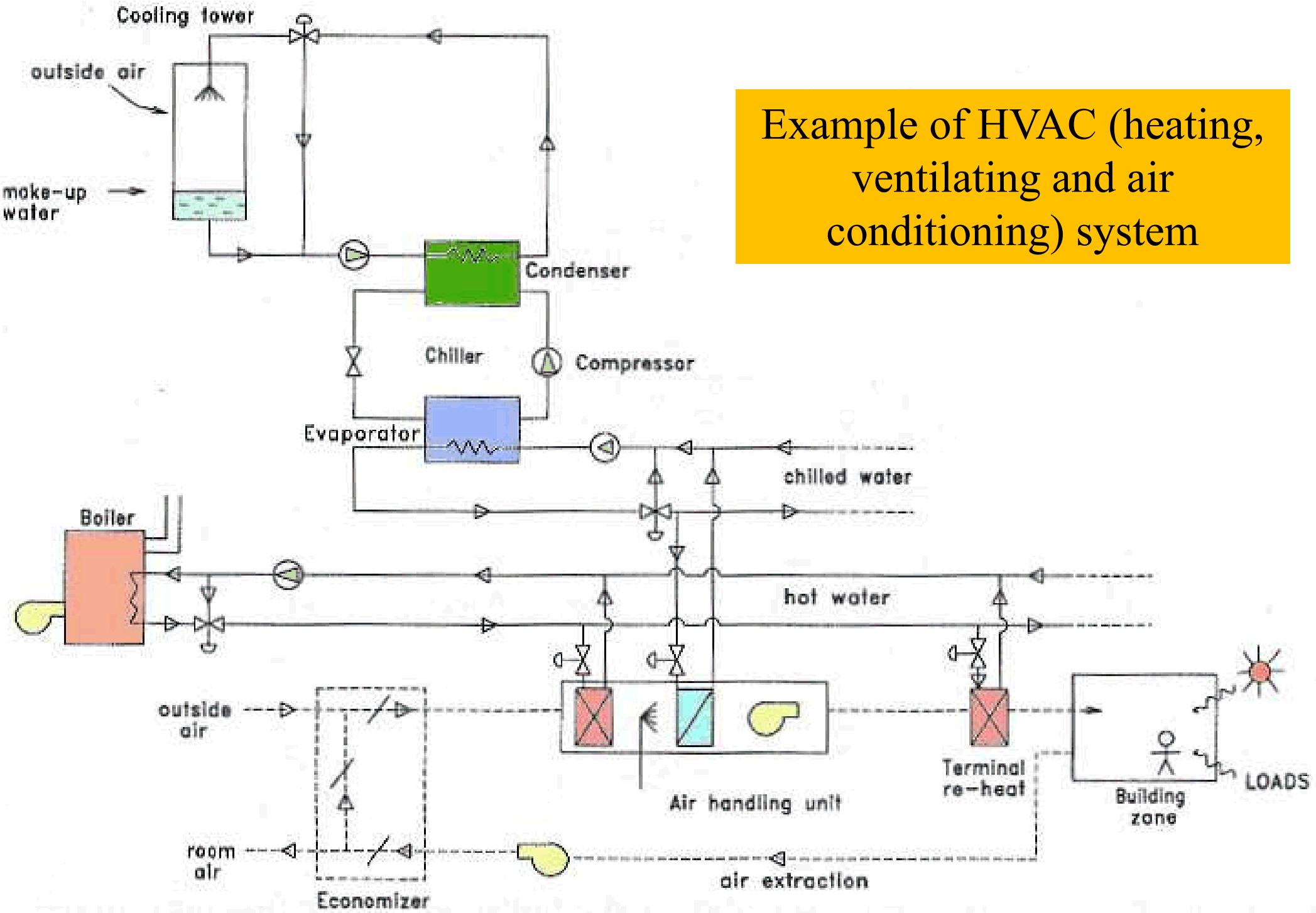
(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.)

Variable refrigerant flow (VRF) system

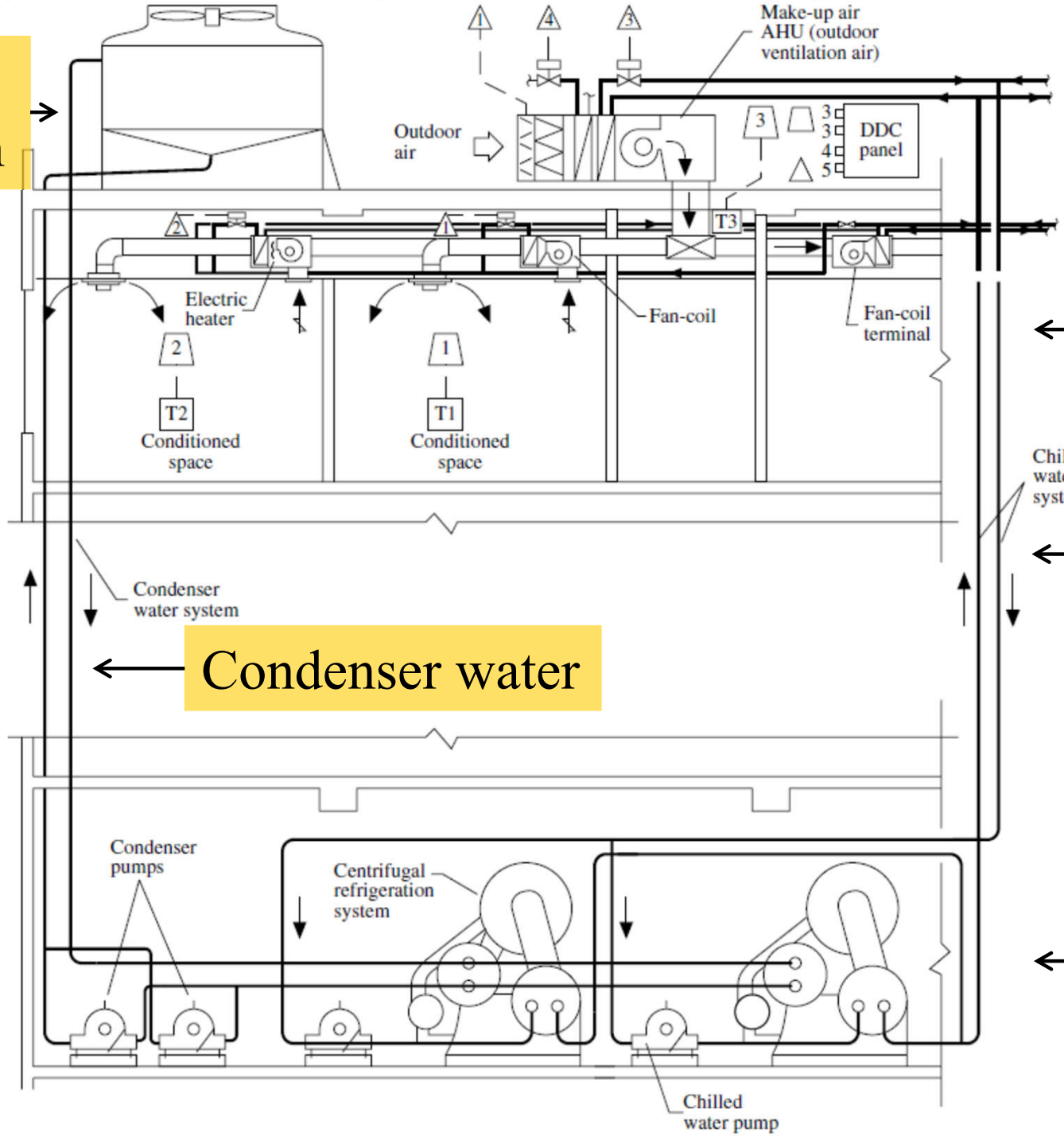


(Source: Fujitsu) (See also: http://en.wikipedia.org/wiki/Variable_refrigerant_flow)

Example of HVAC (heating, ventilating and air conditioning) system



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



Heat rejection

Air side

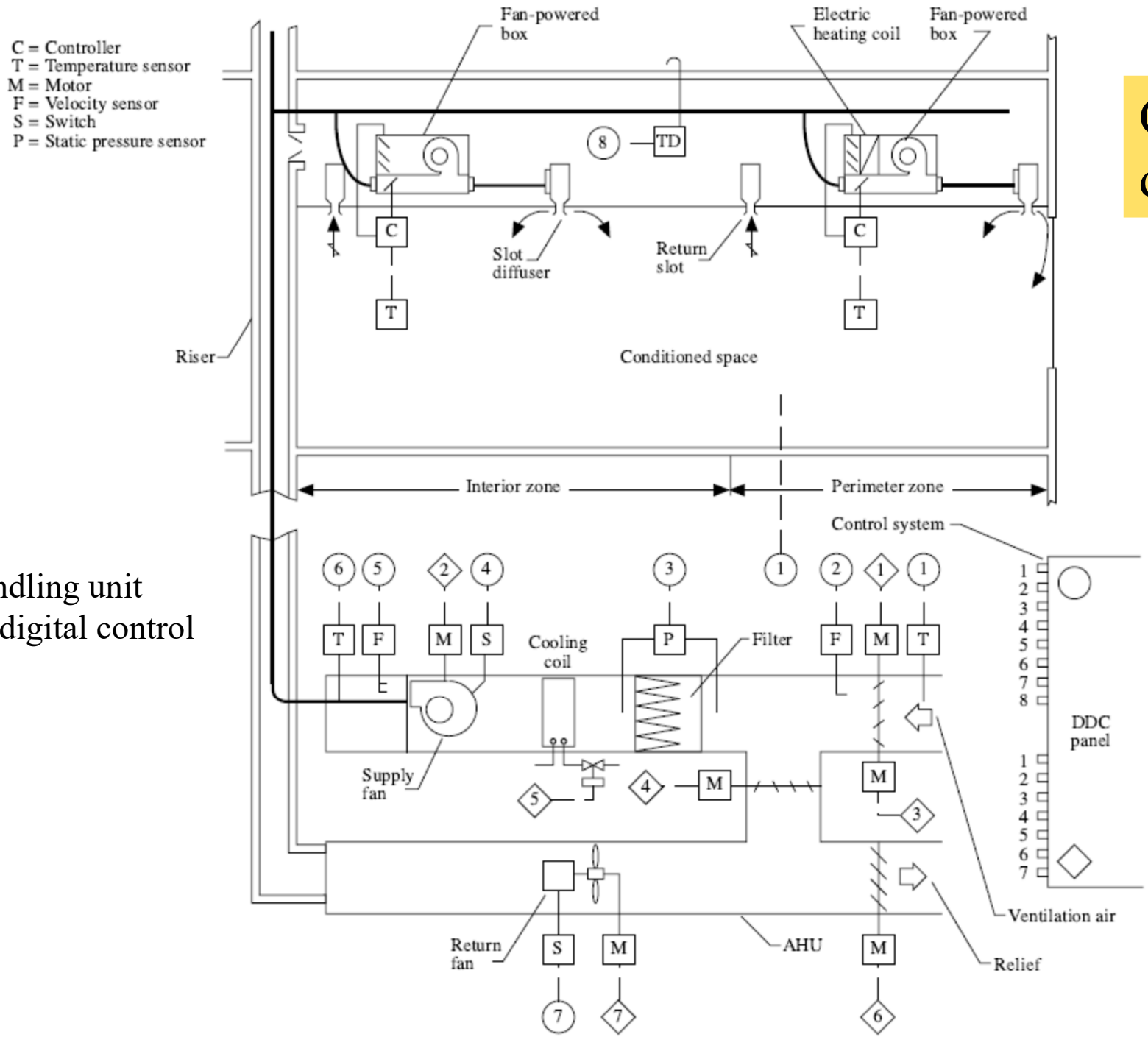
Chilled water

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

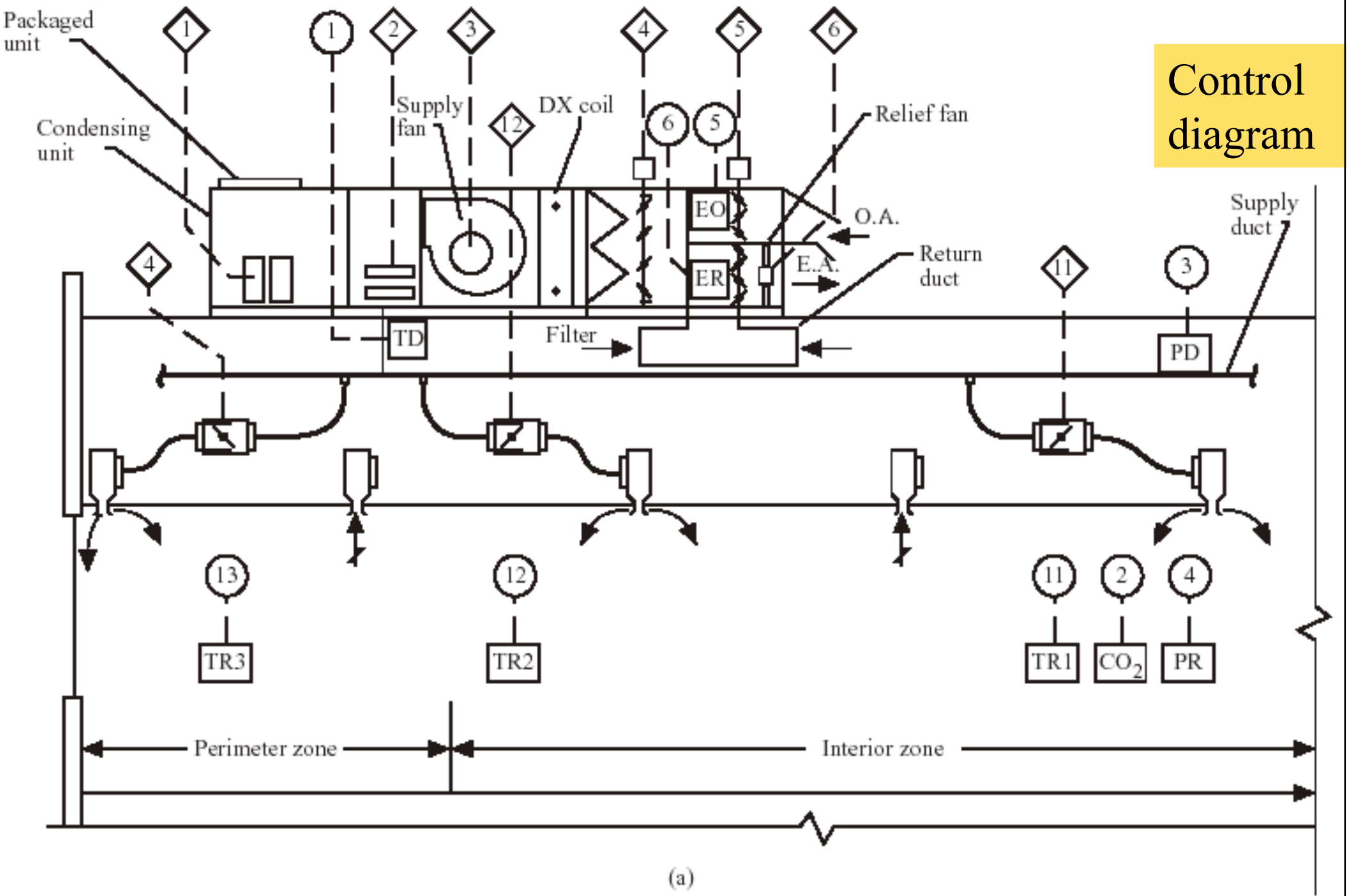


Control diagram

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)

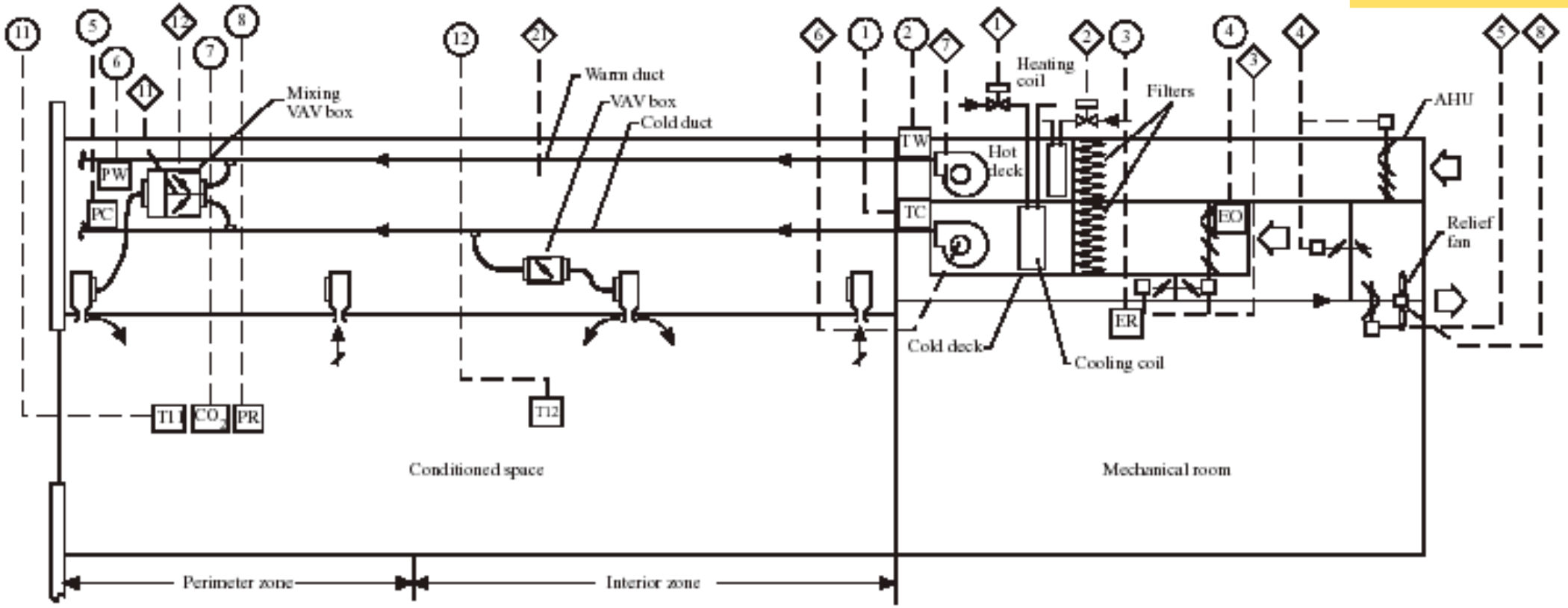


Control diagram

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

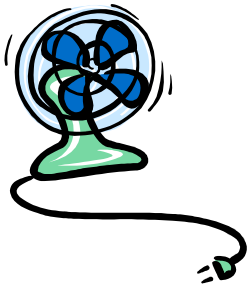
A dual-duct VAV central system

Control diagram

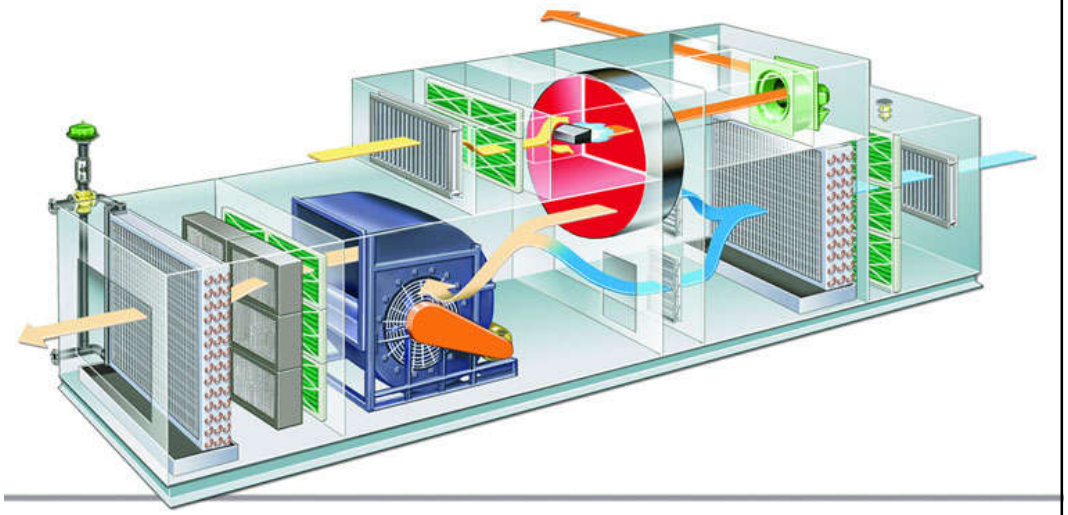


(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.)

Air-side systems

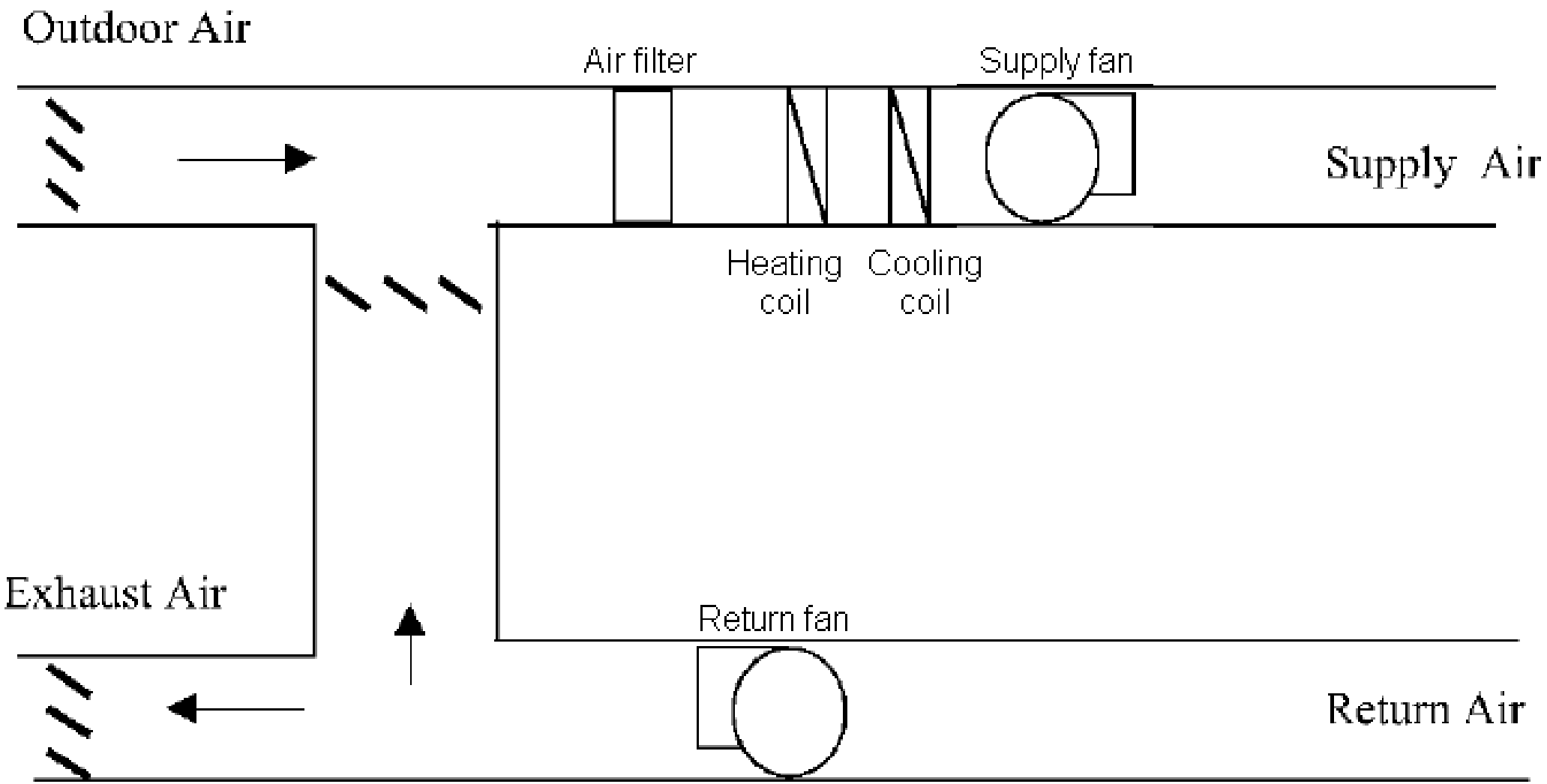


- Main components of air handling unit (AHU)
  - Casing
  - Fans
  - Coils
  - Filters
  - Humidifiers (optional)

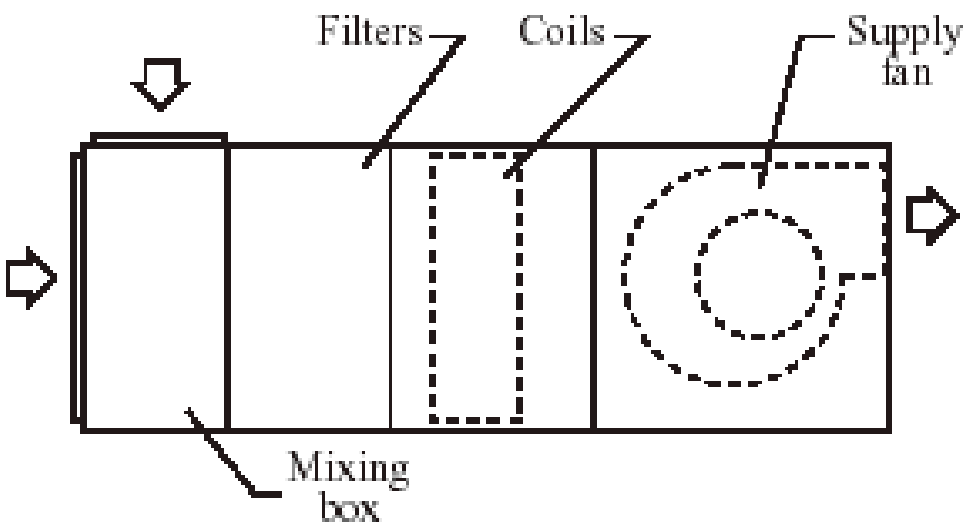


  - Outdoor air intake, mixing & exhaust section
  - Controls

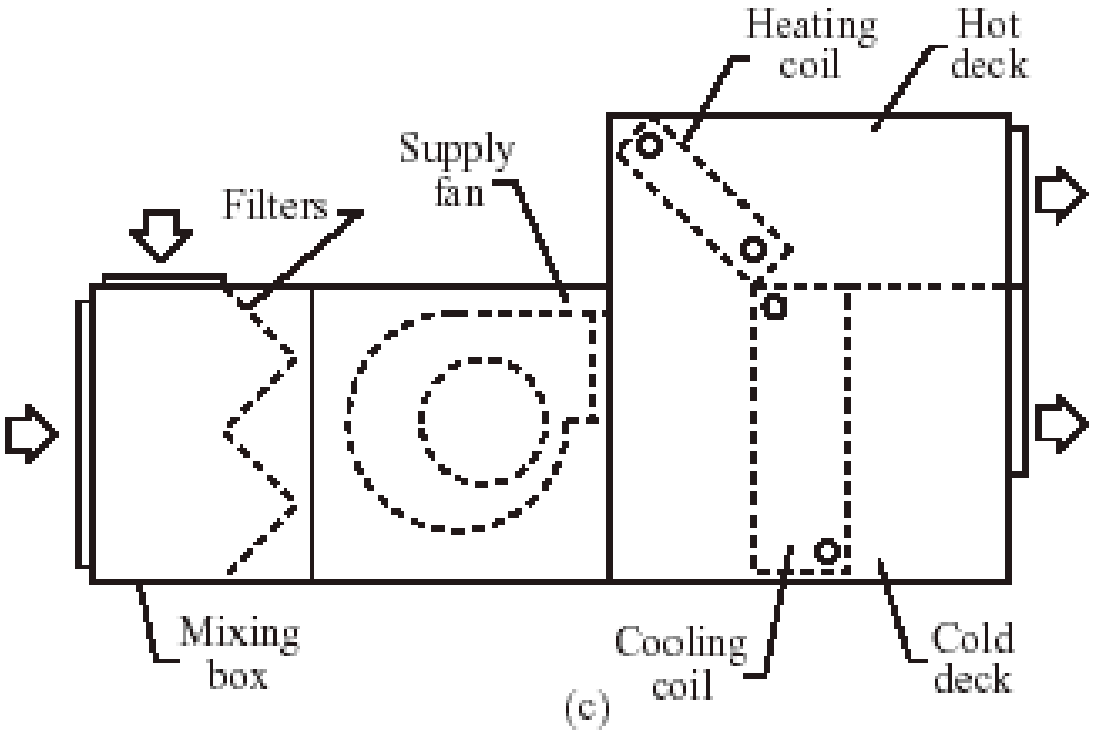
Simple air-handling unit (AHU)



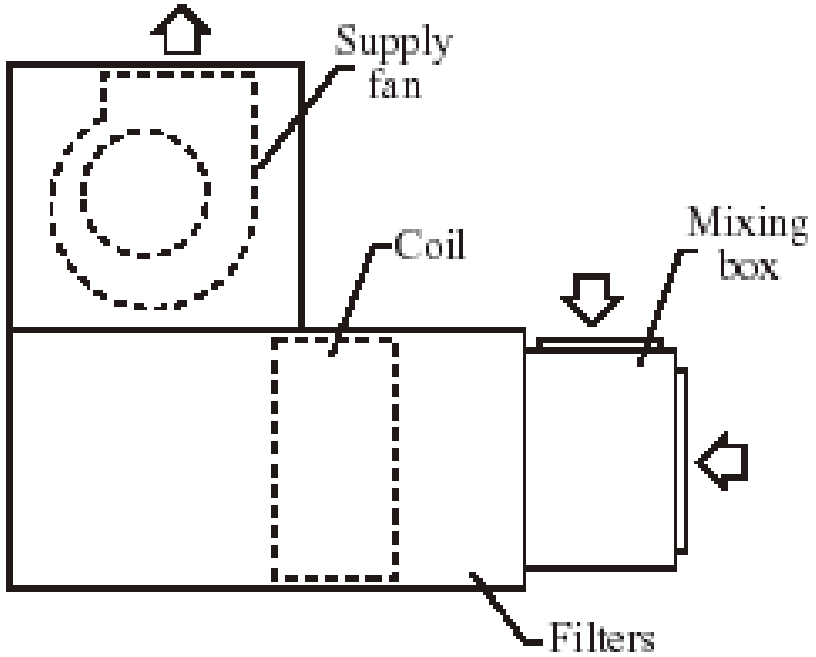
Example of an air-handling unit (modular type)



(a)



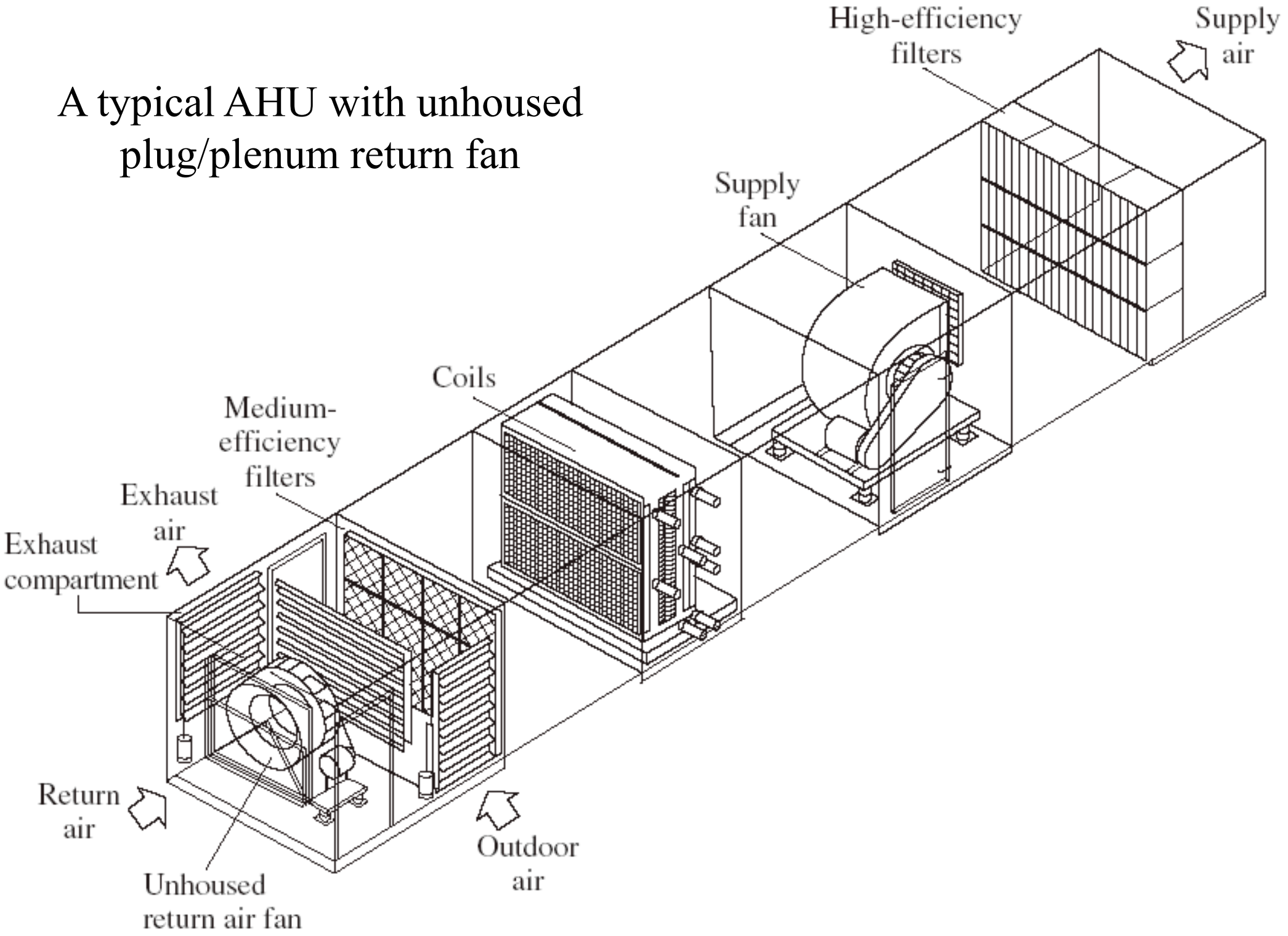
(c)



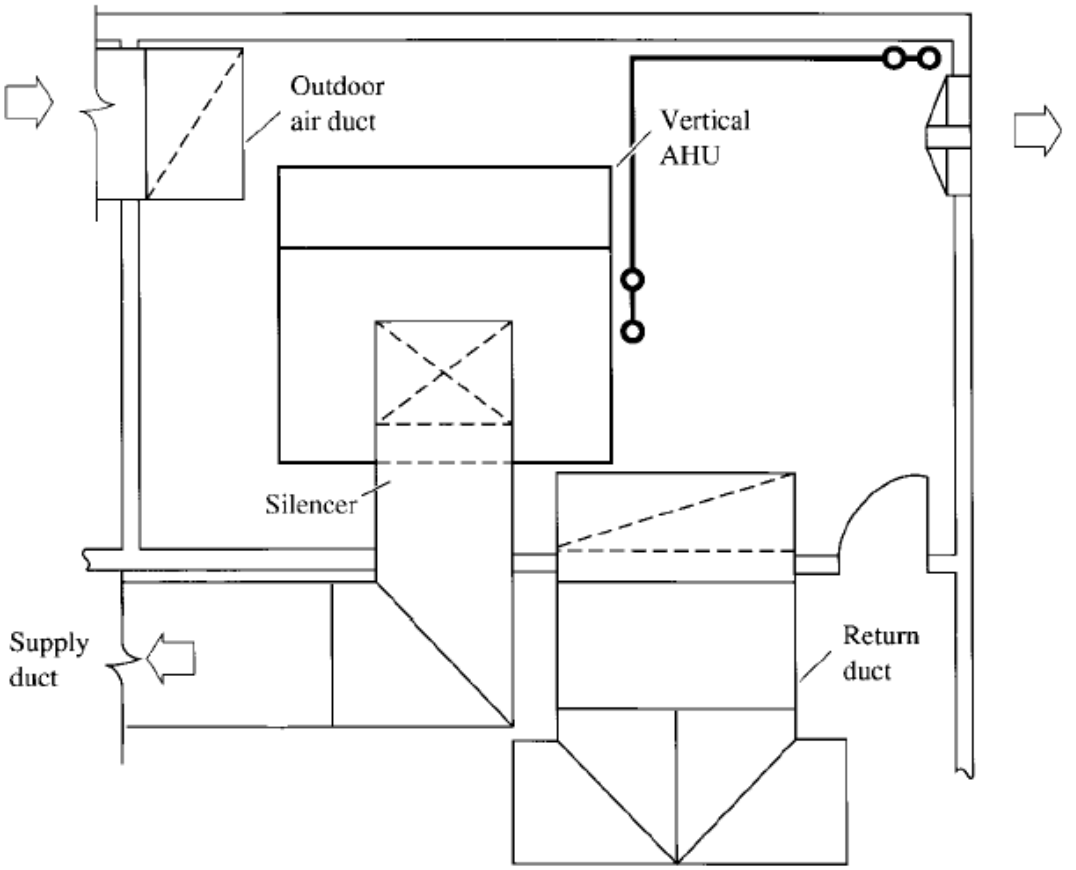
(b)

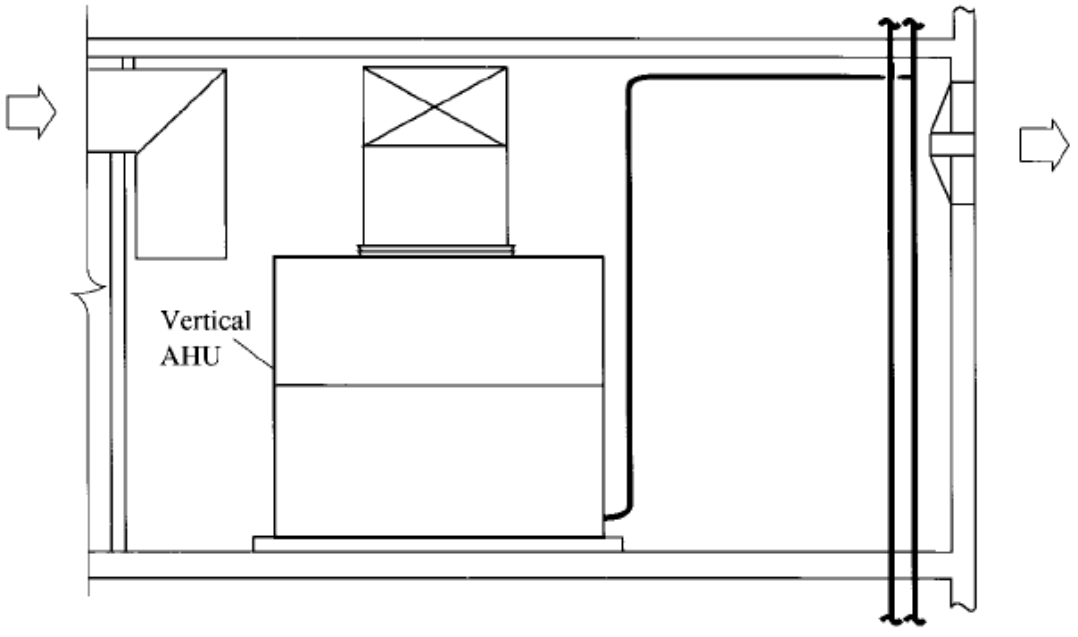
FIGURE 9.7.1 Type of air handling units: (a) horizontal draw-through unit, (b) vertical draw-through unit, and (c) multizone blow-through unit.

A typical AHU with unhoused plug/plenum return fan

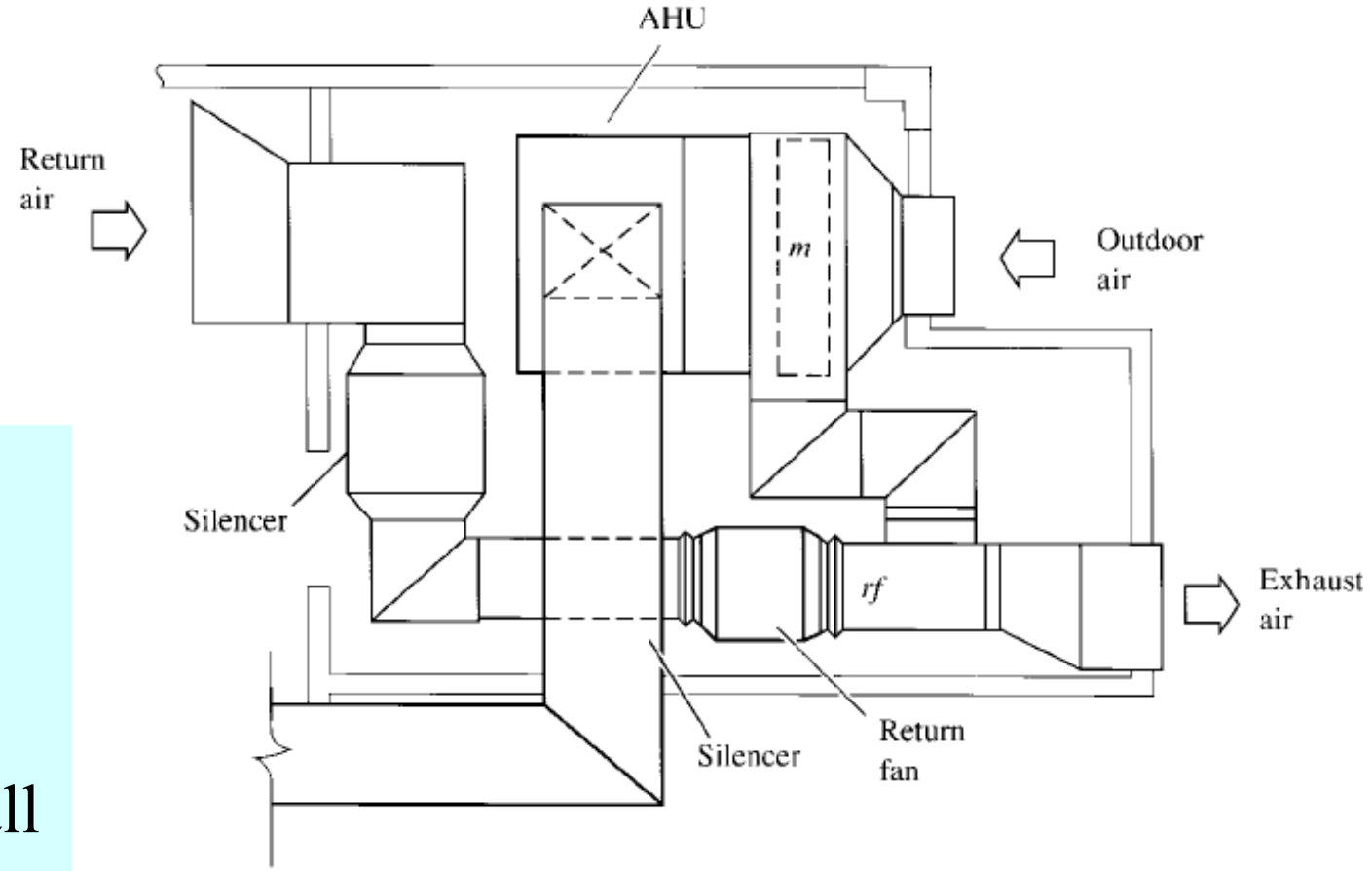


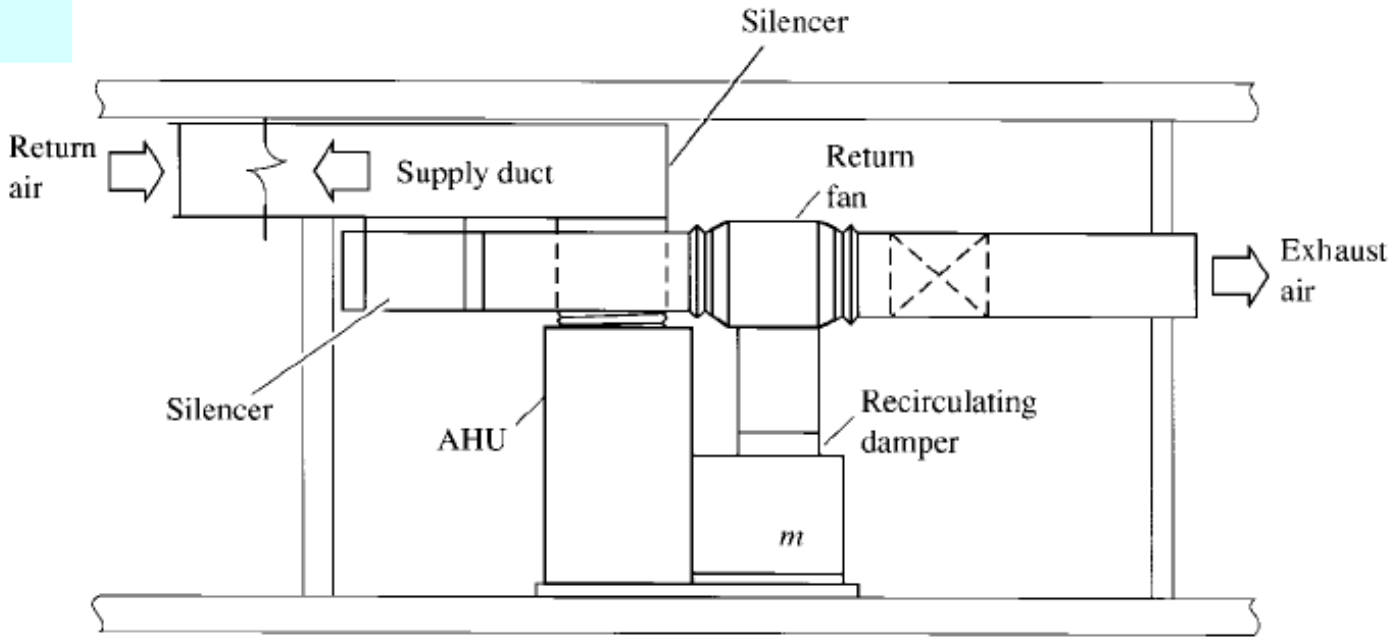
Open
Fan Room
(fan room become the mixing box)



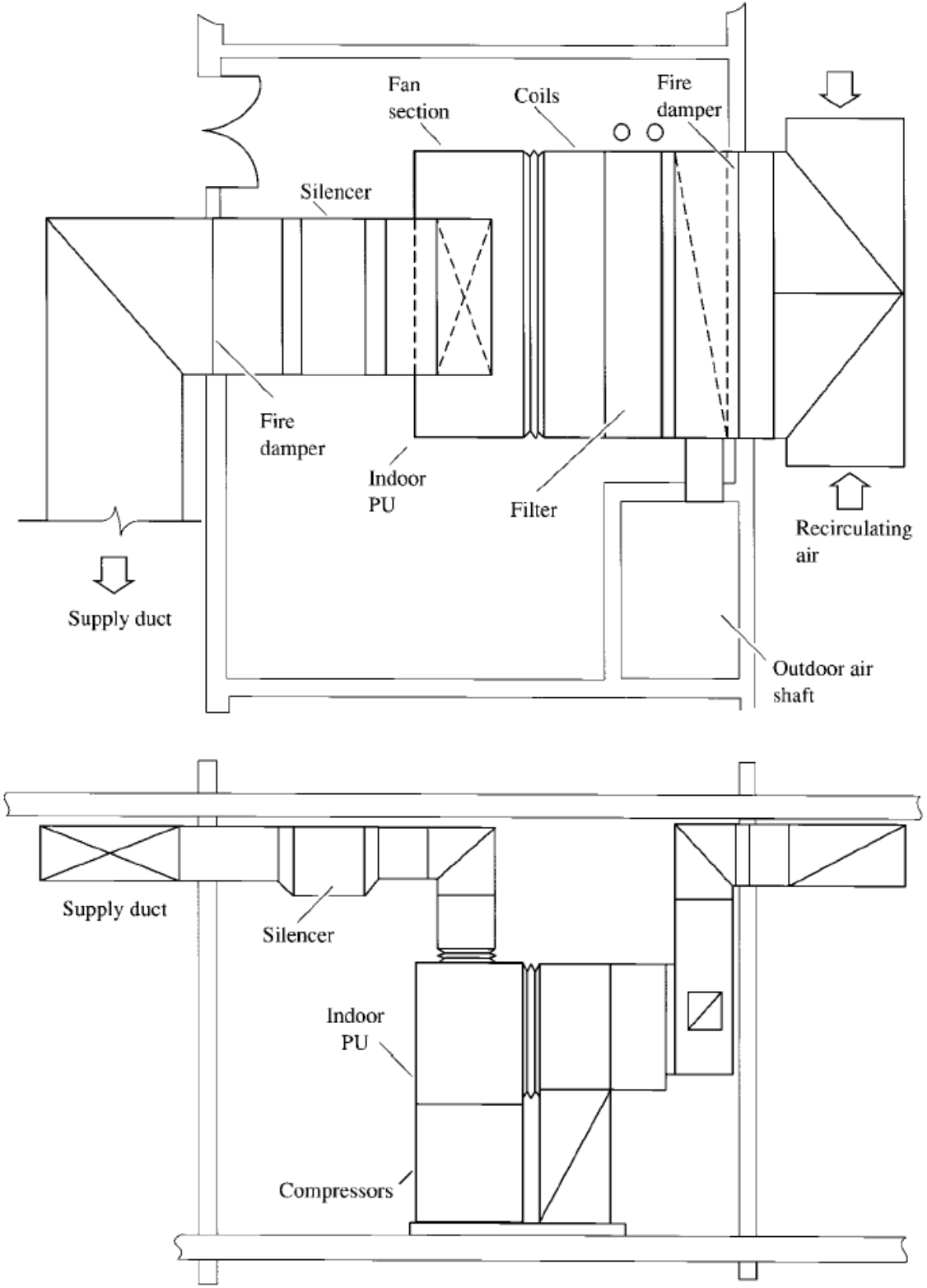


Isolated Fan Room
(outdoor air, return air & exhaust air are all in ductwork)



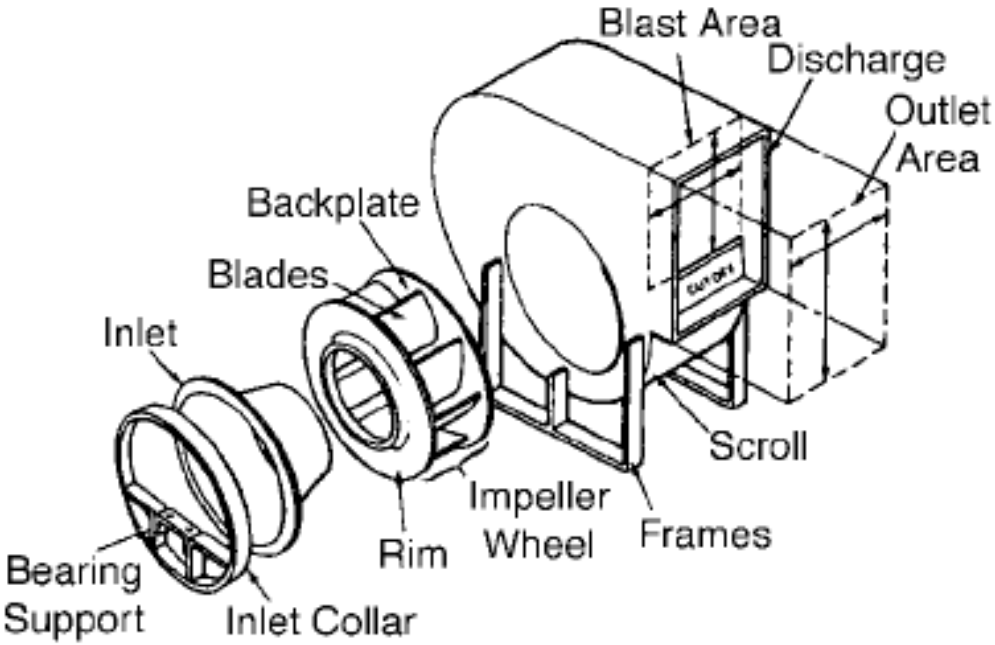


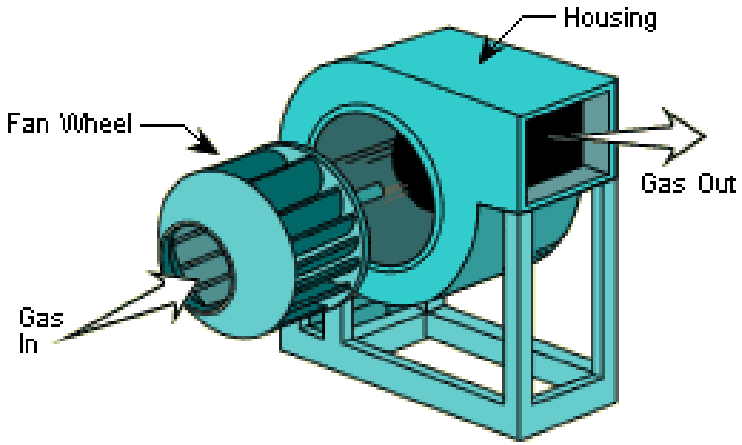
Interior Core Fan Room
(for an indoor package unit)



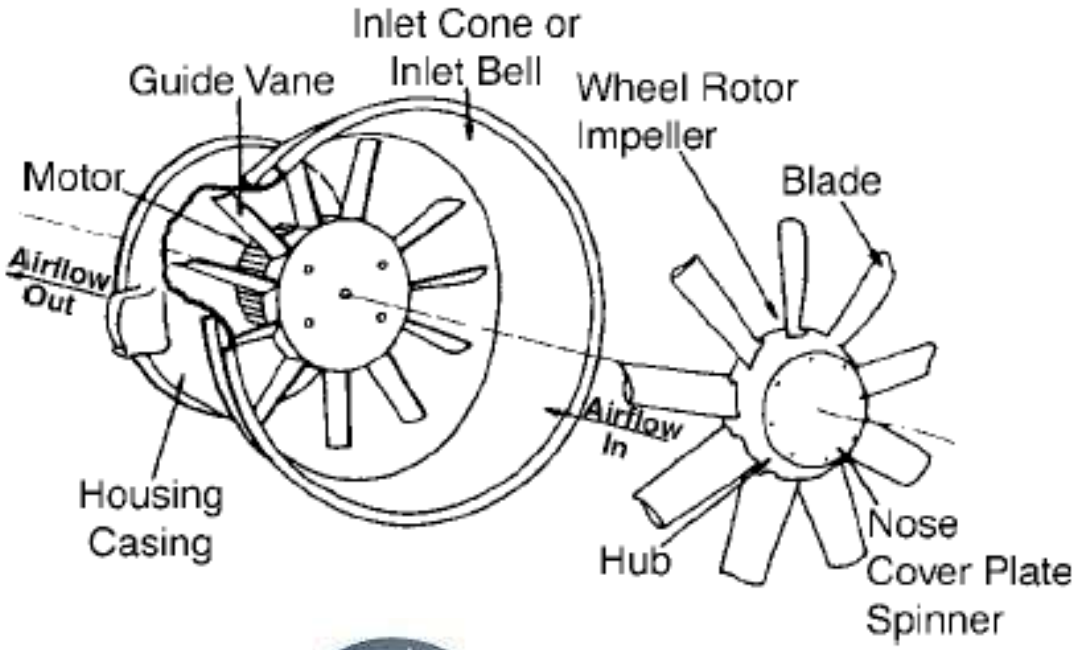
Centrifugal and axial fan components

CENTRIFUGAL FANS



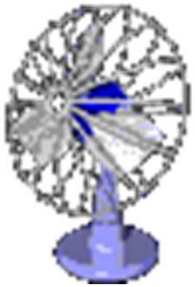


AXIAL FANS



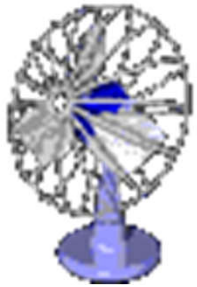
[Source: Kreider, K. F. (ed.), 2001. *Handbook of Heating, Ventilation, and Air Conditioning*, CRC Press, Boca Raton, FL.]

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)

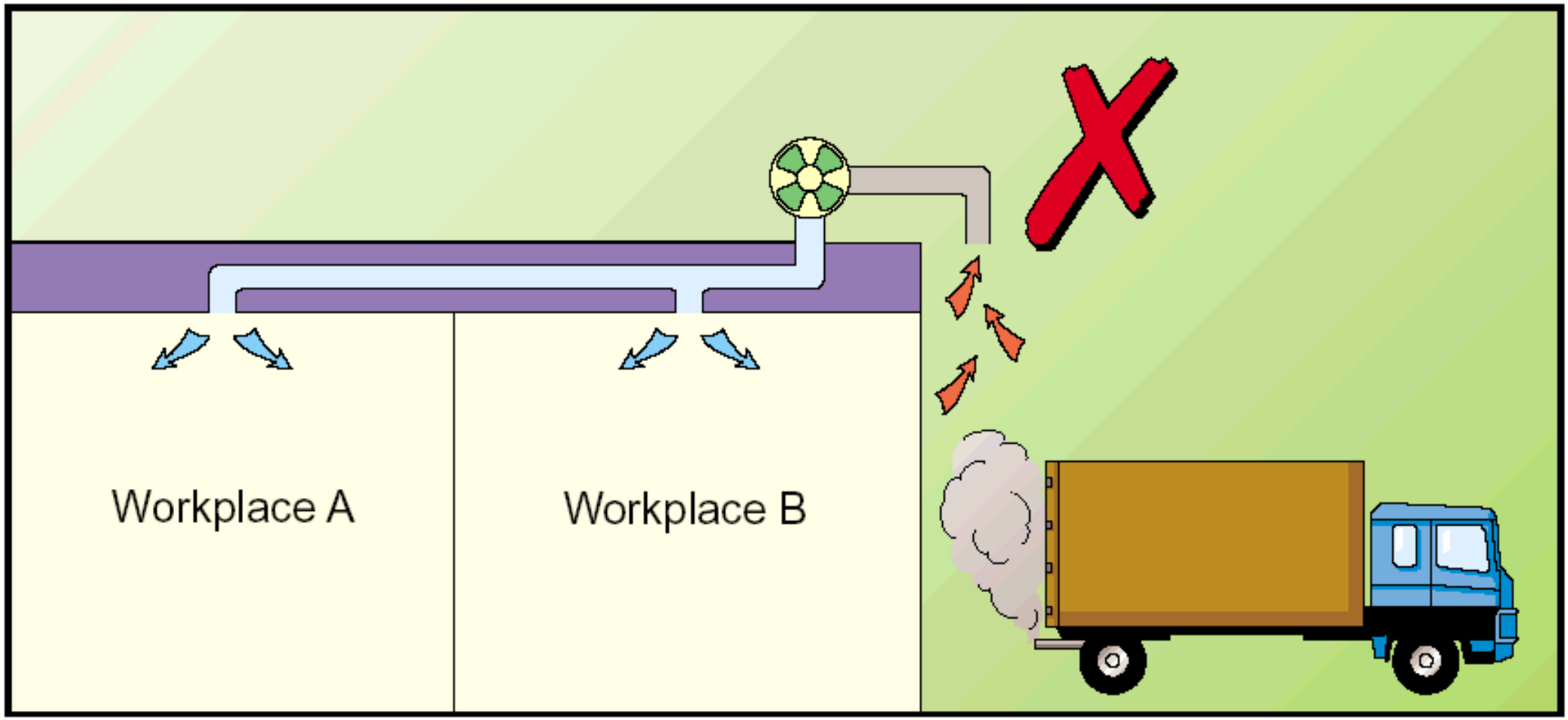
Ventilation systems



- 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)

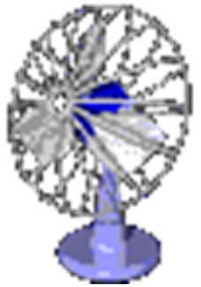
Ventilation system design should avoid intake of vehicle exhaust



* Also ensure outdoor air intake is of adequate quality

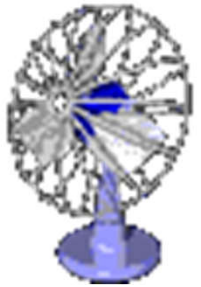
(Source: Environmental Protection Department)

Ventilation systems



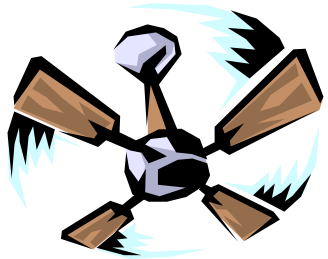
- Ventilation calculations
  - For general mechanical ventilation:
    - Ventilation Rate (m^3/h) = Air Change Rate (/h) x Room Volume (m^3)
      - Ventilation Rate (m^3/s) = Ventilation Rate (m^3/h) / 3600
  - For calculating fresh air ventilation rates
    - Fresh air rate (m^3/s) = Fresh air rate per person (l/s/p) x number of occupants
- Ventilation effectiveness
  - Depend on ventilation strategy, air distribution method, room load & air filtration

Ventilation systems

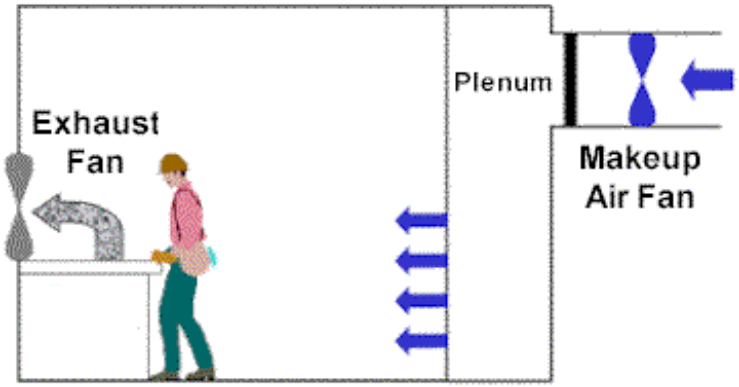


- Determine the required ventilation rate (Q):
  - (a) Maximum allowable concentration of contaminants (C_i)
    - $C_i = C_o + F / Q$
  - (b) Heat generation inside the space (H)
    - $Q = H / [c_p \times \rho \times (T_i - T_o)]$
  - (c) Air change rates (ACH)
    - $Q = V \times ACH / 3.6$

Ventilation systems

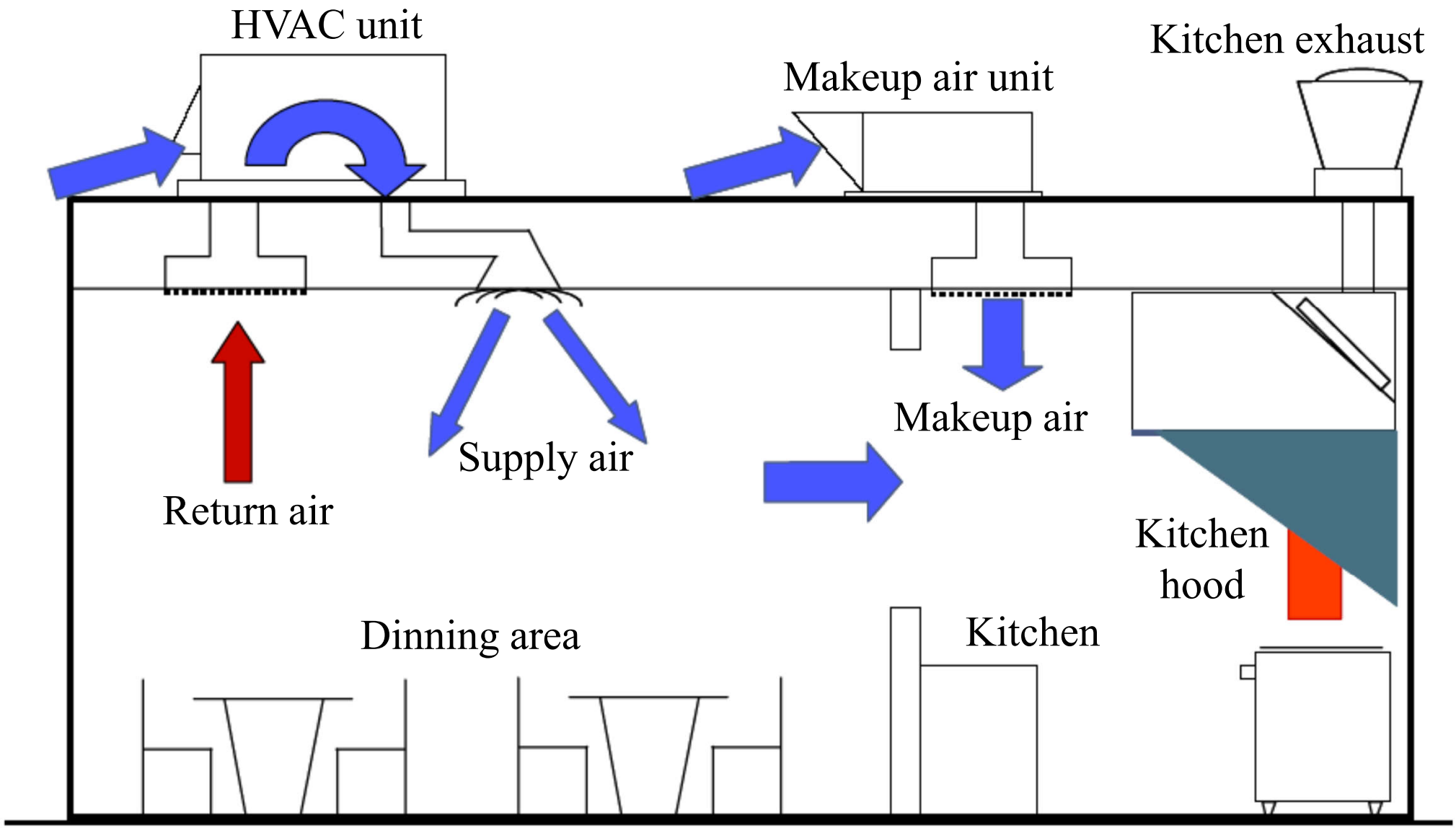


- Extract ventilation, e.g.
  - Commercial kitchens
  - Toilets and bathrooms
  - Underground carparks
  - Factories or industrial buildings
  - Localised industrial extraction

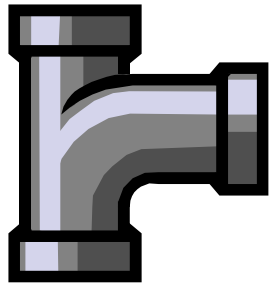


- Supply ventilation
  - Can be used to ensure adequate supply of outside air, e.g. in boiler house ventilation

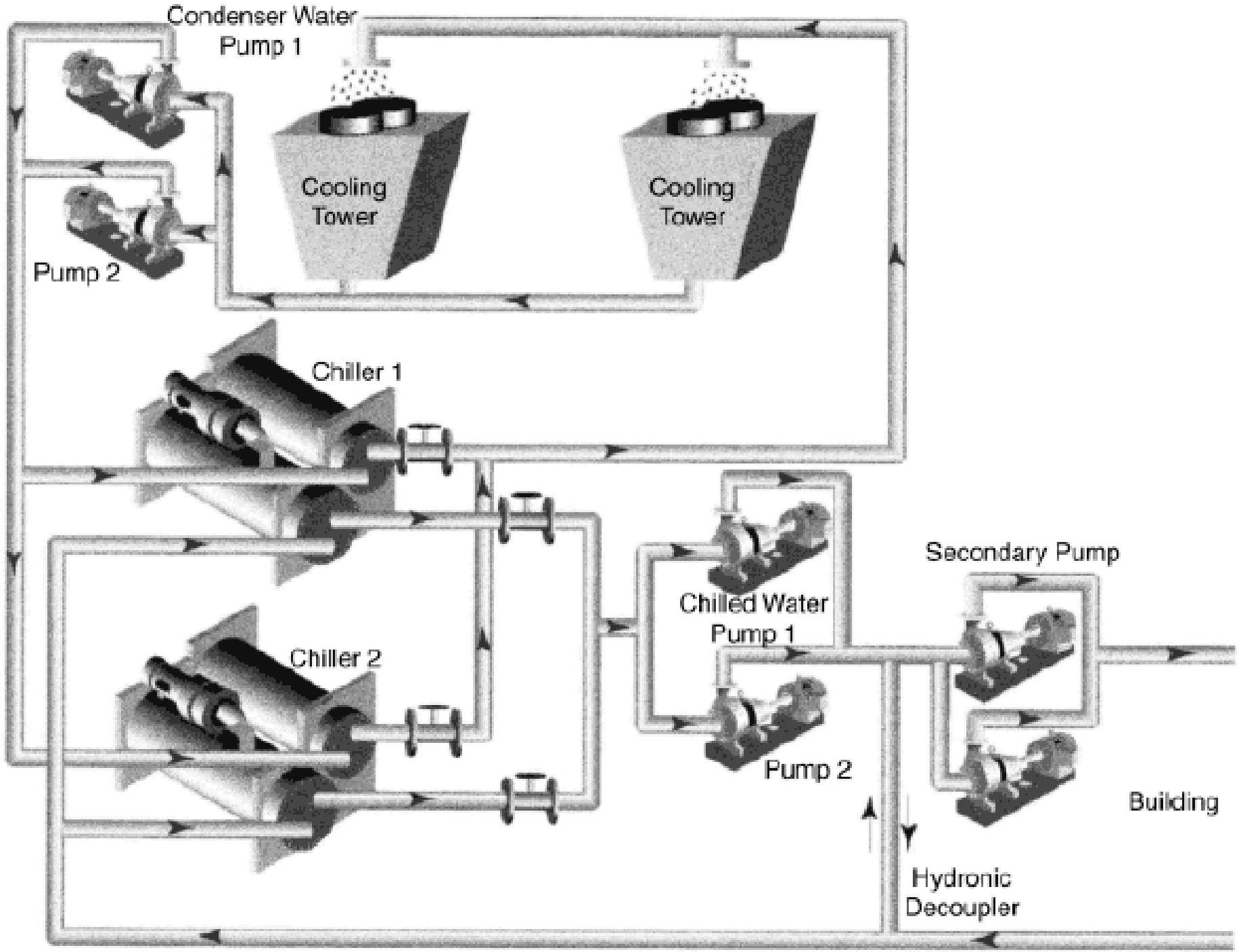
Example of kitchen ventilation system



Water-side systems



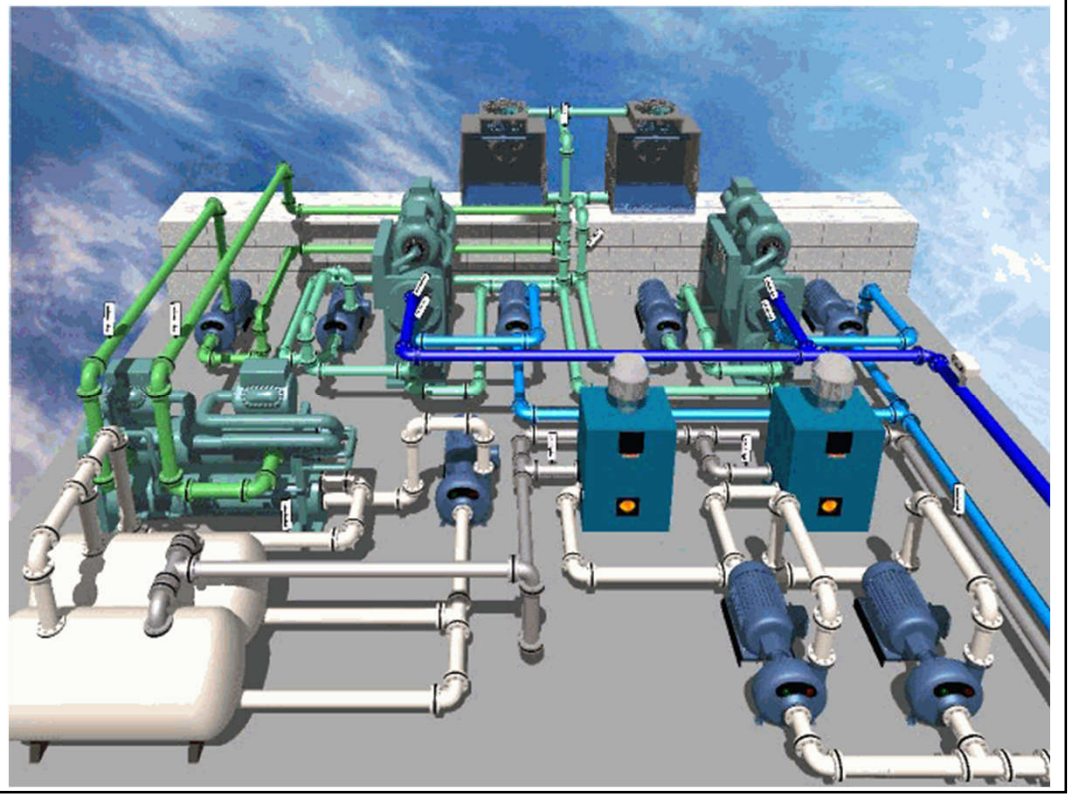
- Common types of HVAC piping systems
  - Chilled water (CHW) system
  - Condenser water (CW) system
  - Sea water system
  - Hot water supply system
  - Steam pipes, gas pipes
- Similar systems in other building services
  - Water supply & distribution (plumbing)



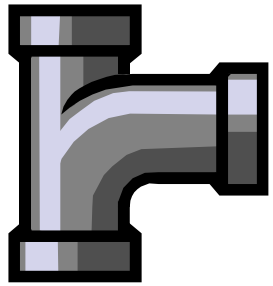
[Source: Kreider, K. F. (ed.), 2001. *Handbook of Heating, Ventilation, and Air Conditioning*, CRC Press, Boca Raton, FL.]

Water-side systems

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

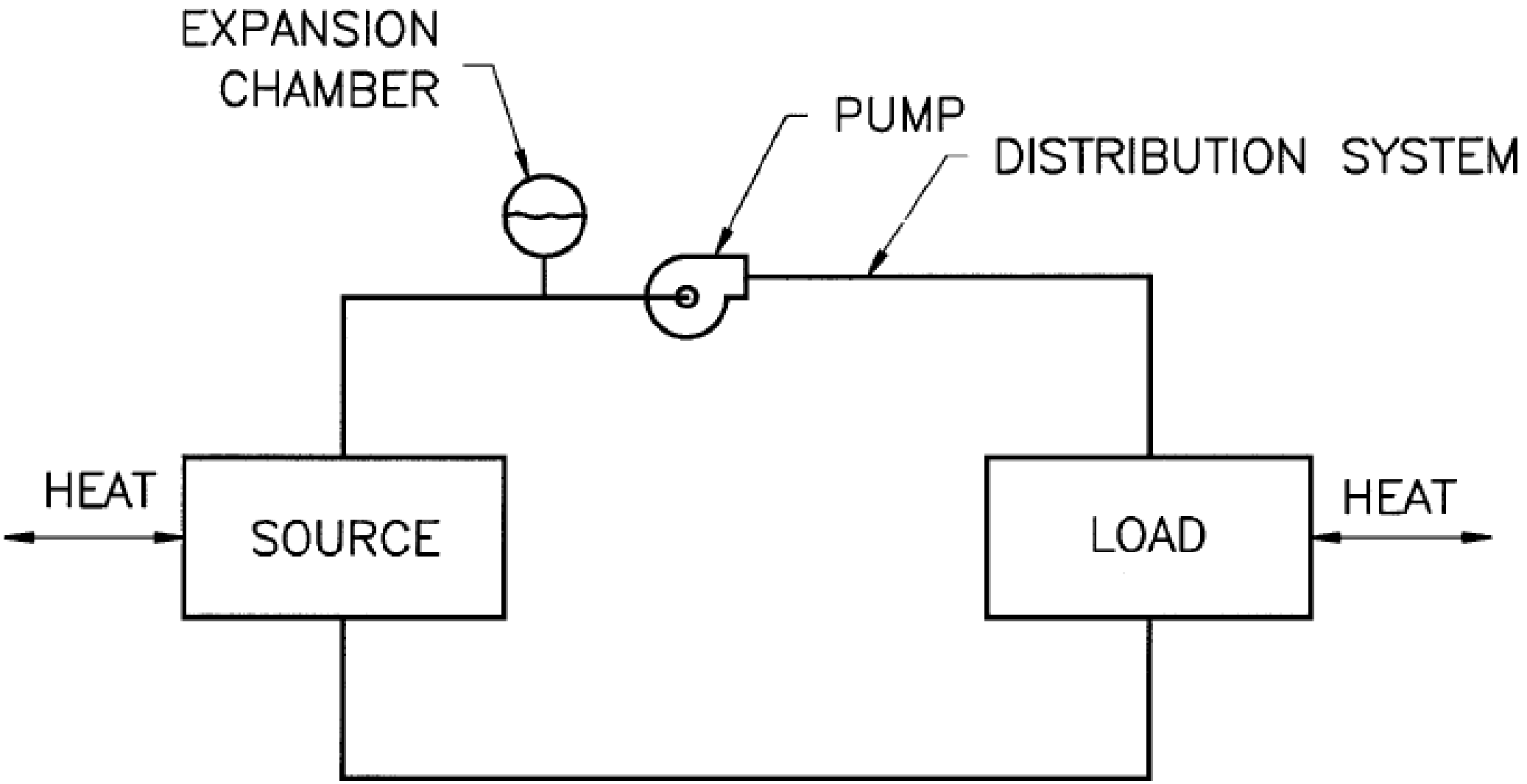


Water-side systems



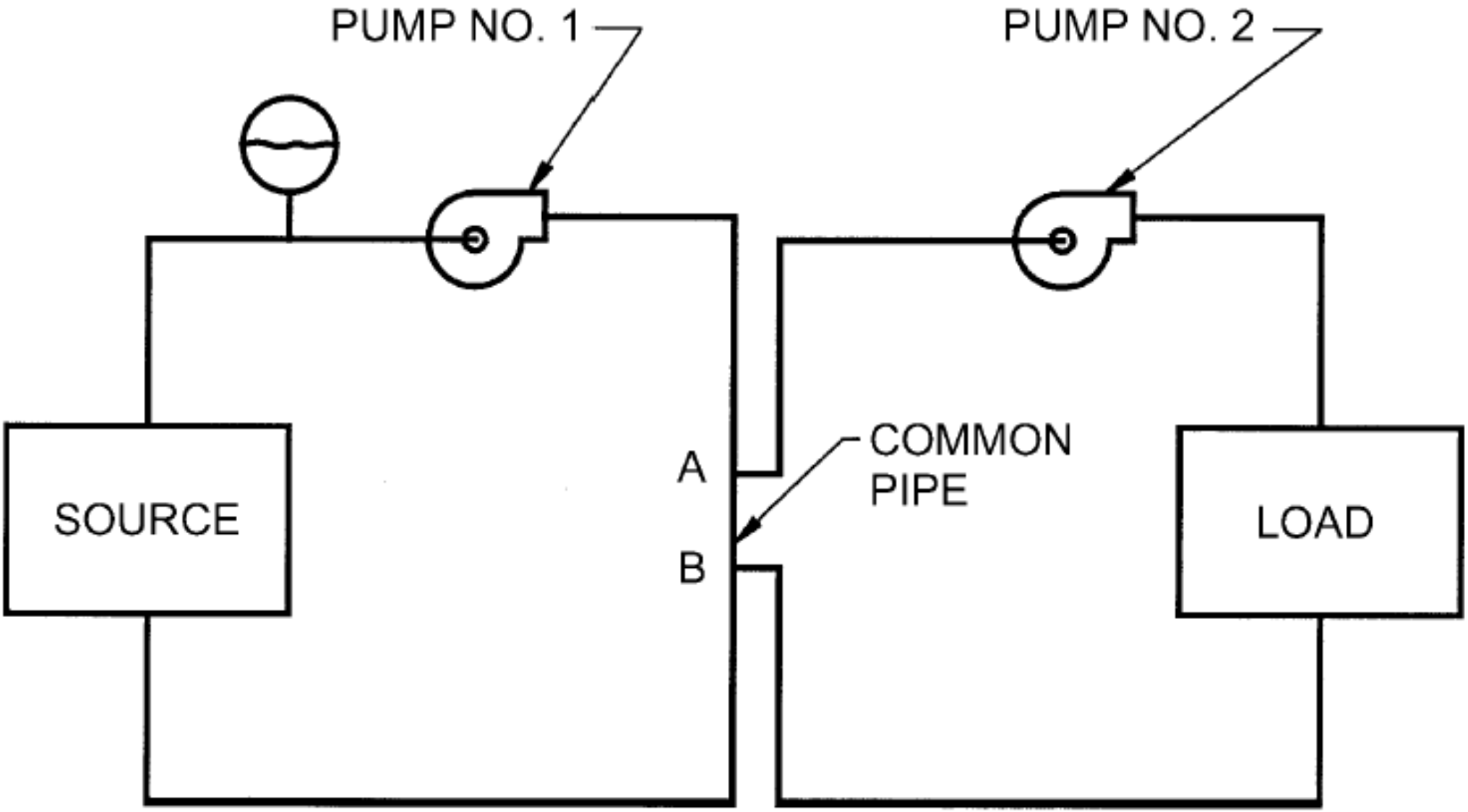
- Open water systems, e.g. using cooling tower
- Closed water systems
  - Chilled water (CHW) system [4-13 °C, 825 kPa]
  - Condenser water (CW) system
  - Dual temperature water system
  - Low temp. water (LTW) system [Max. 120 °C, < 1100 kPa]
  - Medium temp. water (MTW) system [120-125 °C, < 1100 kPa]
  - High temp. water (HTW) system [> 175 °C, > 2070 kPa]
- Once-through system, e.g. sea water system

Basic components of water (hydronic) system



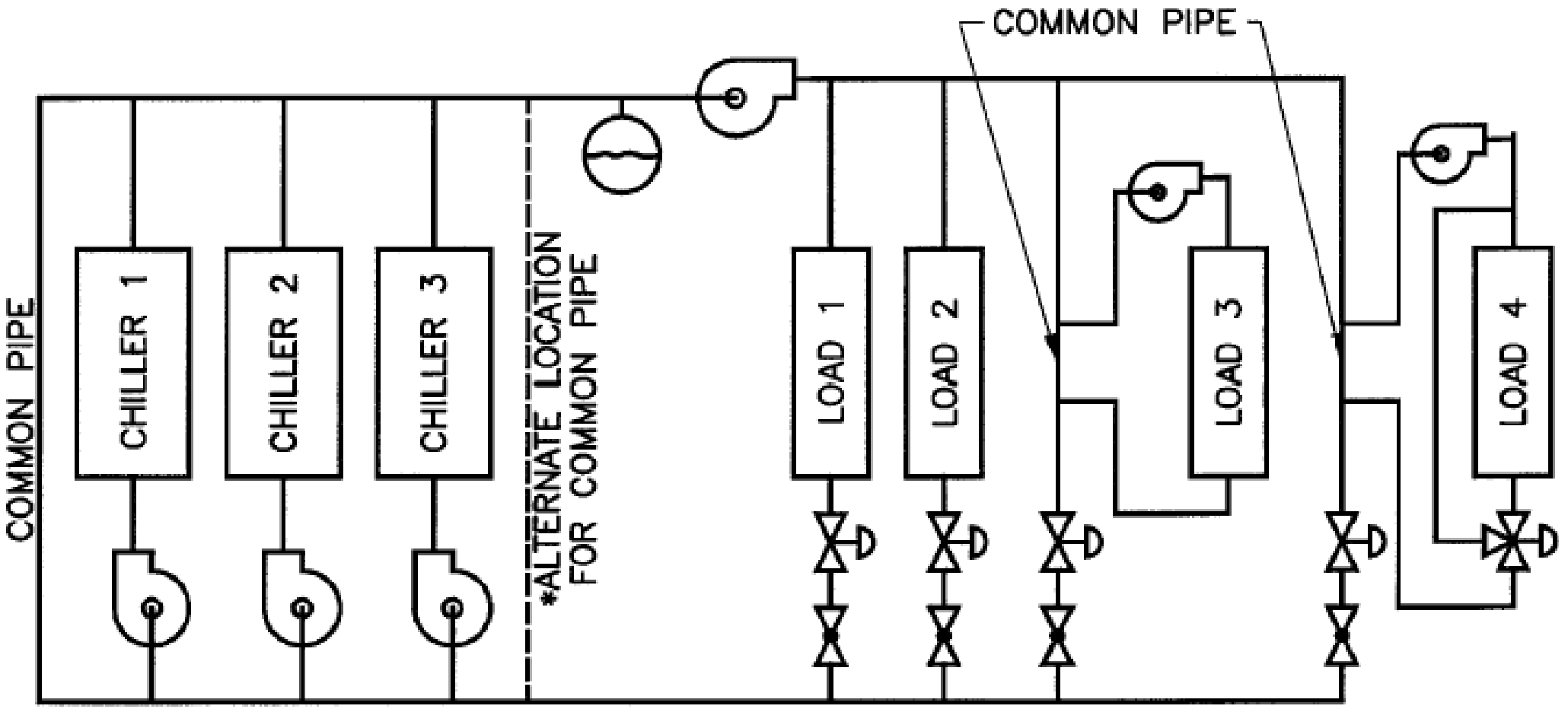
(Source: *ASHRAE HVAC Systems and Equipment Handbook 2004*)

Primary-secondary loop and pumping



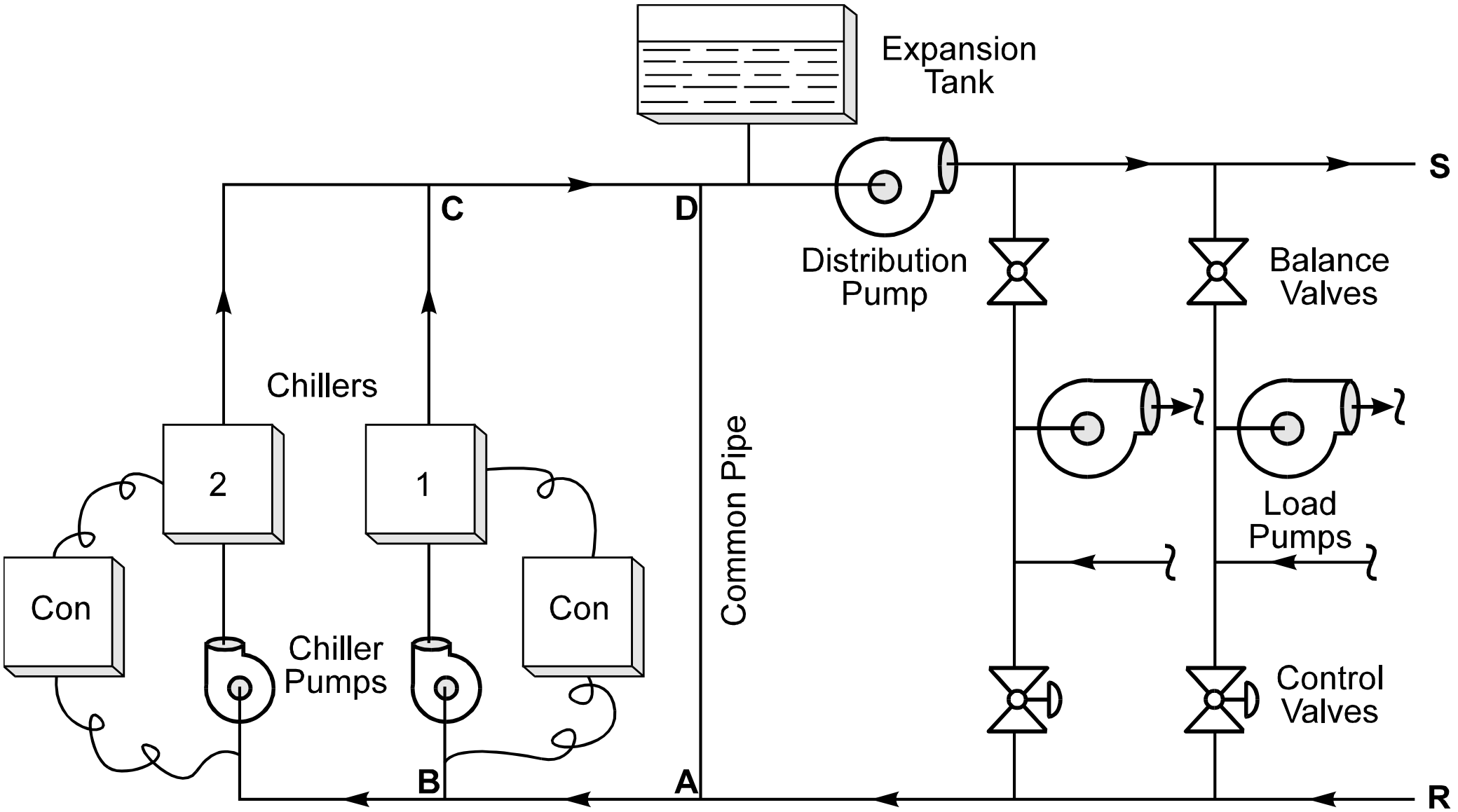
(Source: *ASHRAE HVAC Systems and Equipment Handbook 2004*)

Multiple chiller variable flow chilled water system



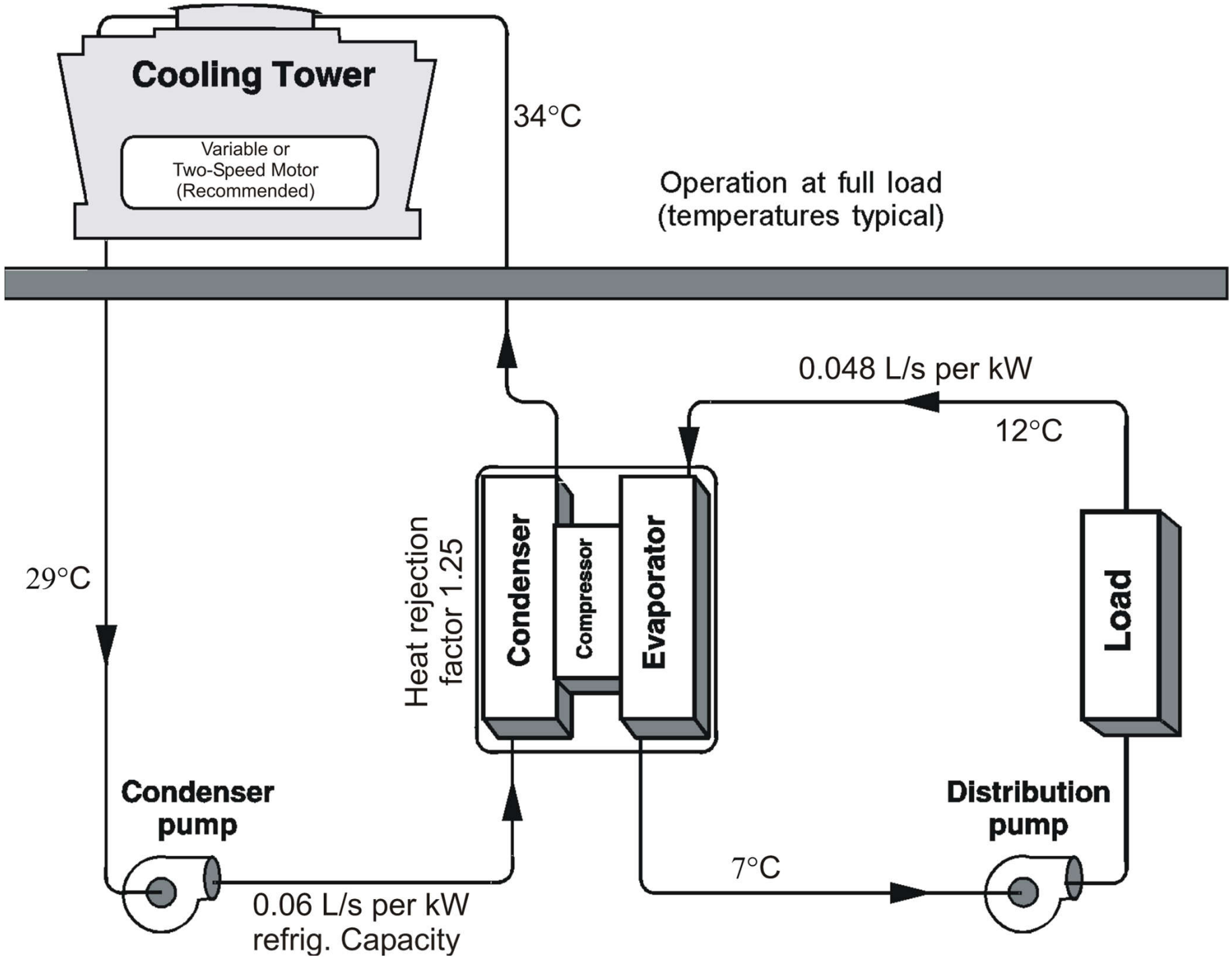
(Source: *ASHRAE HVAC Systems and Equipment Handbook 2004*)

Chilled water pumping system



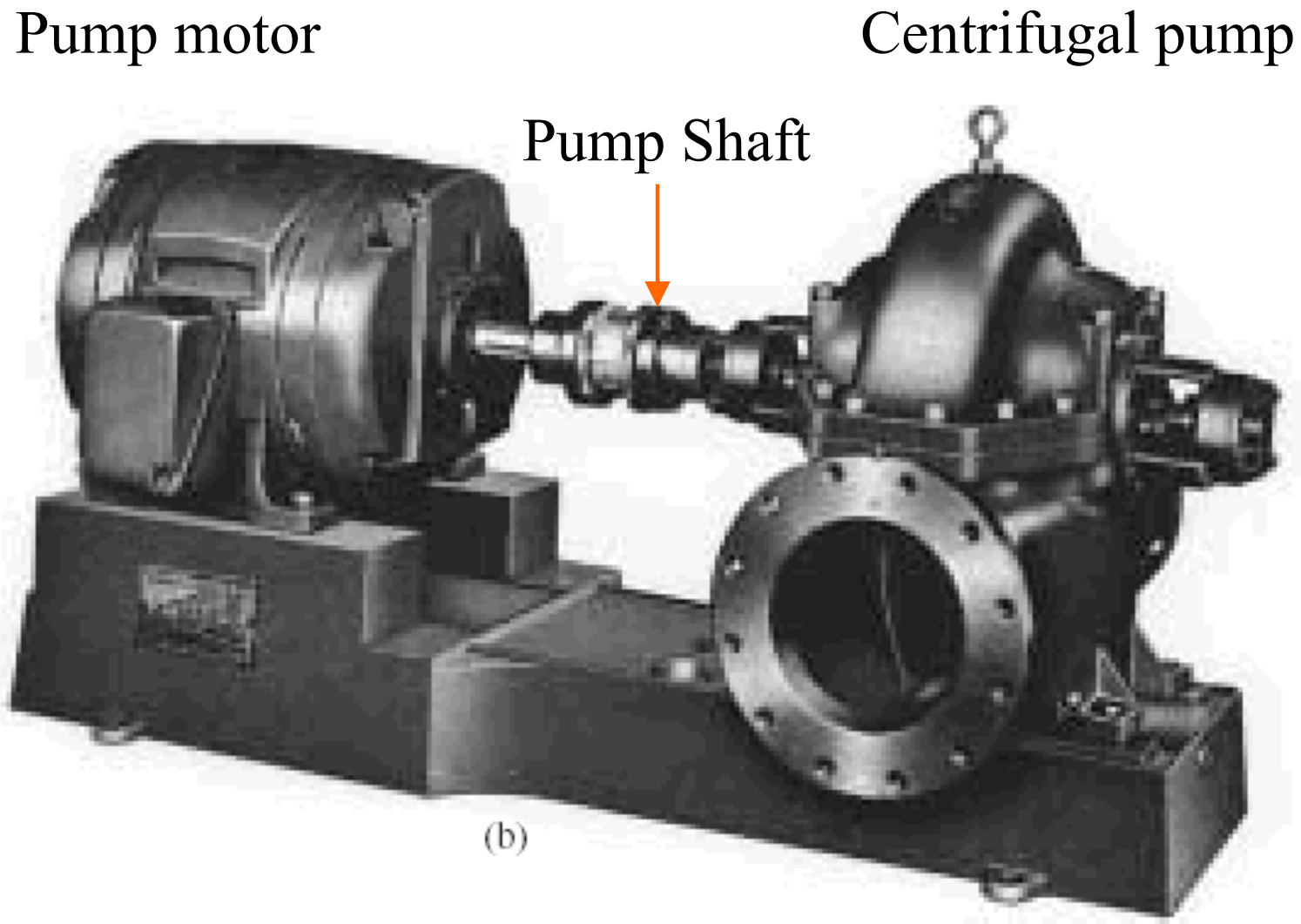
(Source: *Fundamentals of Water System Design*)

Cooling tower pumping system



(Source: *Fundamentals of Water System Design*)

A double-suction, horizontal split-case, single-stage centrifugal pump



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

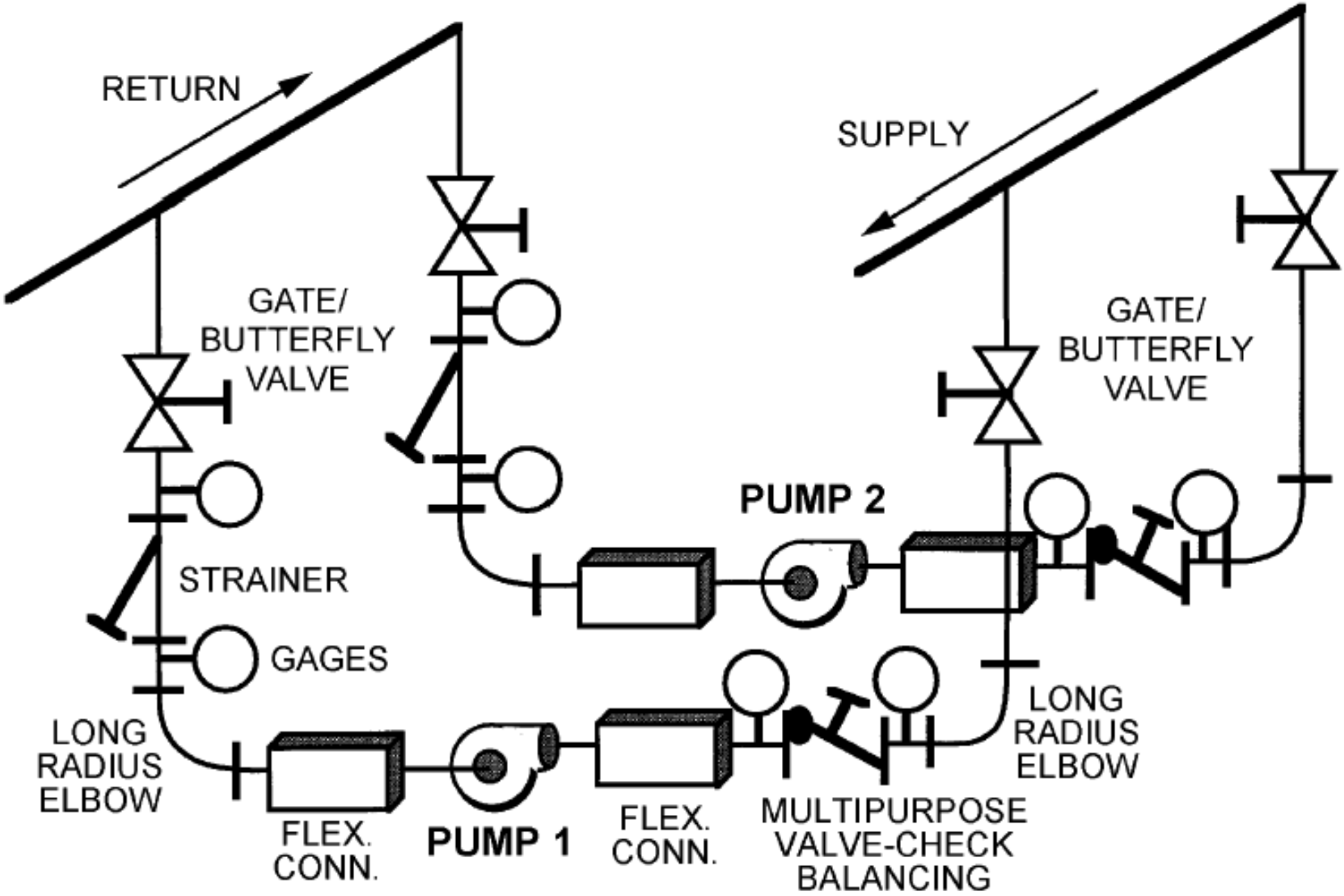
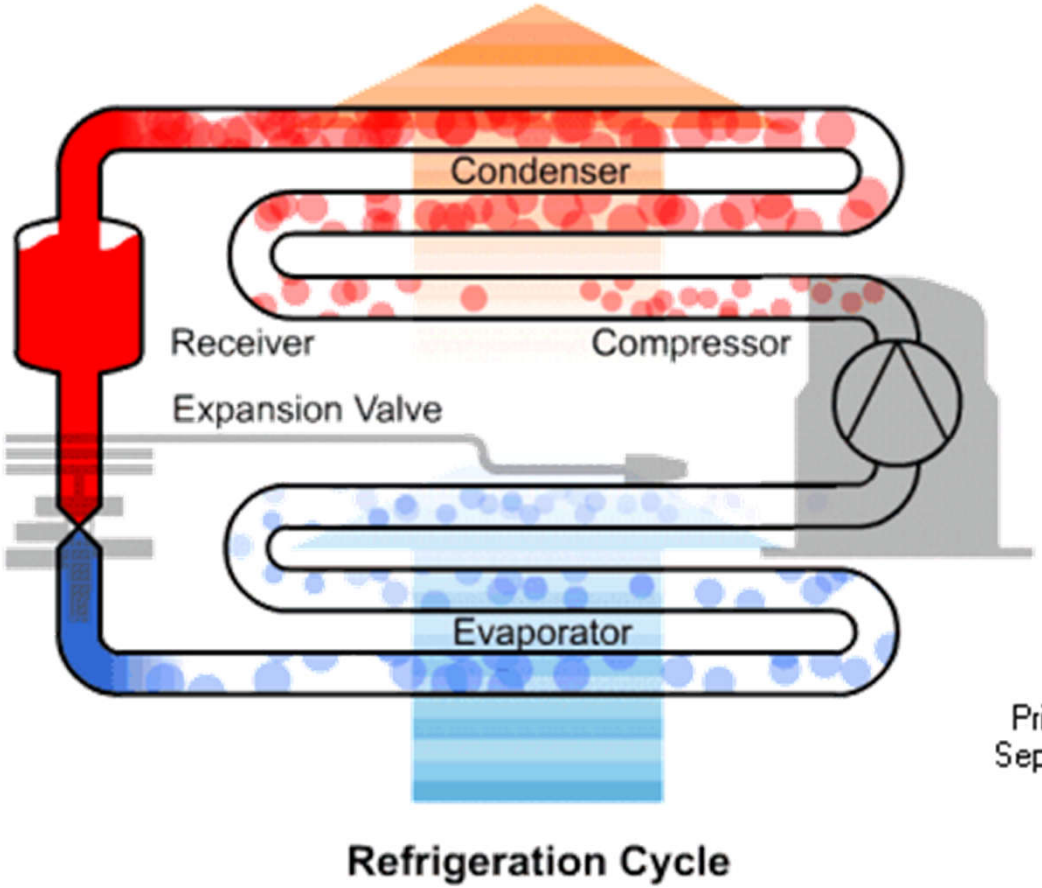


Fig. 35 Typical Piping for Parallel Pumps

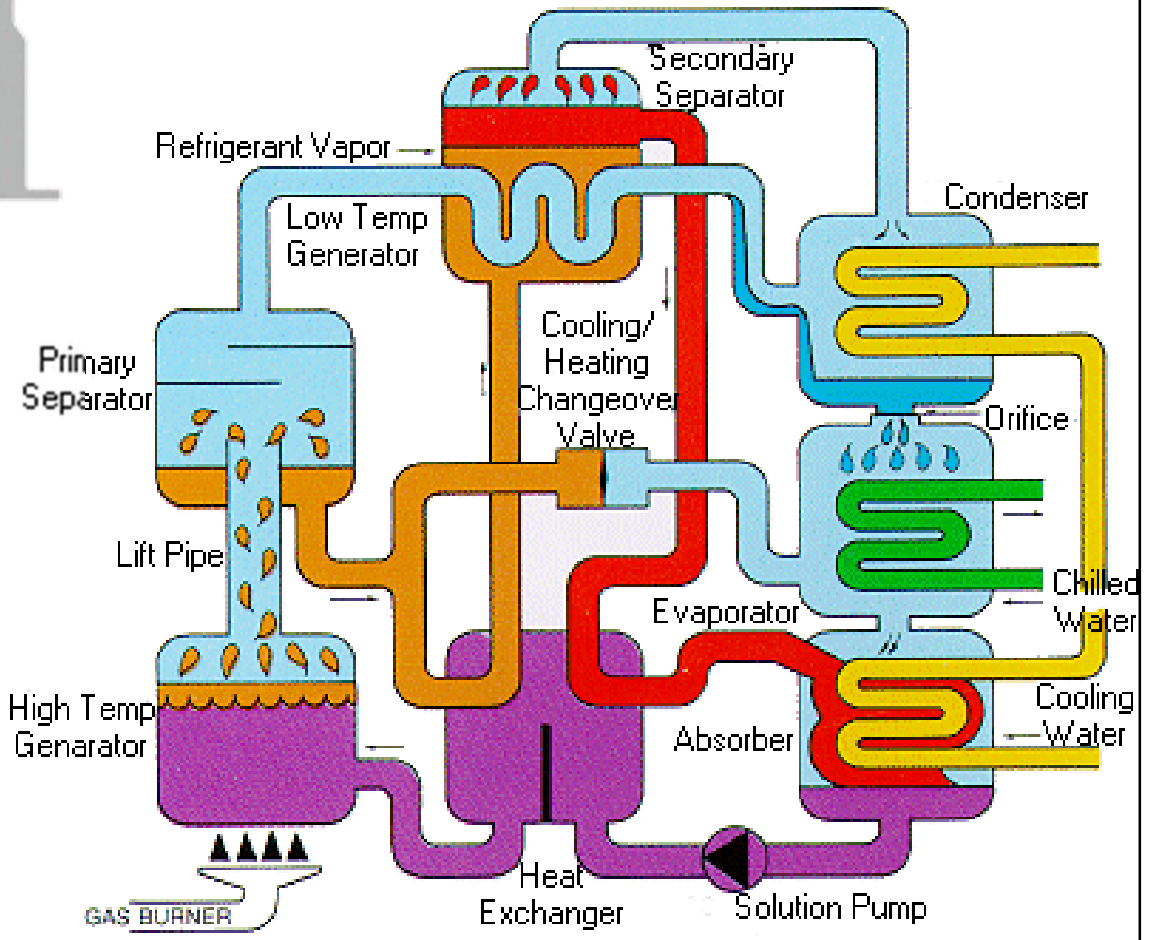
(Source: *ASHRAE HVAC Systems and Equipment Handbook 2004*)

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)

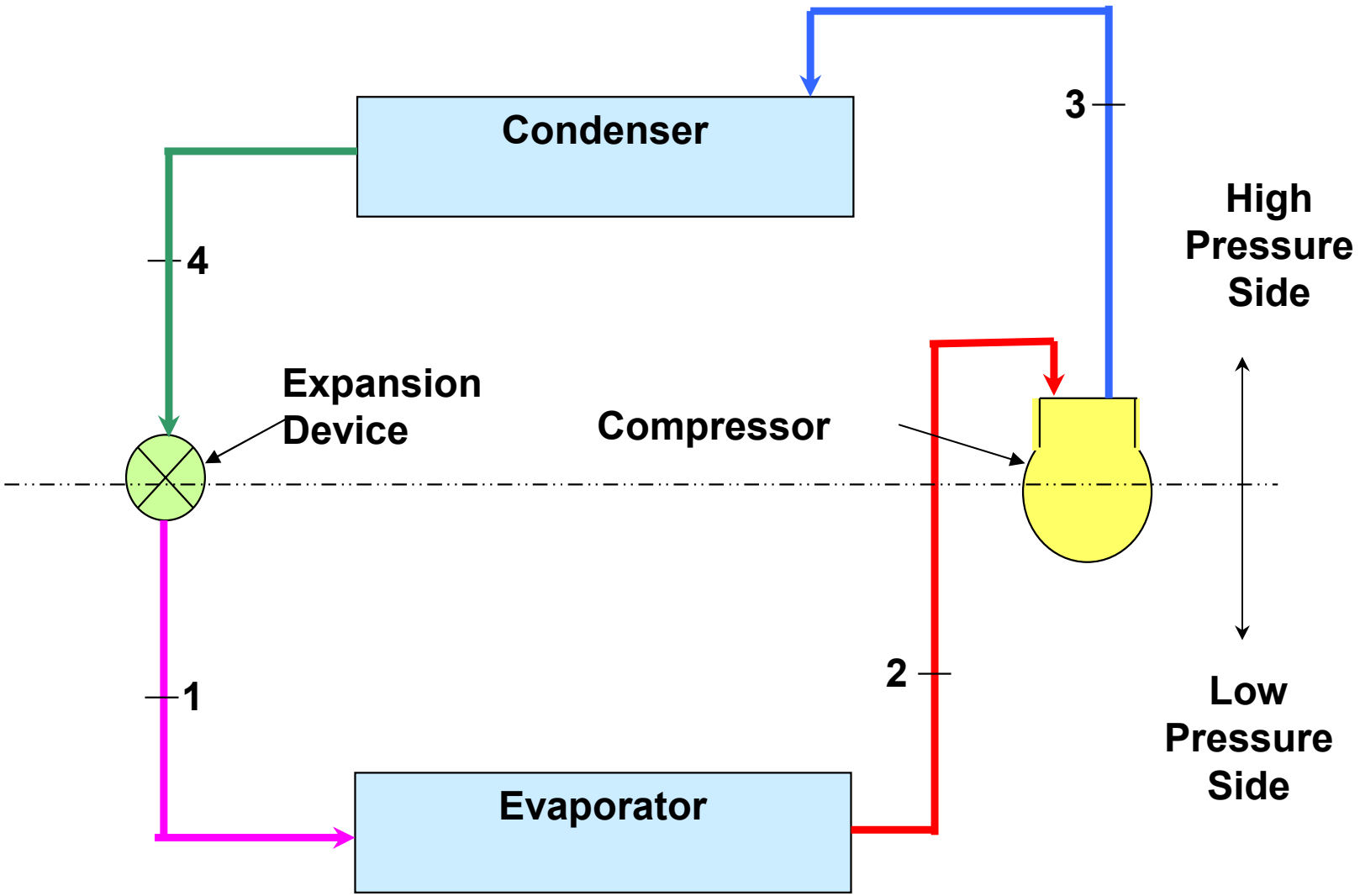


Vapour compression system



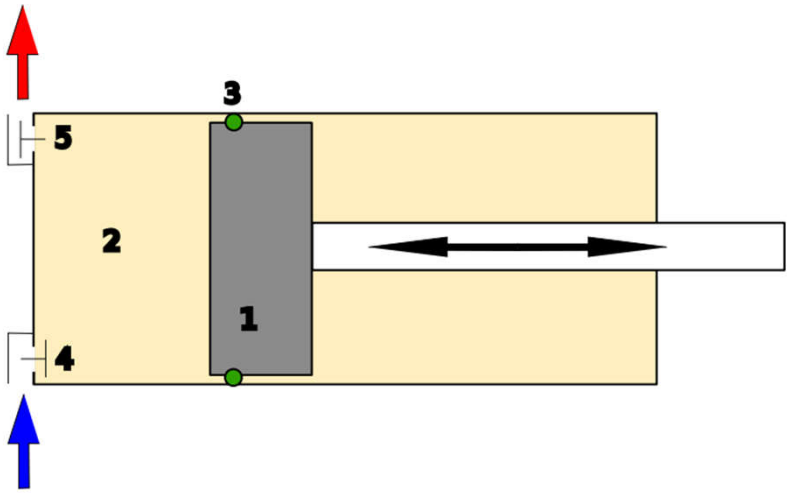
Absorption system

Refrigeration cycle -- vapour compression cycle



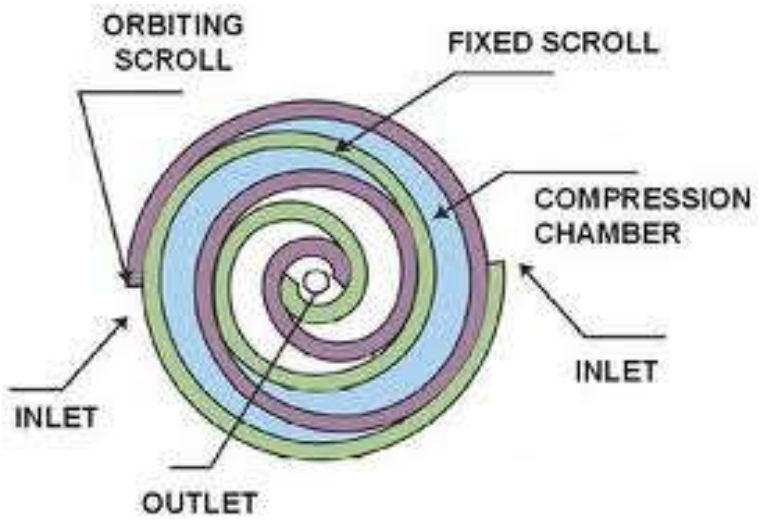
(Video: Refrigeration Cycle Video Animation (1:30) http://www.youtube.com/watch?v=MqnyaUNxs9A)

Common types of compressors used in chillers

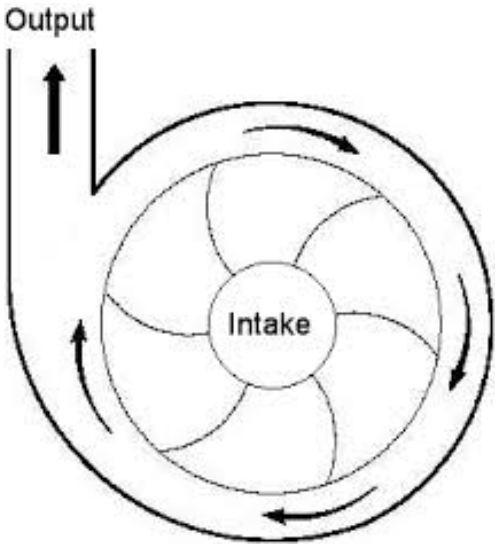


Reciprocating

Rotary screw



Scroll



Centrifugal

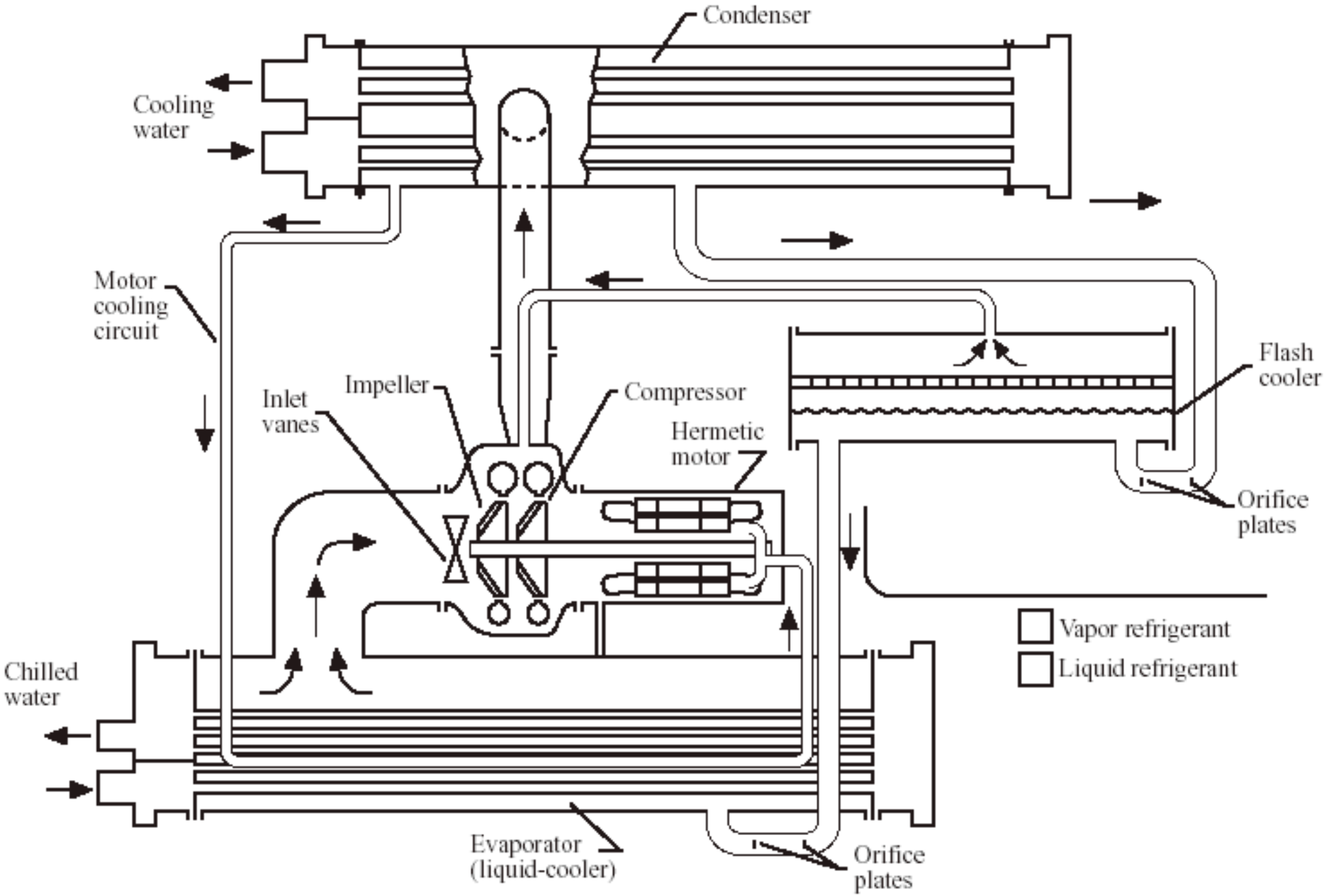
Refrigeration systems

- Arrangement of compressor motor or external drive:
  - Open type
  - Hermetic (or sealed) type
  - Semi-hermetic (or semi-sealed) type

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

- Centrifugal chillers (cont'd)
  - Performance rating: ARI Standard 550
    - COP and Integrated part-load value (IPLV)
    - Water-cooled chillers: COP = 5 (= 0.7 kW/TR)
    - Air-cooled chillers: COP = 2.5 to 2.8 (1.26-1.4 kW/TR)
  - Capacity control:
    - Inlet vanes and variable compressor speed
    - Centrifugal compressor performance map
  - Partload operation

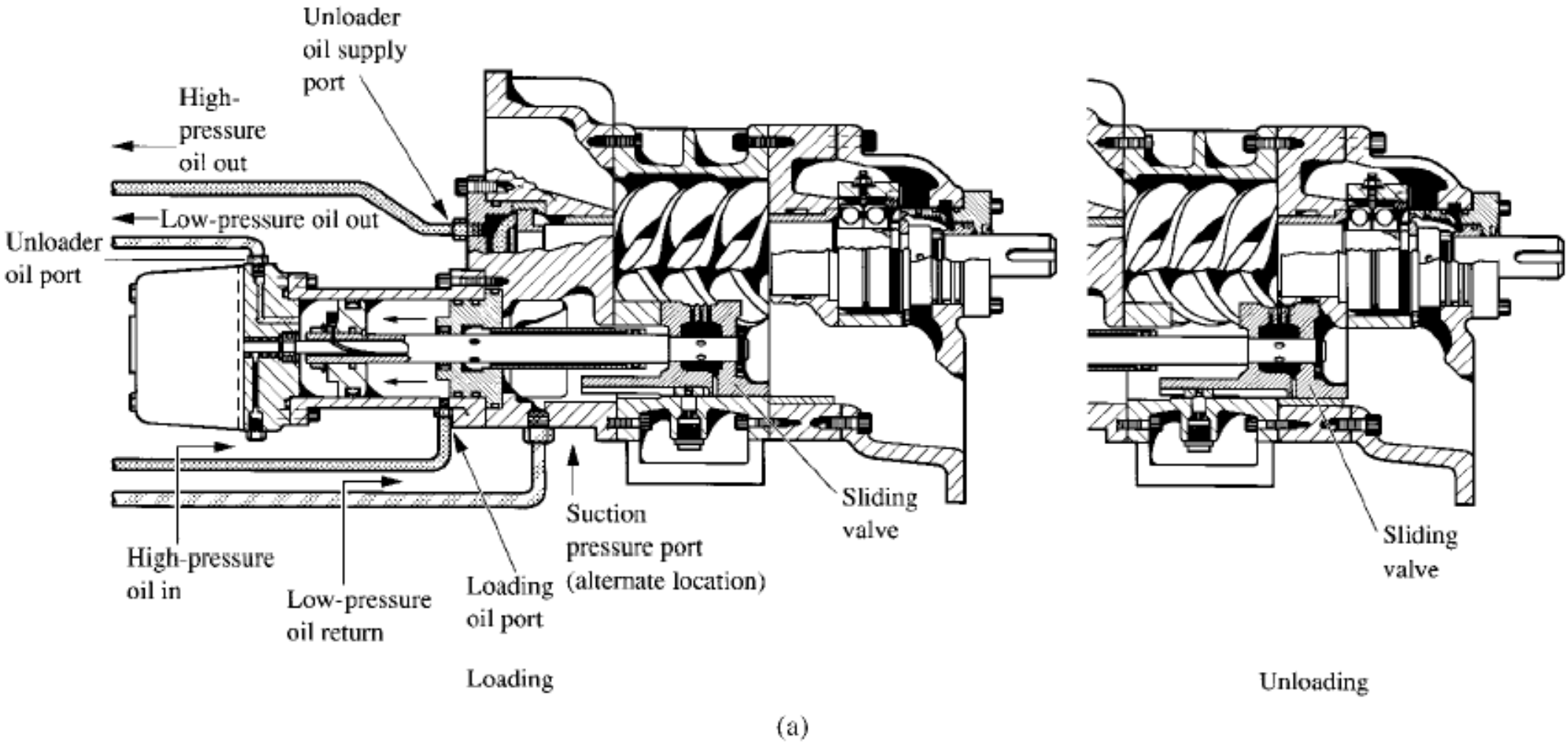
Refrigeration systems

- Centrifugal chillers (cont'd)
  - Specific controls
    - Chilled water leaving temperature and reset
    - Condenser water temperature control
    - On/off of multiple chillers based on measured coil load
    - Air purge control
    - Safety controls e.g. oil pressure, freezing protection, etc.
  - Incorporating heat recovery
    - Double-bundle condenser

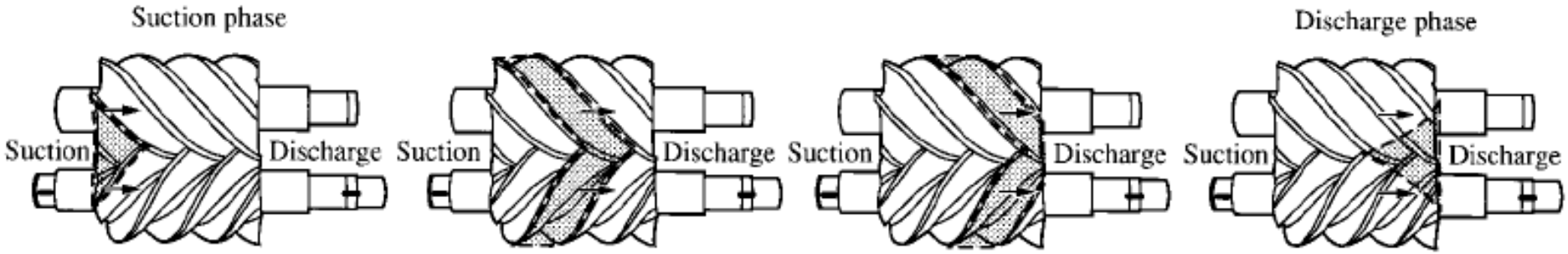
Refrigeration systems

- 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



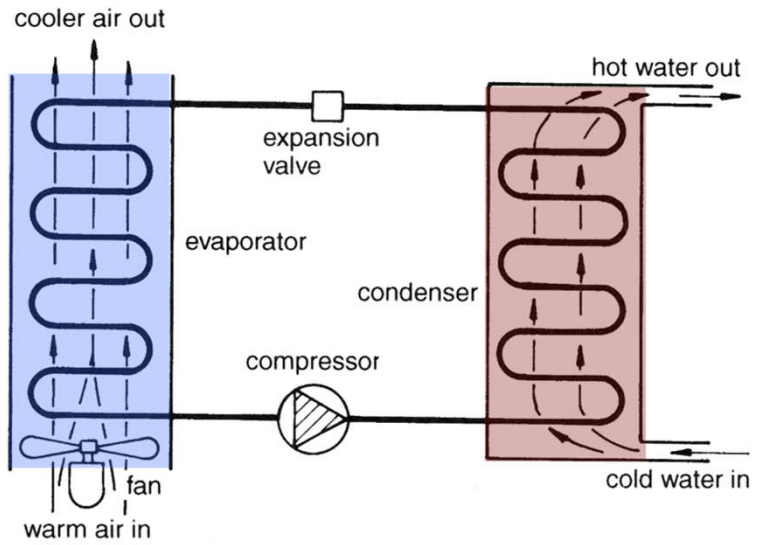
(a)



(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)



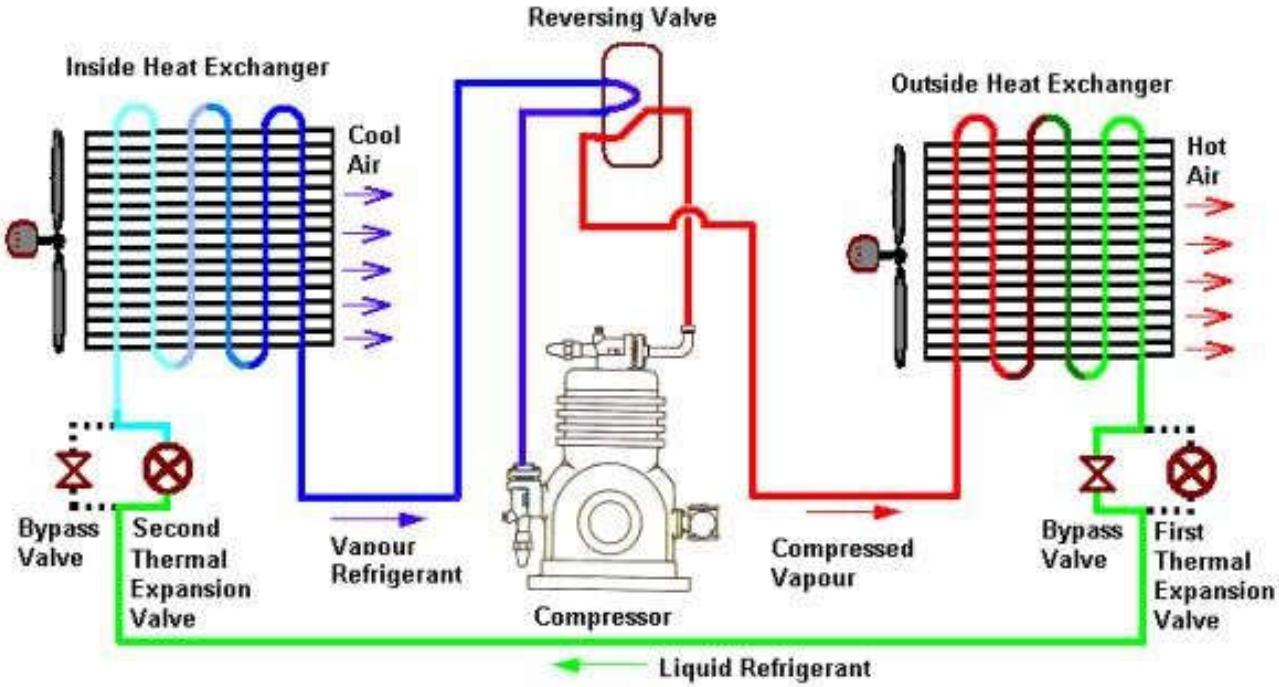


Fig. 1 - Heat Pump in Cooling Mode

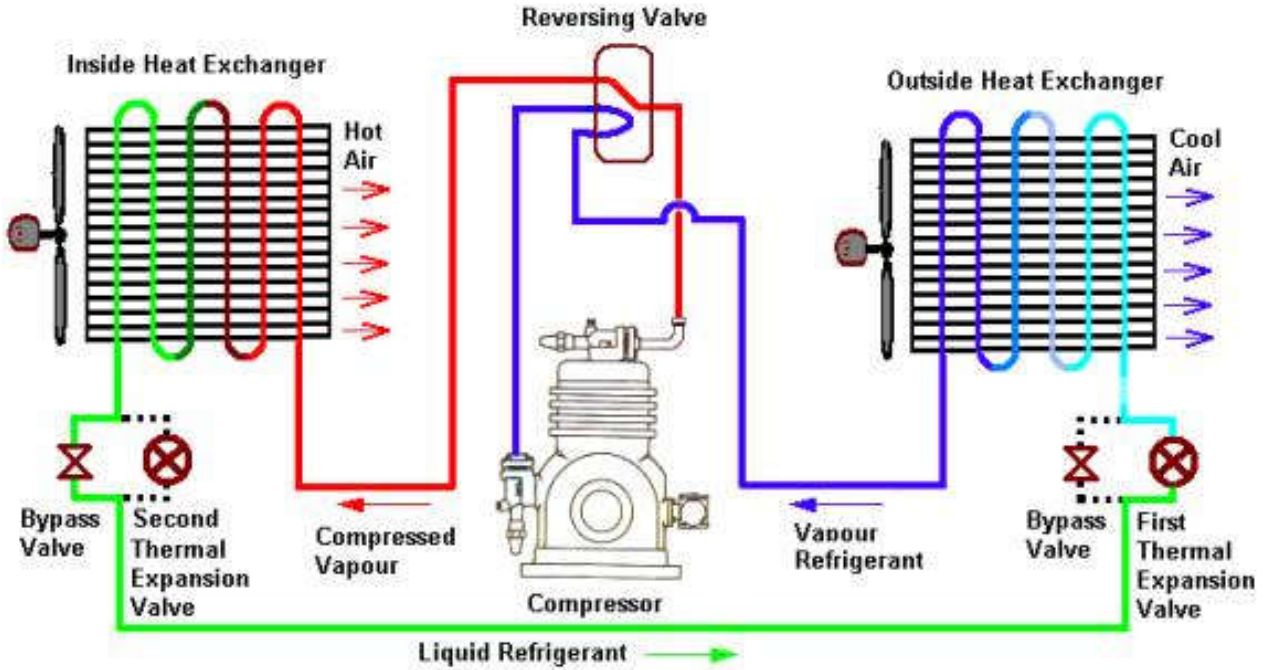


Fig. 2 - Heat Pump in Heating Mode