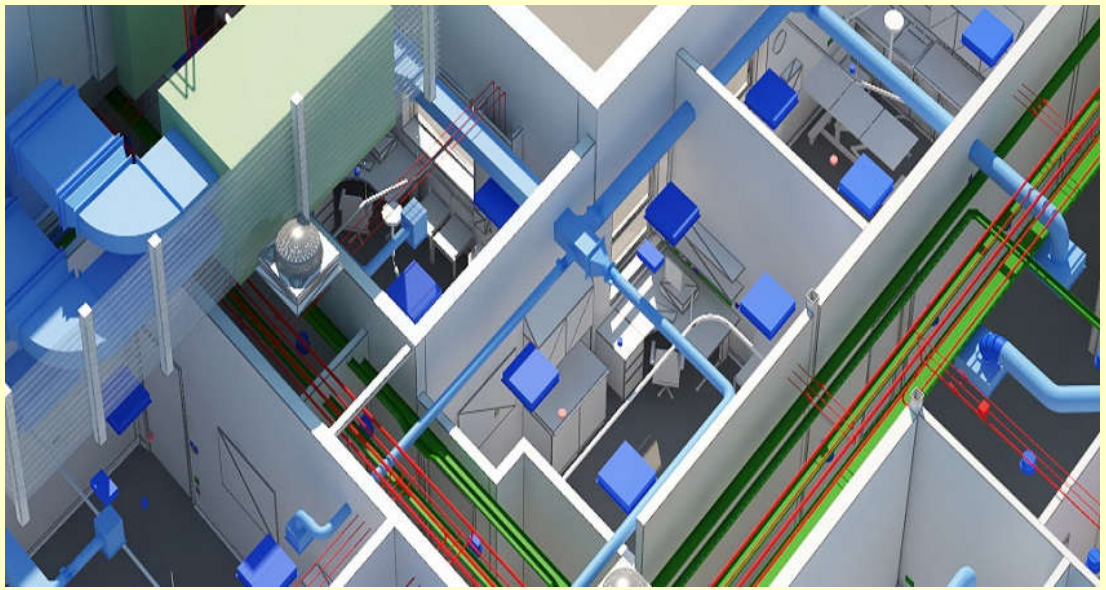

7. HVAC Part 3

7.1 Practical skills on operation and maintenance

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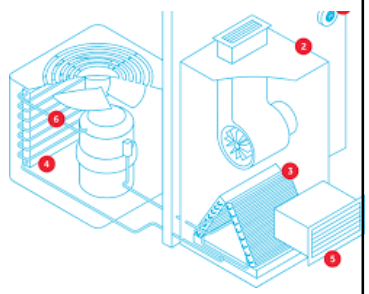
Contents 內容

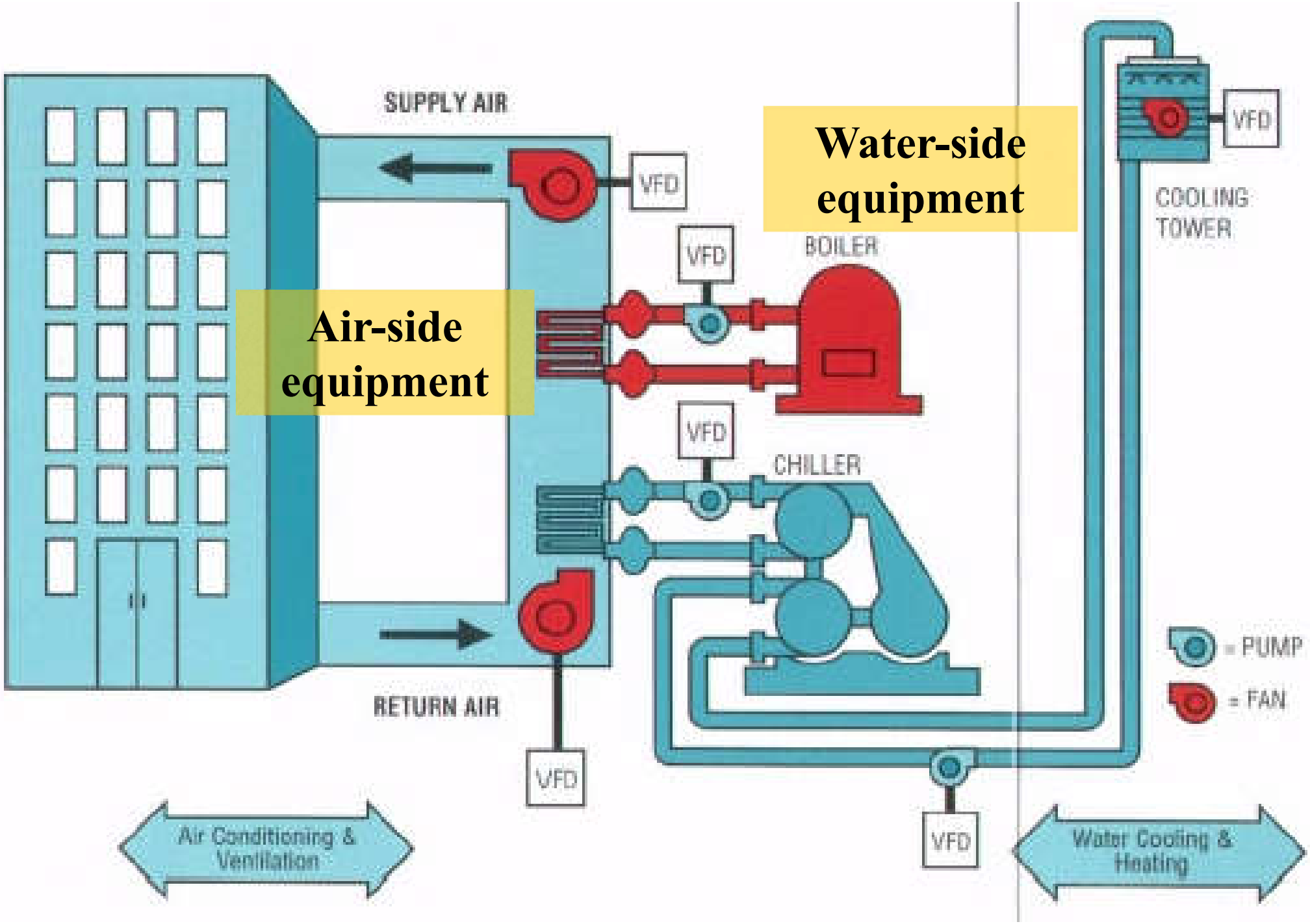
- HVAC system equipment 暖通空調系統設備
- HVAC air-side equipment 暖通空調空側設備
- HVAC water-side equipment 暖通空調水側設備
- Operation & maintenance 操作和維護
- HVAC safety tips 暖通空調安全提示

HVAC system equipment

- HVAC main equipment
  - 1. Equipment to generate cooling or heating
    - Chillers, boilers, heat pumps
  - 2. A means of distributing heat, cooling, and/or filtered ventilation air where needed
    - Air duct & piping for water or steam
  - 3. Devices or terminals that deliver the heat, cooling, and/or fresh air into the building
    - Fan coil units, VAV boxes, registers & diffusers, hydronic radiators or convectors



Example of a centralised HVAC system



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

Components of HVAC systems

Air side: 空氣側

1. Outdoor air intake (screen, louvers, dampers)
2. Preheater
3. Return air intake (dampers)
4. Filter
5. Cooling coil
6. Dehumidifier
7. Heating coil
8. Humidifier
9. Fan
10. Duct system
11. Air outlet
12. Air terminal (with outlet)

Refrigeration side: 製冷側

1. Refrigeration machine or chiller (compressor, condenser, cooler and refrigerant piping)

Water side: 水側

1. Pumps
2. Water piping

Heat rejection: 散熱

1. Cooling tower

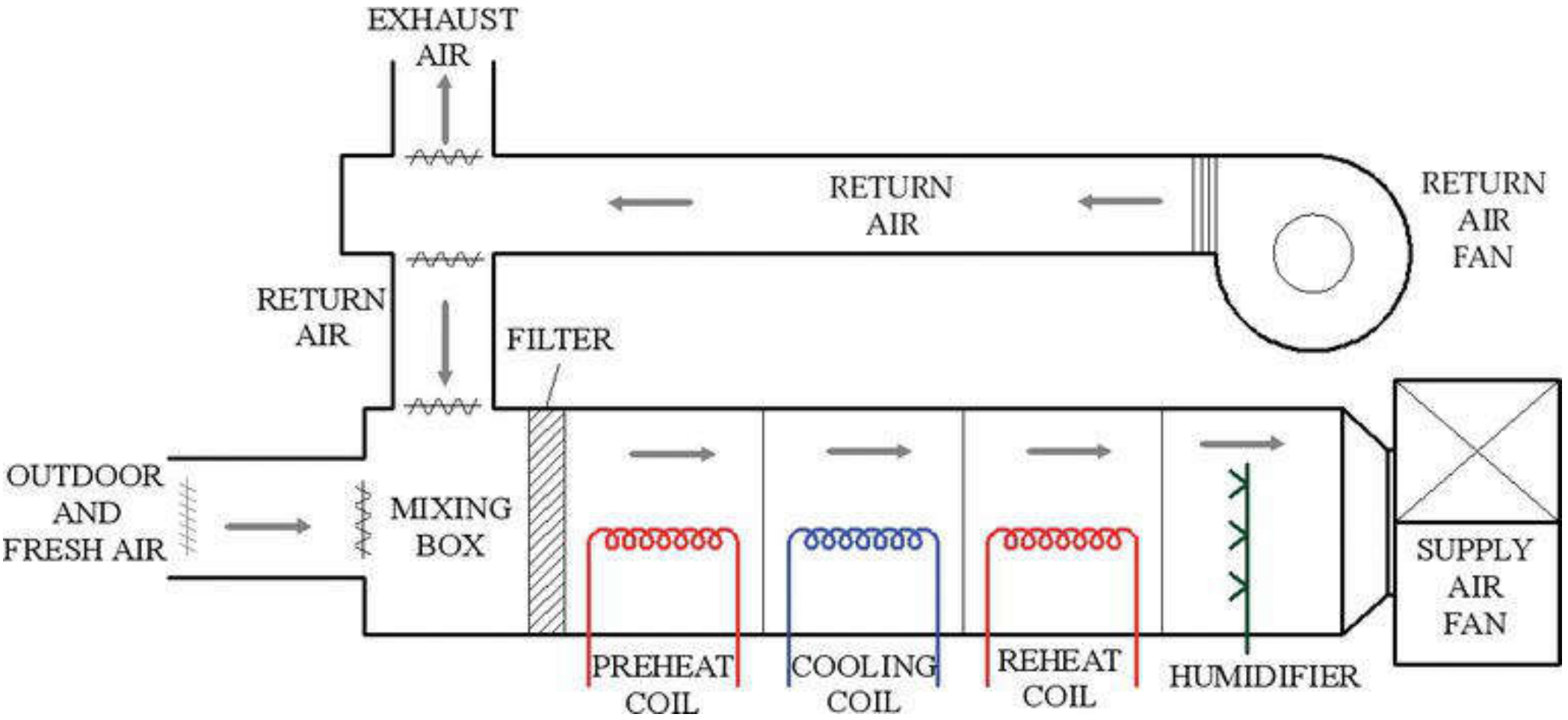
Heating side: 加熱側

1. Boiler and auxiliaries
2. Piping (hot water or steam)

HVAC system equipment

- Practical HVAC skills
  - Electrical (AC/DC, relays, motors, wiring)
  - Electronics (controls, VSD, Ethernet)
  - Mechanical (pumps, piping, vibration)
  - Thermal (refrigerants, steam, heat pump)
  - Safety (work safety, occupational health, regulations)
- Common types of works
  - Cleaning, inspection, maintenance, operation, repairs, trouble shooting, emergency response

Equipment arrangement for central HVAC system

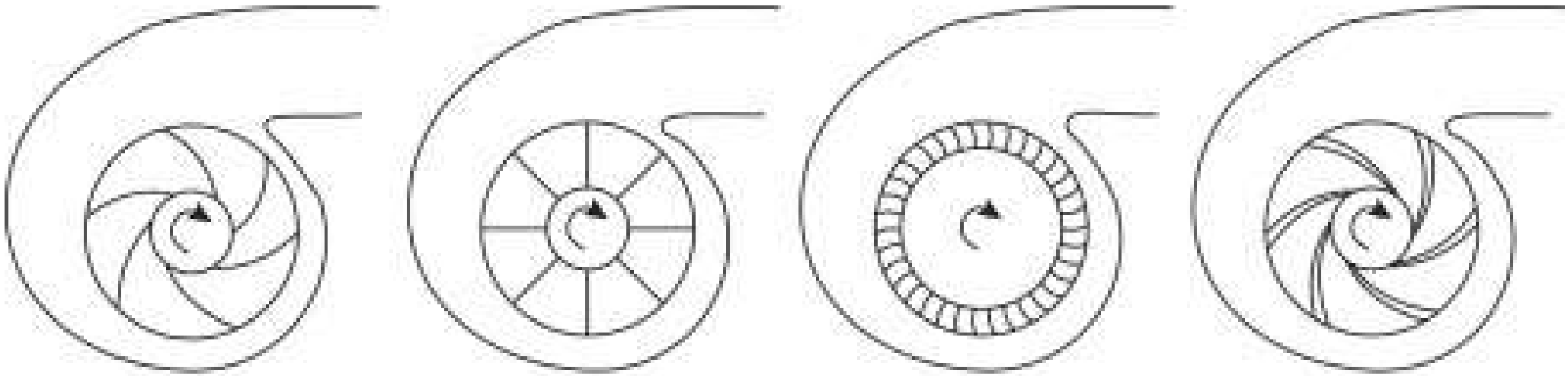


[Source: https://www.intechopen.com/books/hvac-system/types-of-hvac-systems]

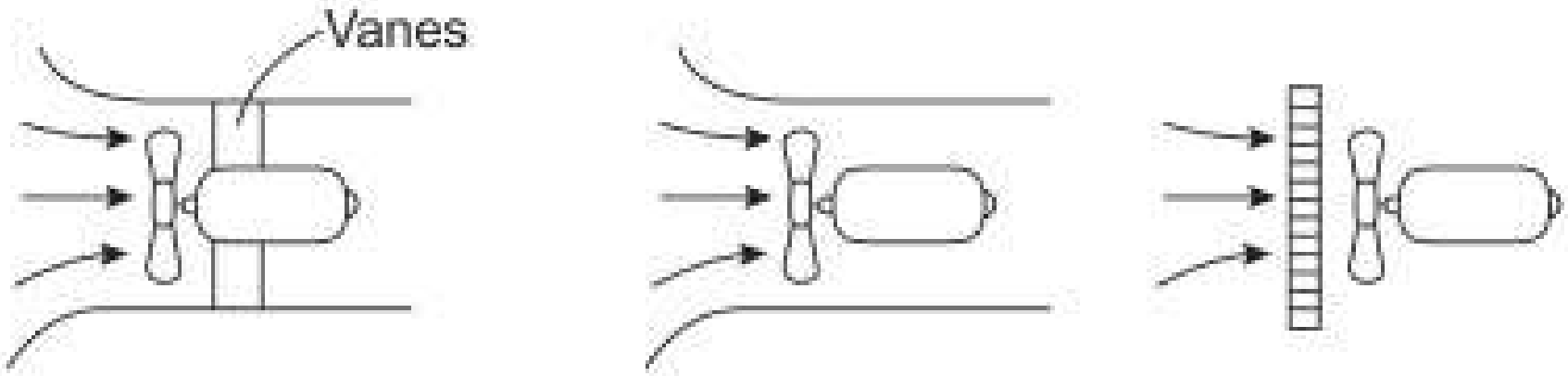
HVAC air-side equipment

- Common types of fans
  - **Centrifugal fans (離心風機)**: radial, forward curved, air foil (backward curved), backward inclined, tubular, roof ventilator
  - **Axial fans (軸流風機)**: propeller, tube-axial, vane-axial
- Fan arrangements
  - Motor location, air discharge orientation, drive train type (direct drive or pulley drive)
  - Centrifugal: single width single inlet (SWSI), double width double inlet (DWDI)

Different types of centrifugal and axial fans



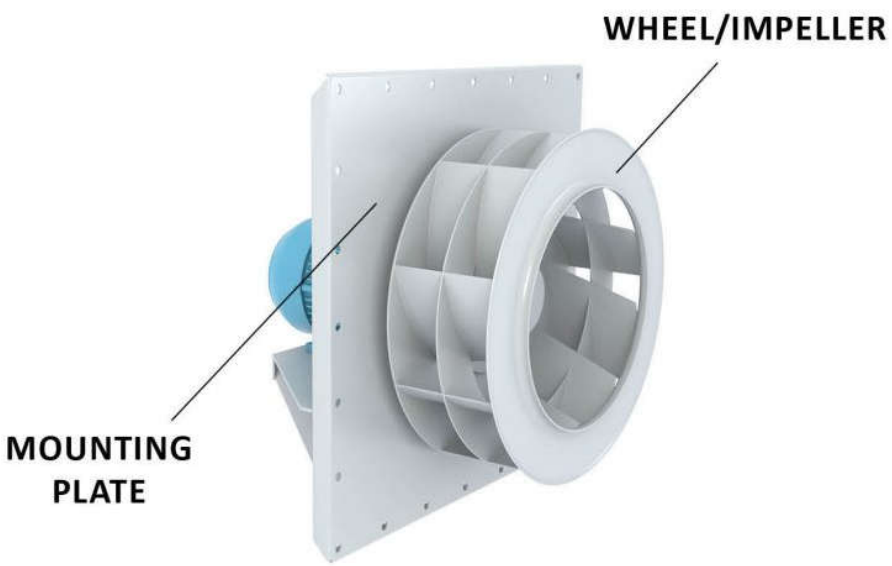
(A)

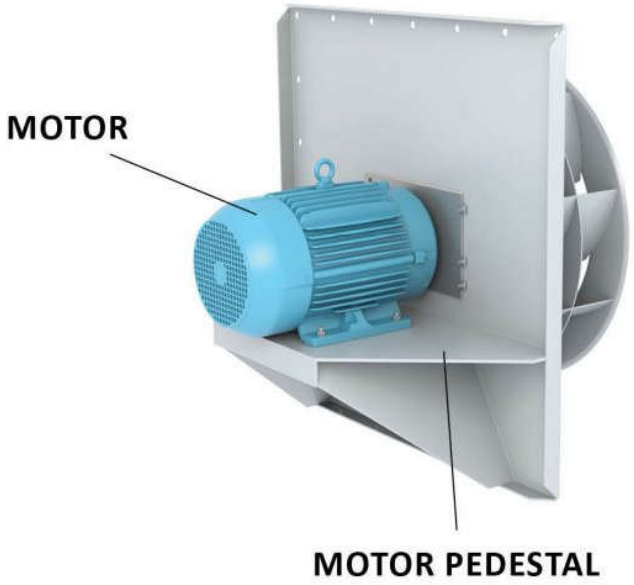


(B)

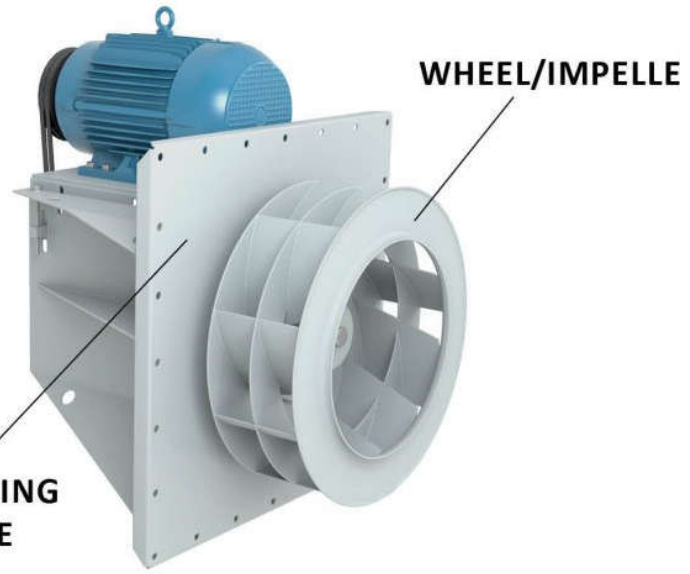
Plug fans (also known as plenum or unhoused centrifugal fans)

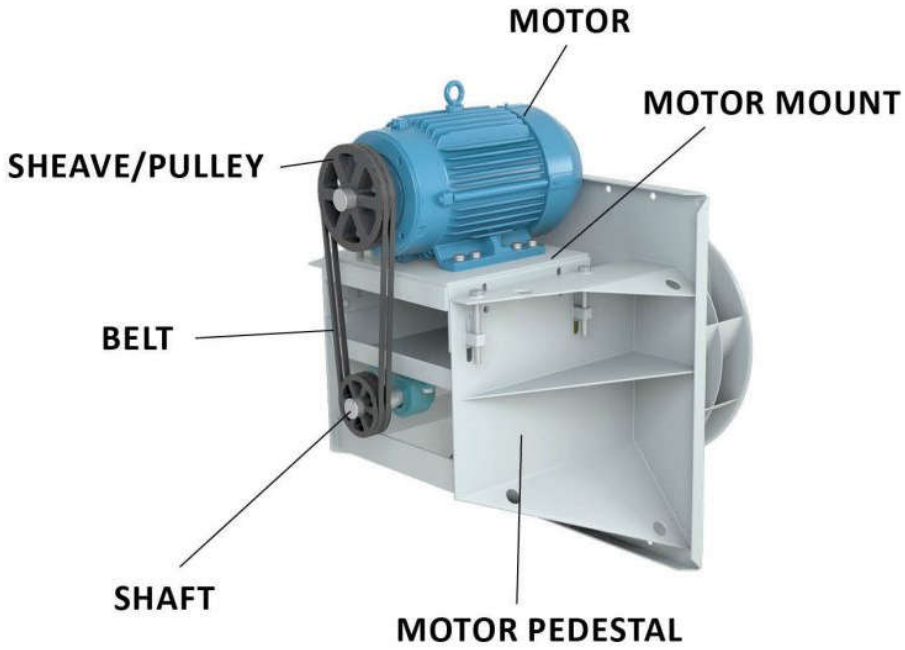
DIRECT DRIVE PLUG FANS





BELT DRIVEN PLUG FANS

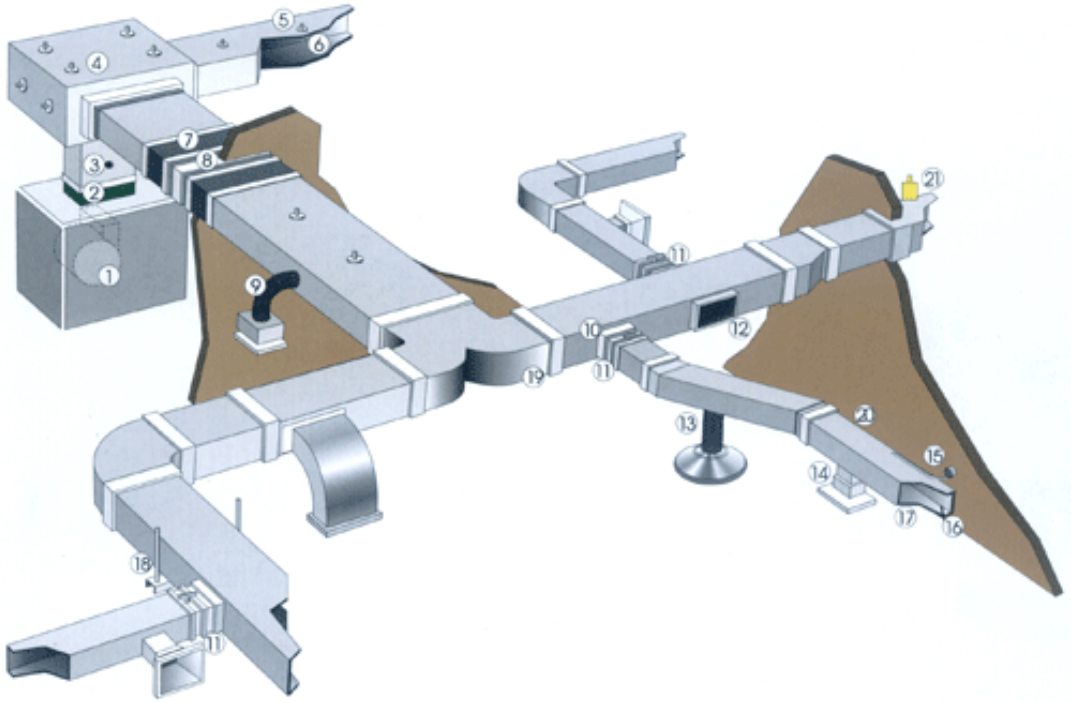




(Source: Plug fans https://www.tcf.com/products/plug/)

HVAC air-side equipment

- Types of air duct
  - Supply air duct
  - Return air duct
  - Outdoor air duct
  - Exhaust air
- Duct sections
  - Header or main duct (trunk)
  - Branch duct or runout



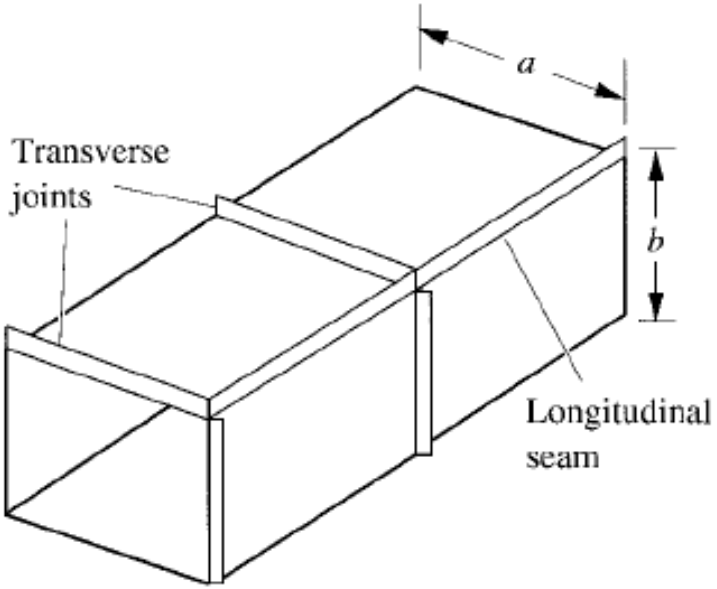
HVAC air-side equipment

- Materials of air duct
  - Galvanized steel (sheet metal)
  - Aluminium

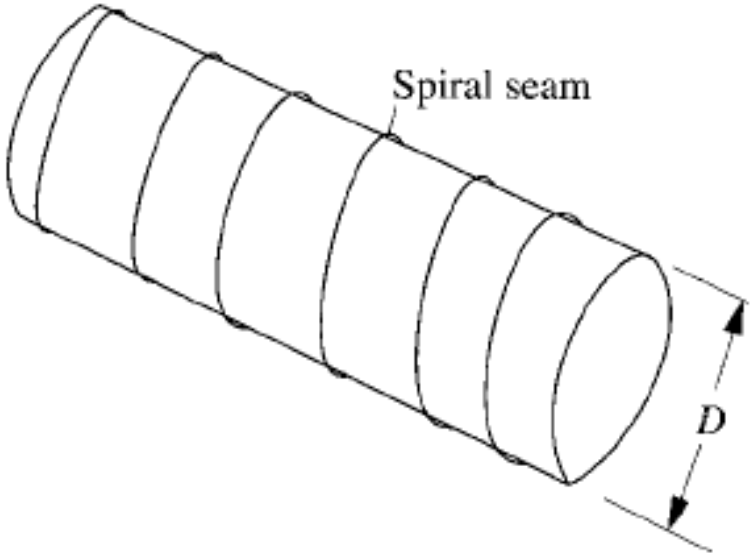
  - Polyurethane and phenolic insulation panels (pre-insulated air ducts)
  - Fiberglass duct board (preinsulated non-metallic ductwork)
  - Flexible ducting
  - Fabric air duct

(See also: Duct (flow) -- Wikipedia http://en.wikipedia.org/wiki/Duct_(flow))

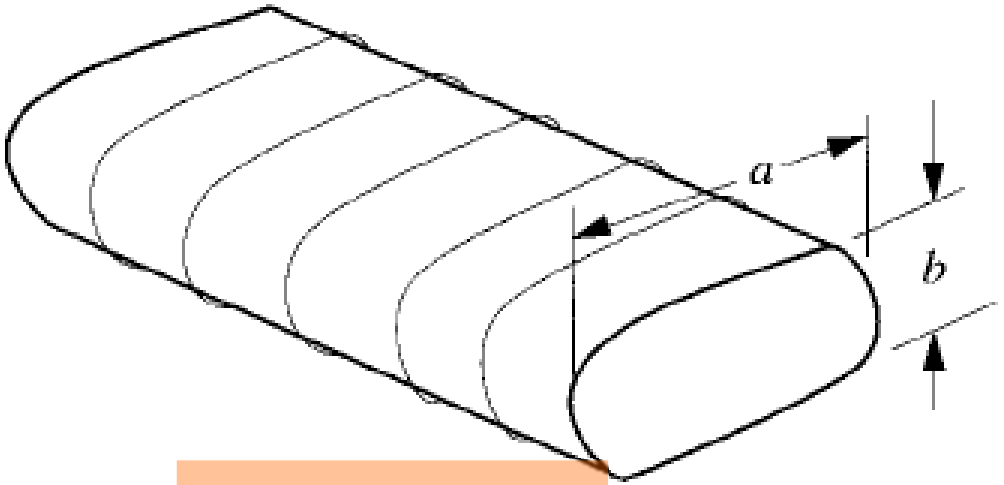
Different types of air ducts



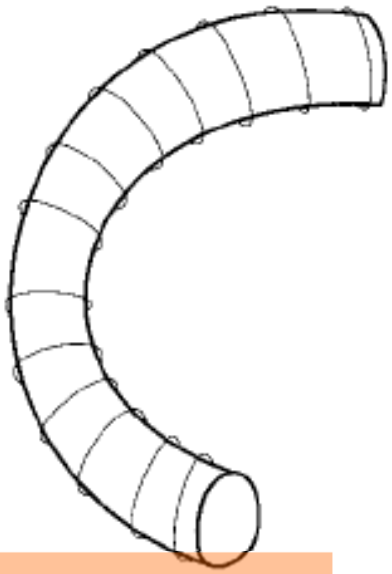
Rectangular duct



Round duct w/ spiral seam



Flat oval duct

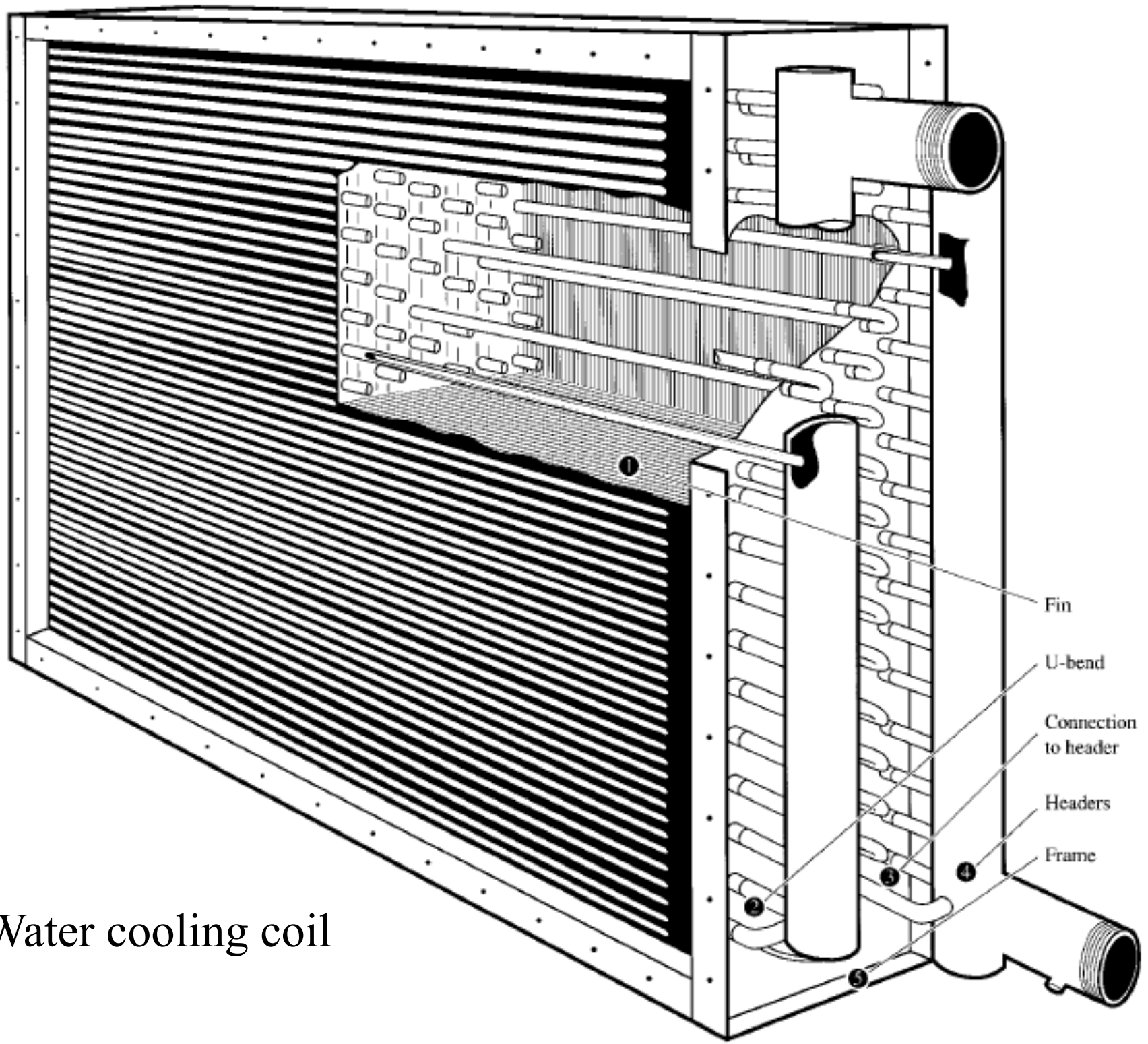


Flexible duct

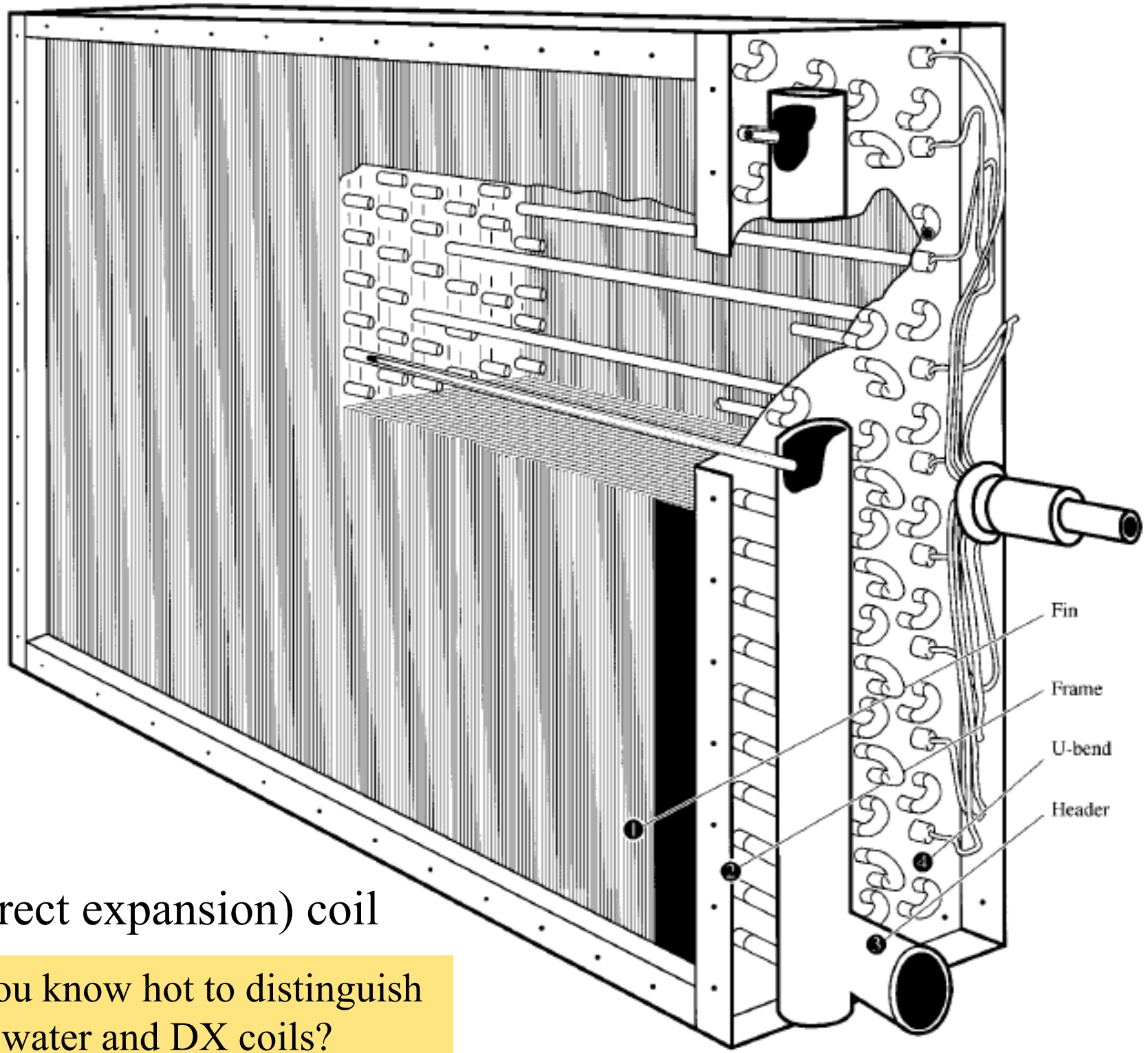
(Source: *Wang, S. K., 2001. Handbook of Air Conditioning and Refrigeration*)

HVAC air-side equipment

- Types of coils
  - Water cooling coil
  - Direct-expansion (DX) coil
  - Water heating coil
  - Steam heating coil
- Coil accessories
  - Air vents
  - Condensate collection & drain system
  - Coil cleaning & freeze protection



Water cooling coil

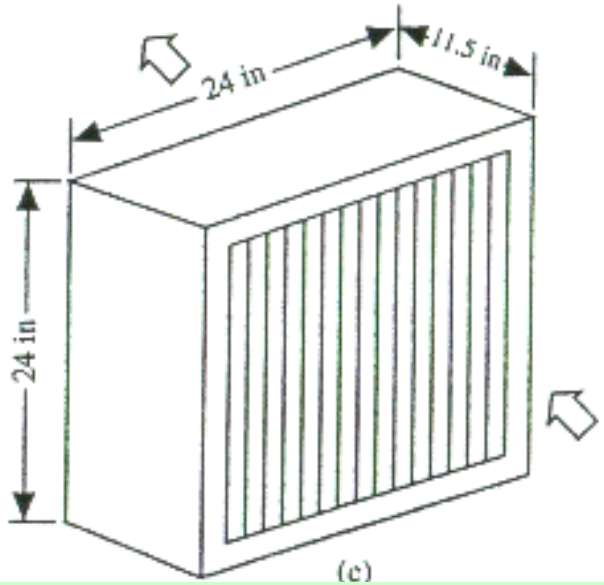


DX (direct expansion) coil

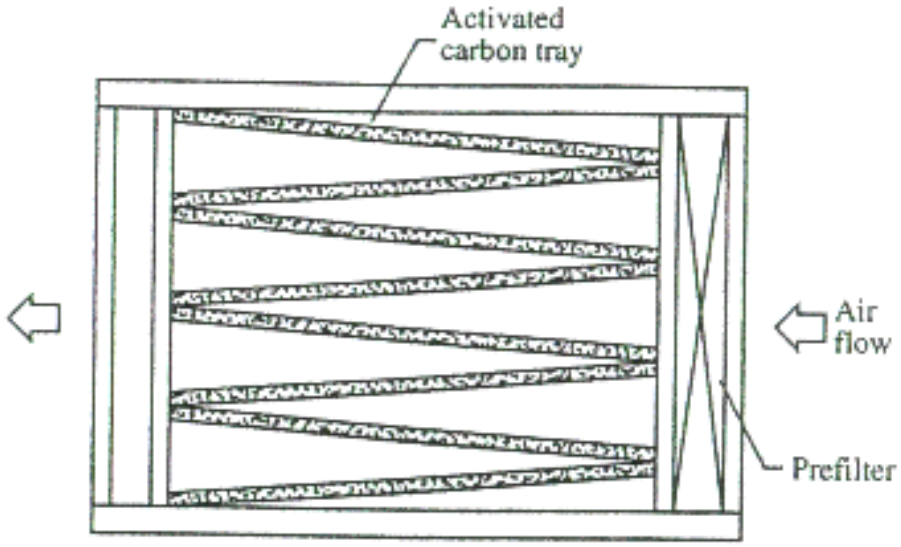
Do you know hot to distinguish water and DX coils?

HVAC air-side equipment

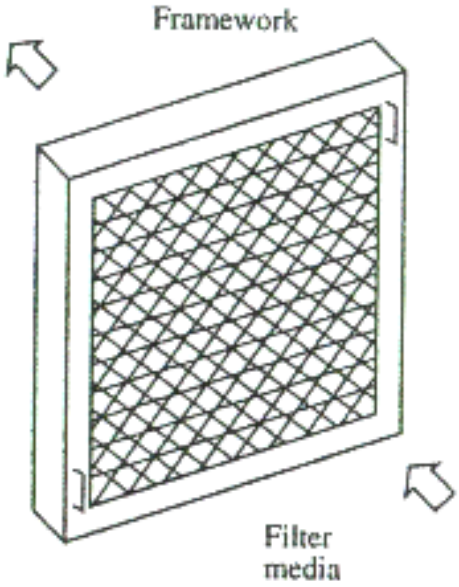
- Air filters
  - Air cleaning and filtration
  - Operating performance:
    - Efficiency or effectiveness of dust removal
    - Dust holding capacity
    - Initial & final pressure drop
    - Service life
  - Types: low-, medium-, and high-efficiency filters + carbon activated filters



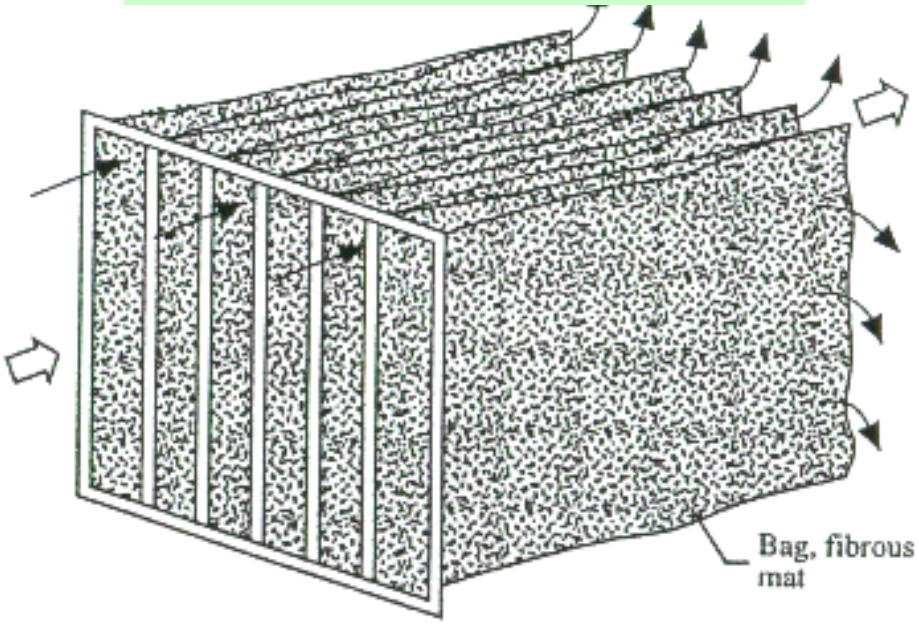
HEPA and ULPA filters



Activated carbon filter

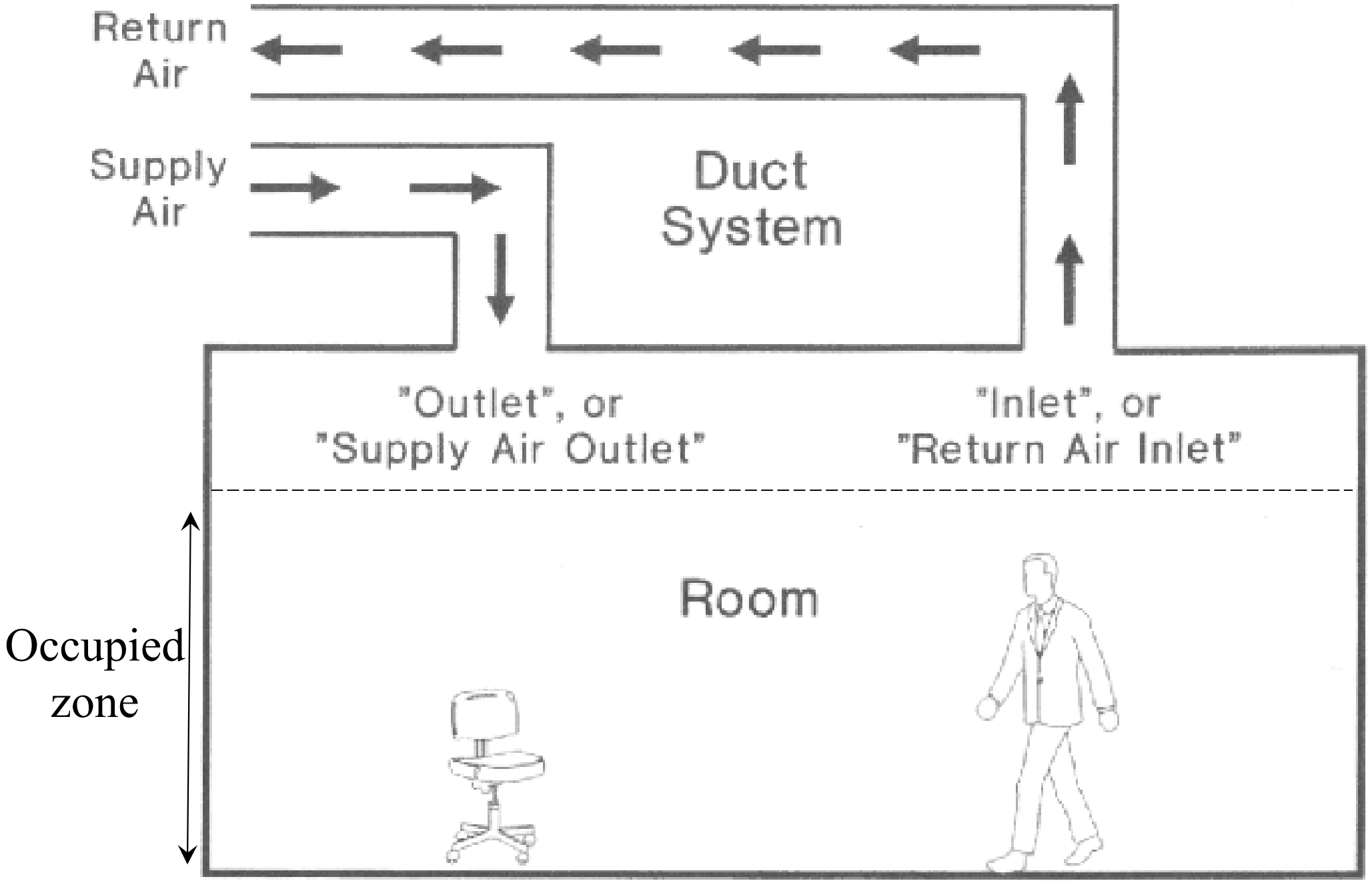


Low efficiency (panel-type)



Medium efficiency (bag-type)

Air distribution in HVAC duct system and room



(Video: 4- Fundamentals of HVAC - Space Air Diffusion (8:37) http://www.youtube.com/watch?v=zephL3PidMI)

(Source: Rock, B. A. and Zhu, D., 2002. *Designer's Guide to Ceiling-based Air Diffusion*.)

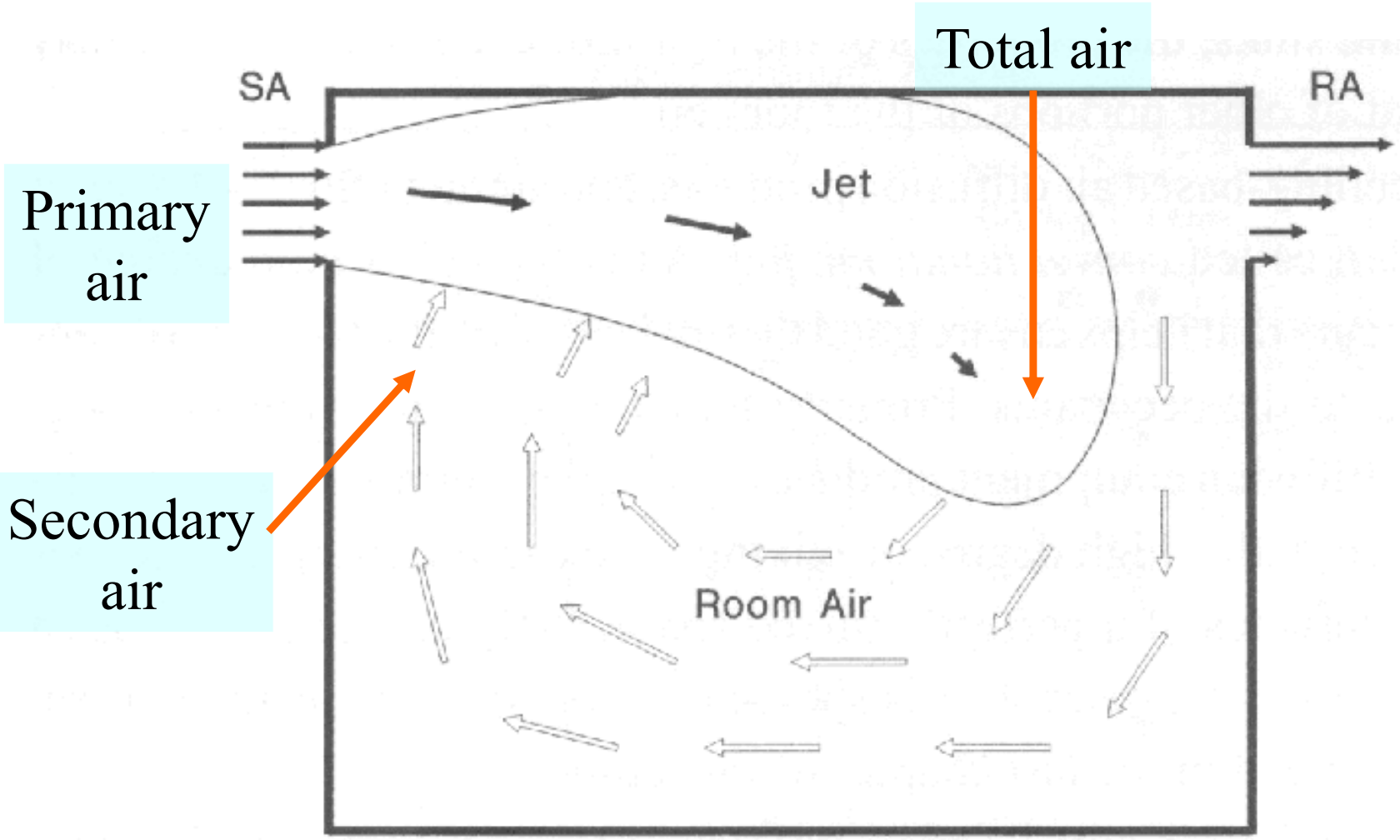
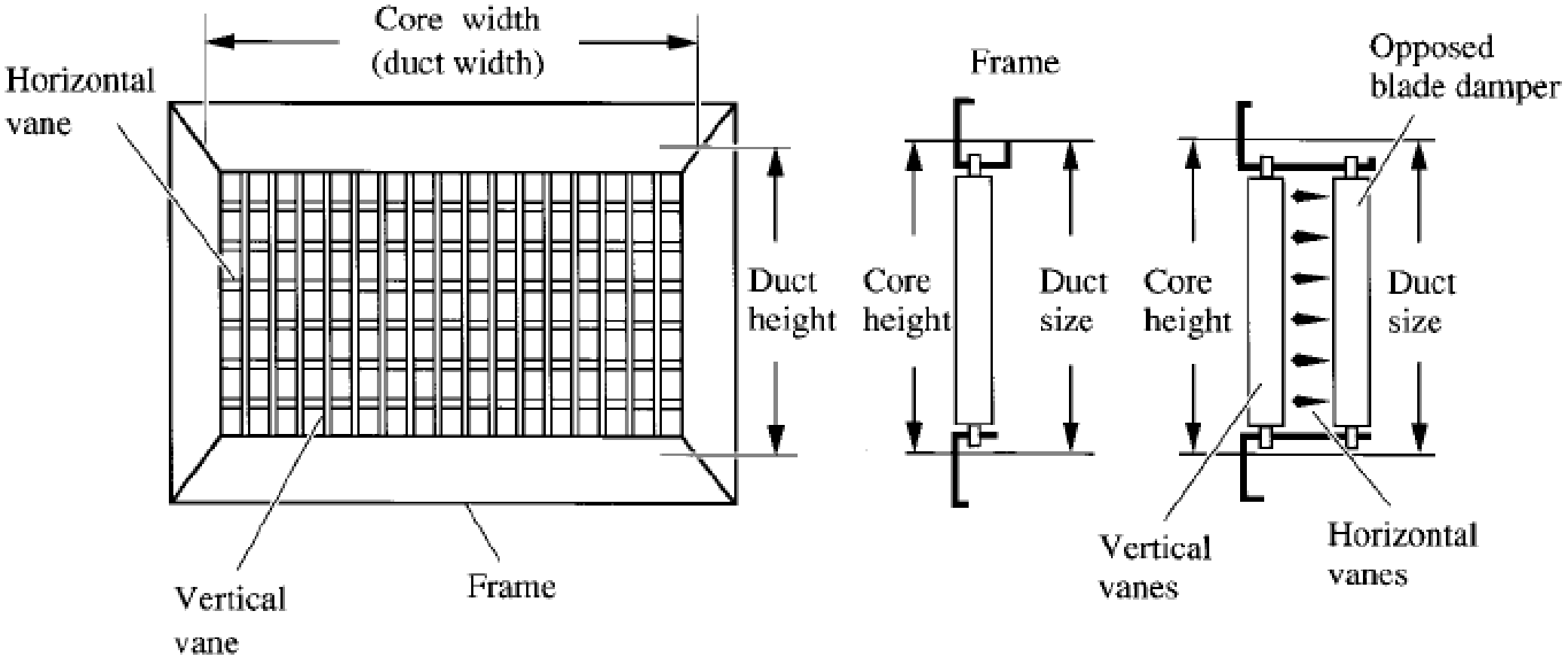


Figure 6.2 *Real airflows in rooms are most often "entrainment flow" or "conventional mixing" where confined jets and surfaces affect the resulting pattern.*

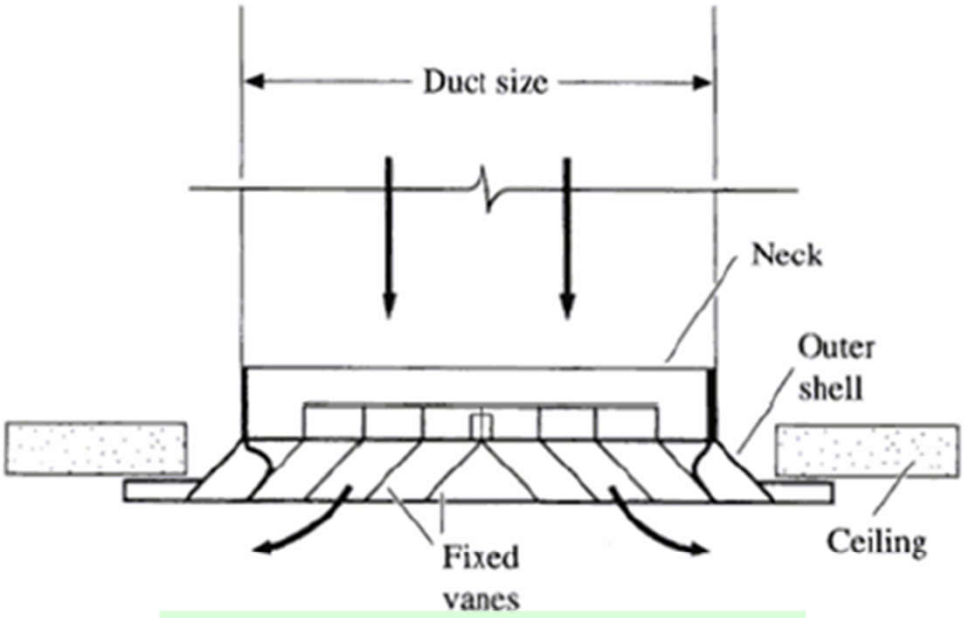
(Source: Rock, B. A. and Zhu, D., 2002. *Designer's Guide to Ceiling-based Air Diffusion*.)

Supply grille and register

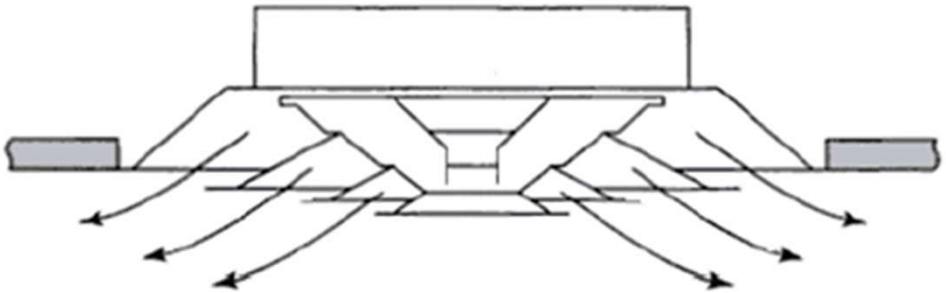


(Source: *Wang, S. K., 2001. Handbook of Air Conditioning and Refrigeration*)

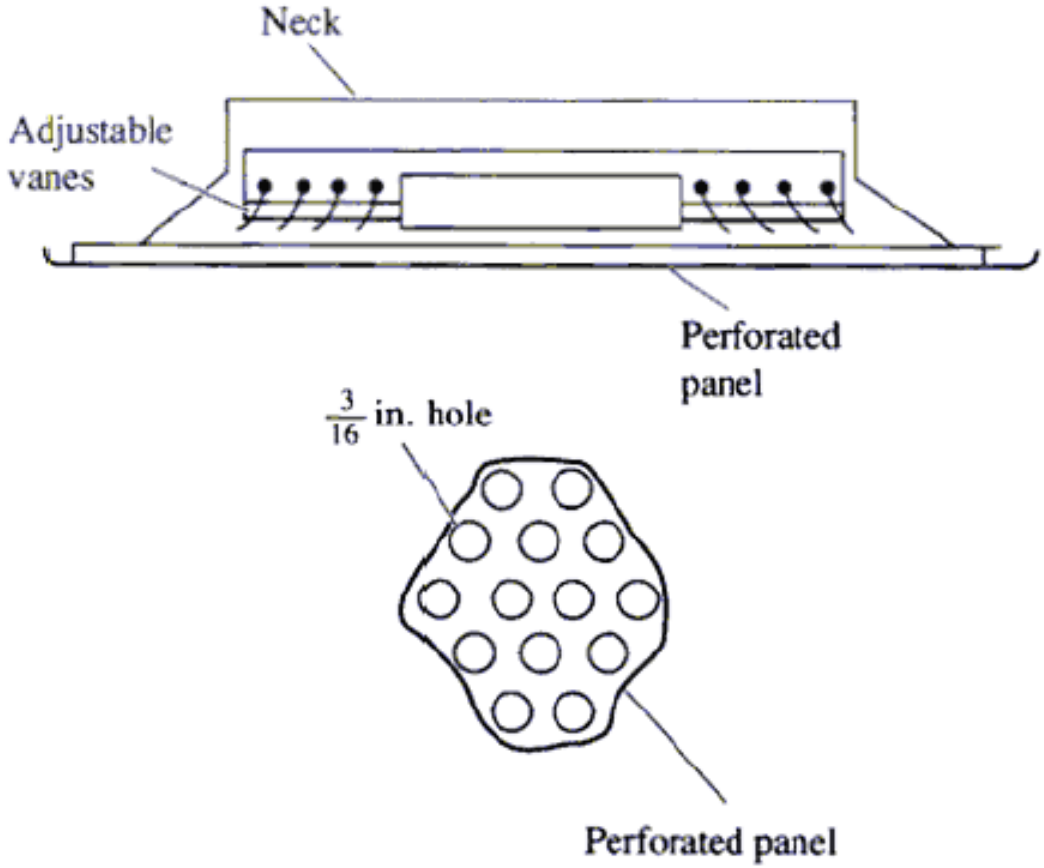
Ceiling diffusers



Square & rectangular



Removable inner-core



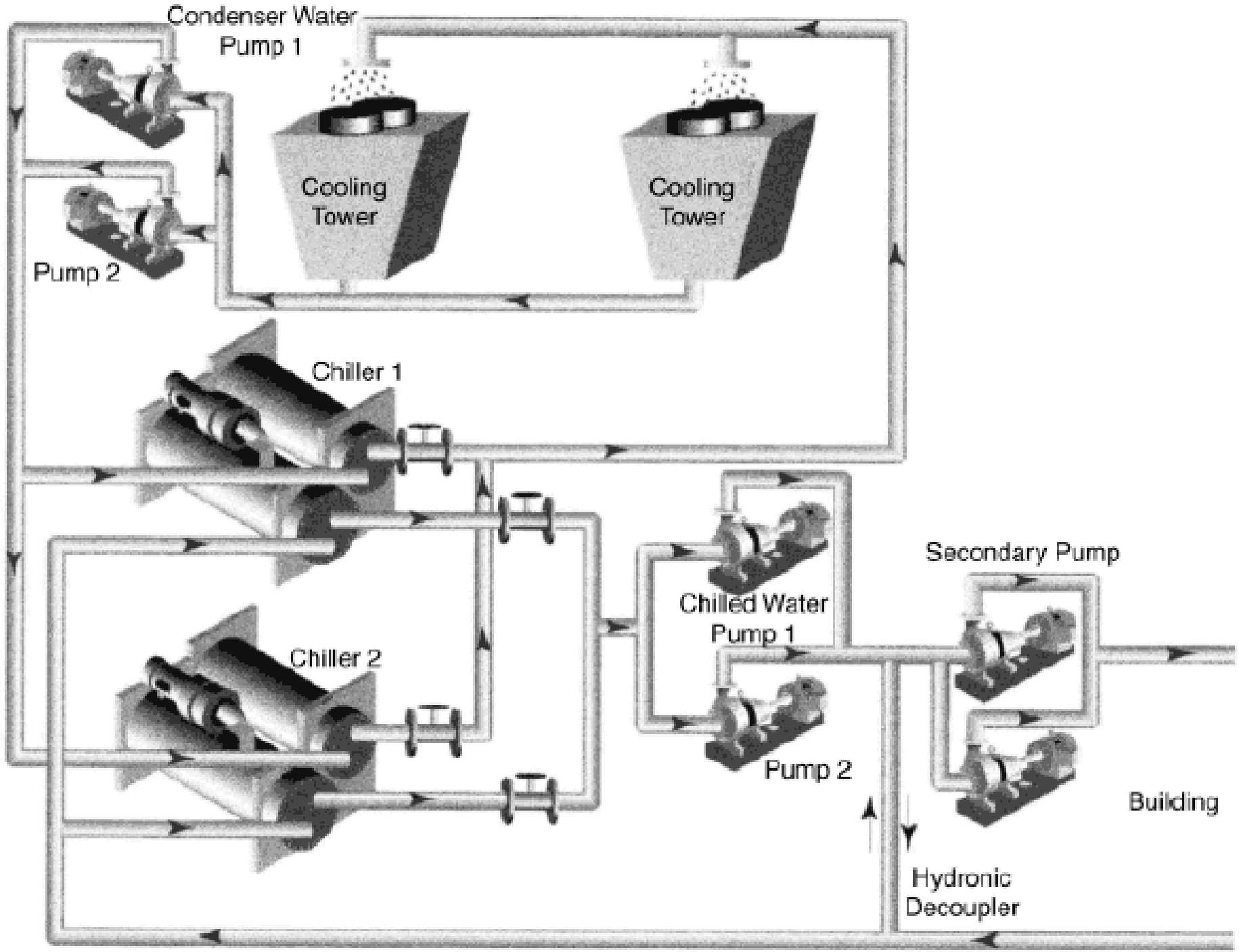
Perforated ceiling diffuser

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

HVAC water-side equipment

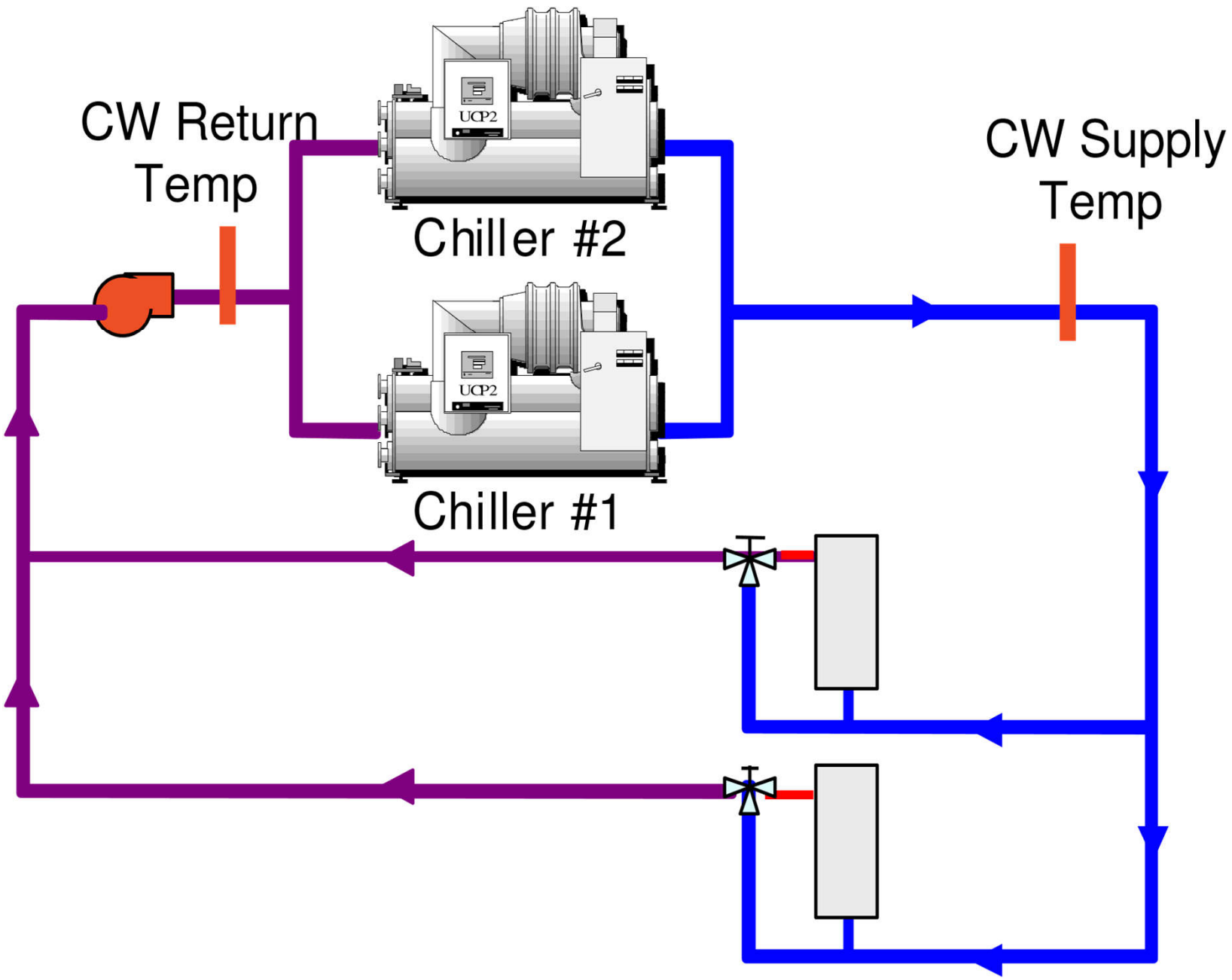
- Common types of HVAC piping systems
  - Chilled water (CHW) system
  - Condenser water (CW) system
  - Sea water system
  - Hot water supply system
  - Steam pipes, gas pipes

- Similar systems in other building services
  - Water supply & distribution (plumbing)



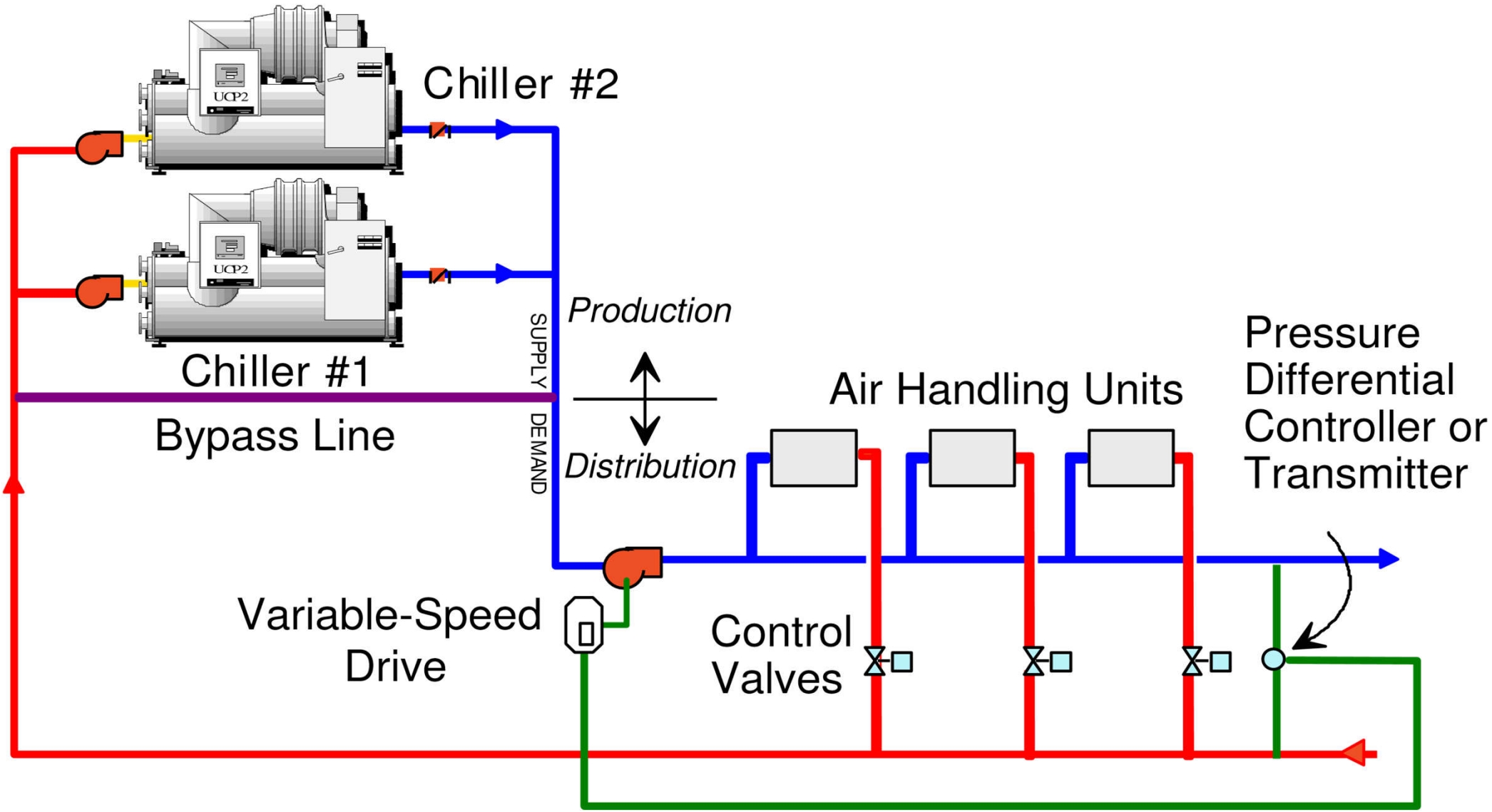
[Source: Kreider, K. F. (ed.), 2001. *Handbook of Heating, Ventilation, and Air Conditioning*, CRC Press, Boca Raton, FL.]

Constant flow



(Source: Trane)

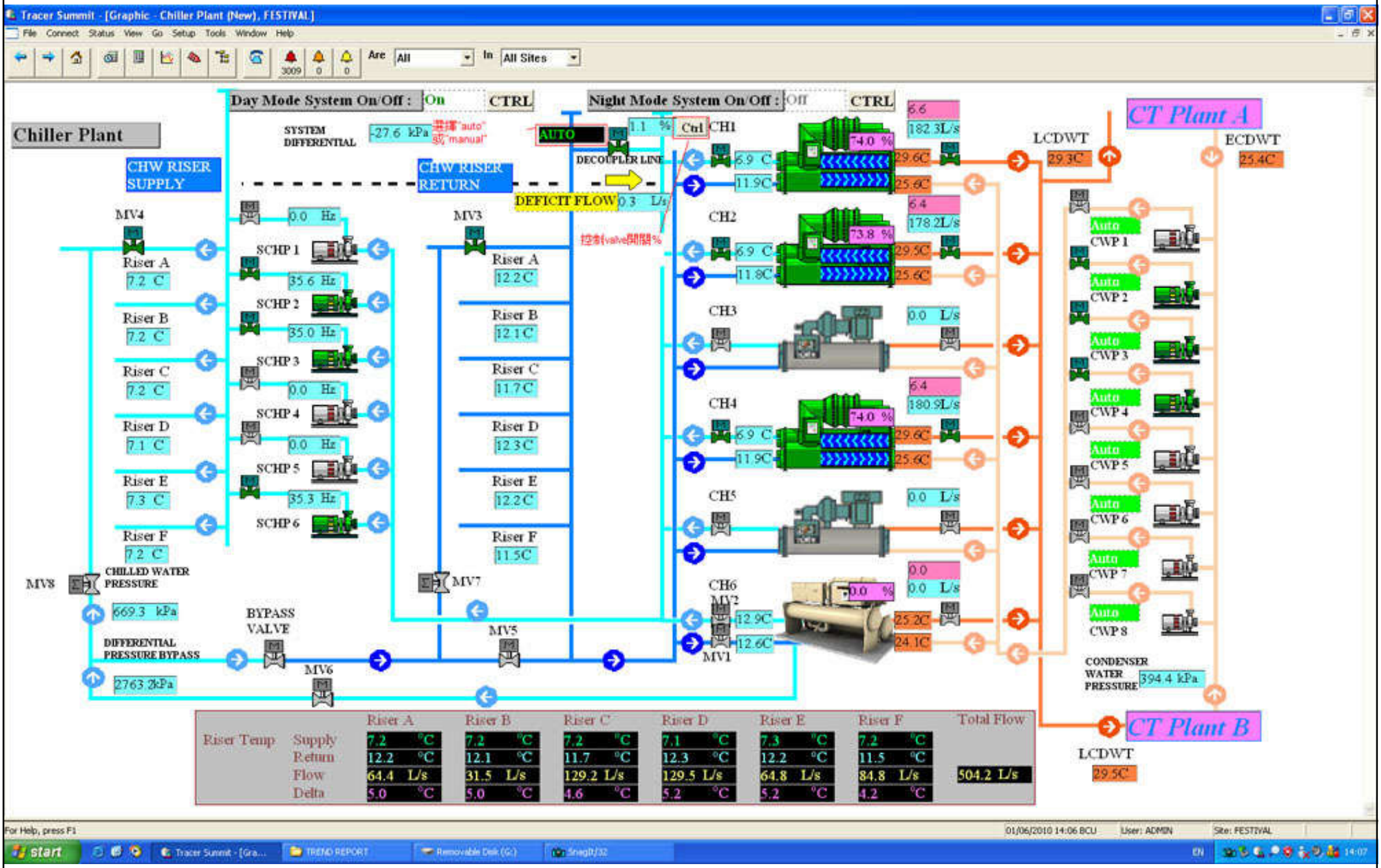
Variable flow – decoupled (primary-secondary flow)



Old paradigm: Variable flow causes low temperature trips, locks out chiller, requires manual reset (may even freeze). Hence, maintain constant flow through chillers in the primary loop.

(Source: Trane)

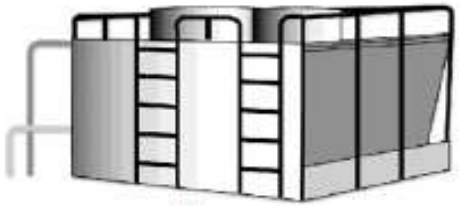
Example of chiller plant control interface



(Source: Trane)

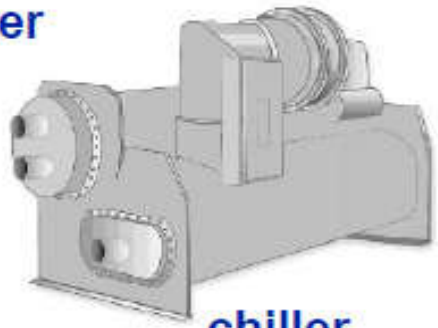
Chiller system components

cooling coil



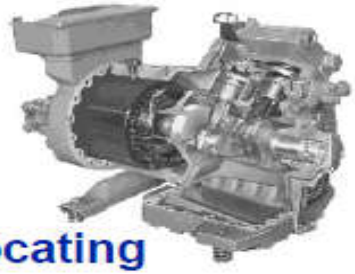
cooling tower

pumps



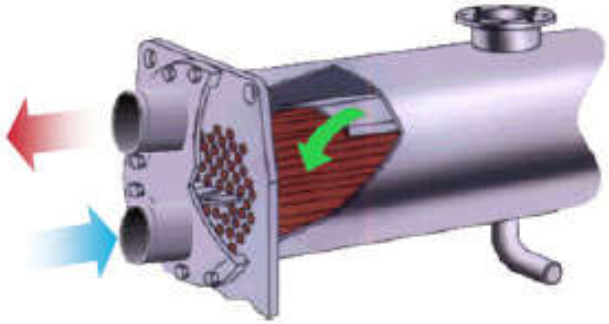
chiller

air-cooled chiller

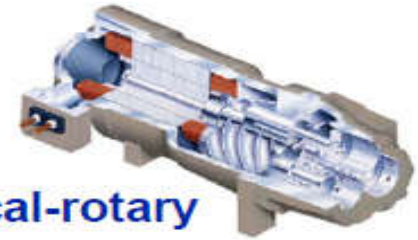


reciprocating

scroll



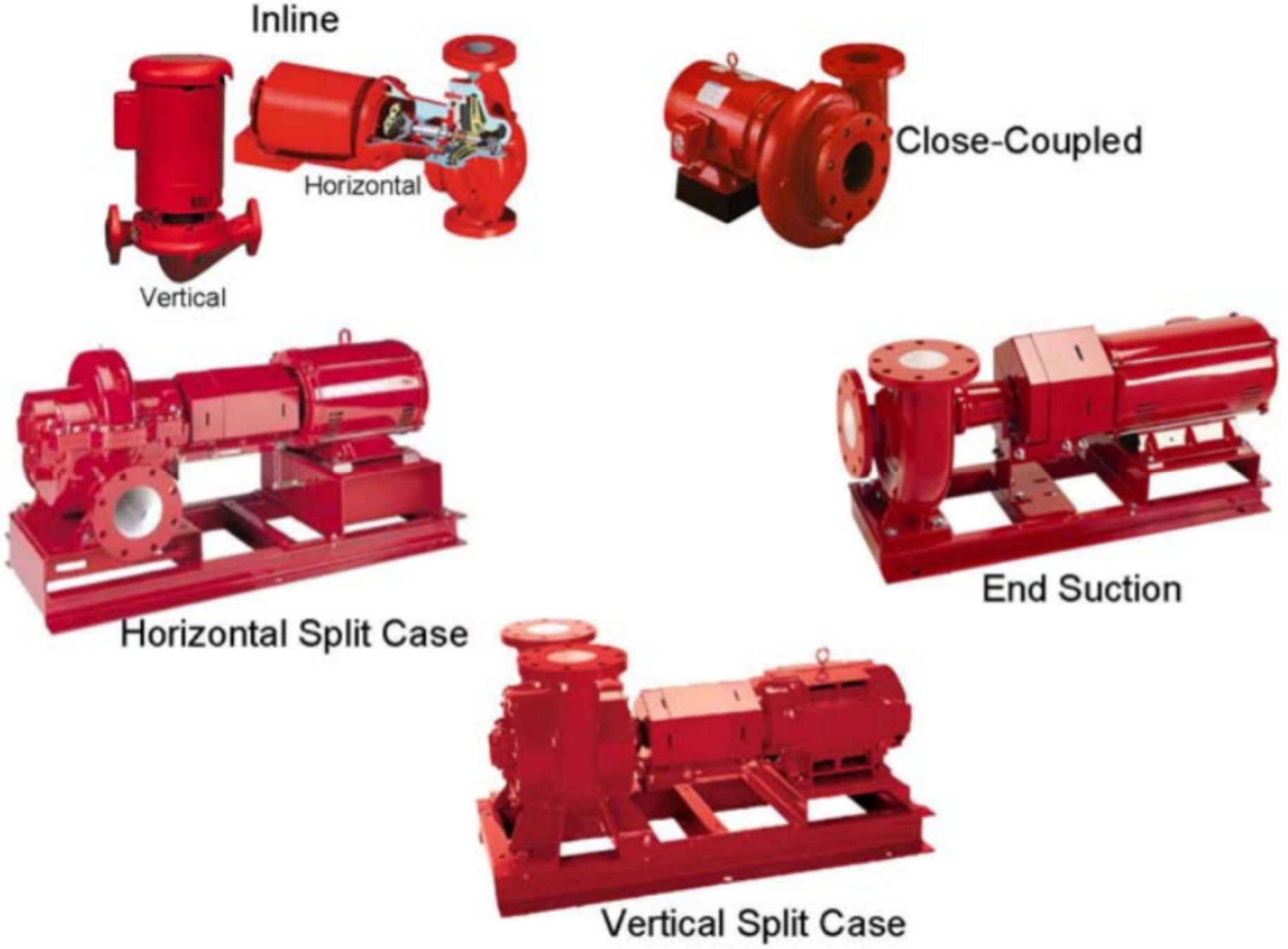
water-cooled



helical-rotary

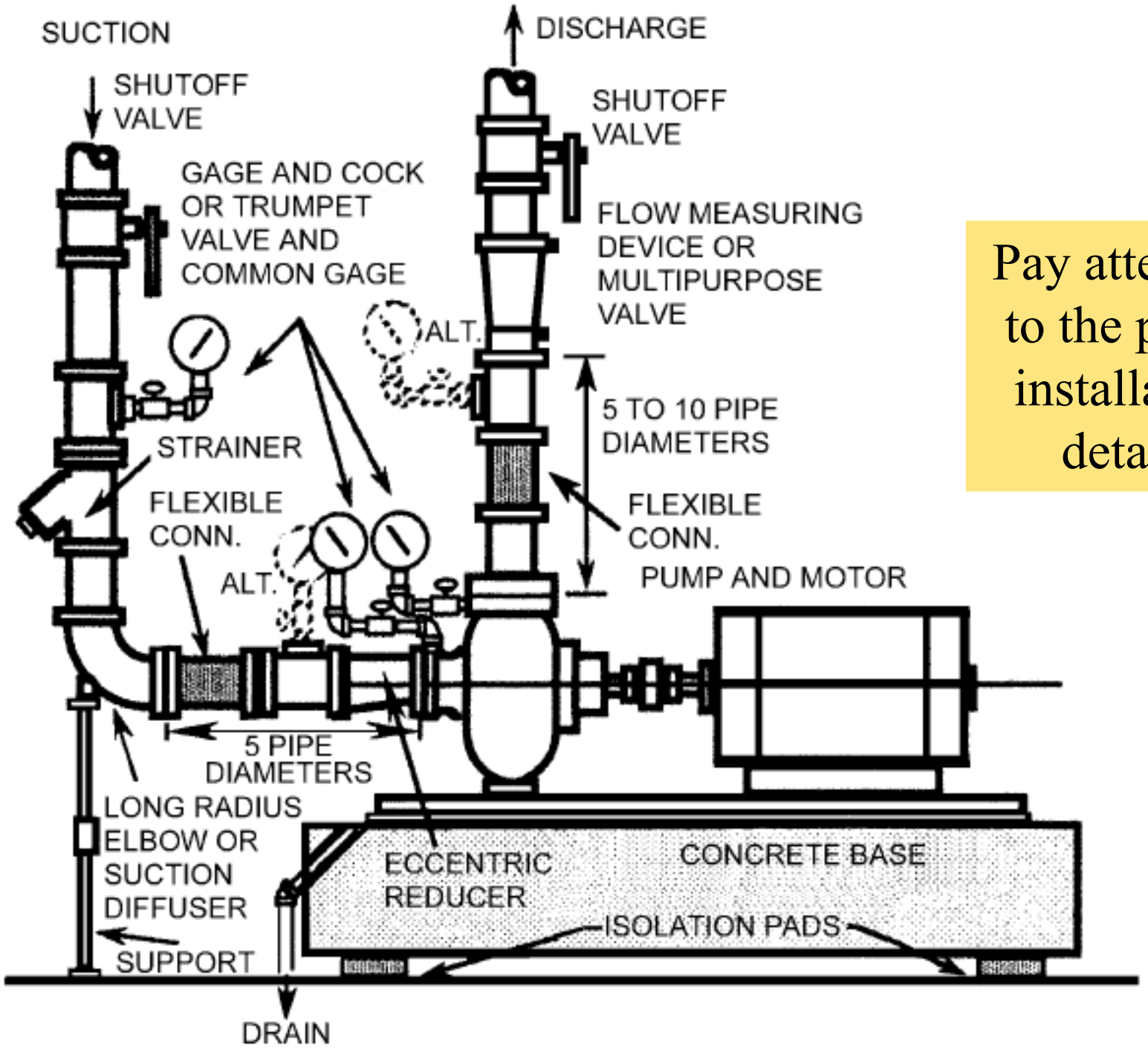
centrifugal

Types of centrifugal pumps



(Source: Carrier Corporation, 2005. *Distribution Systems: Water Piping and Pumps*, Technical Development Program.)

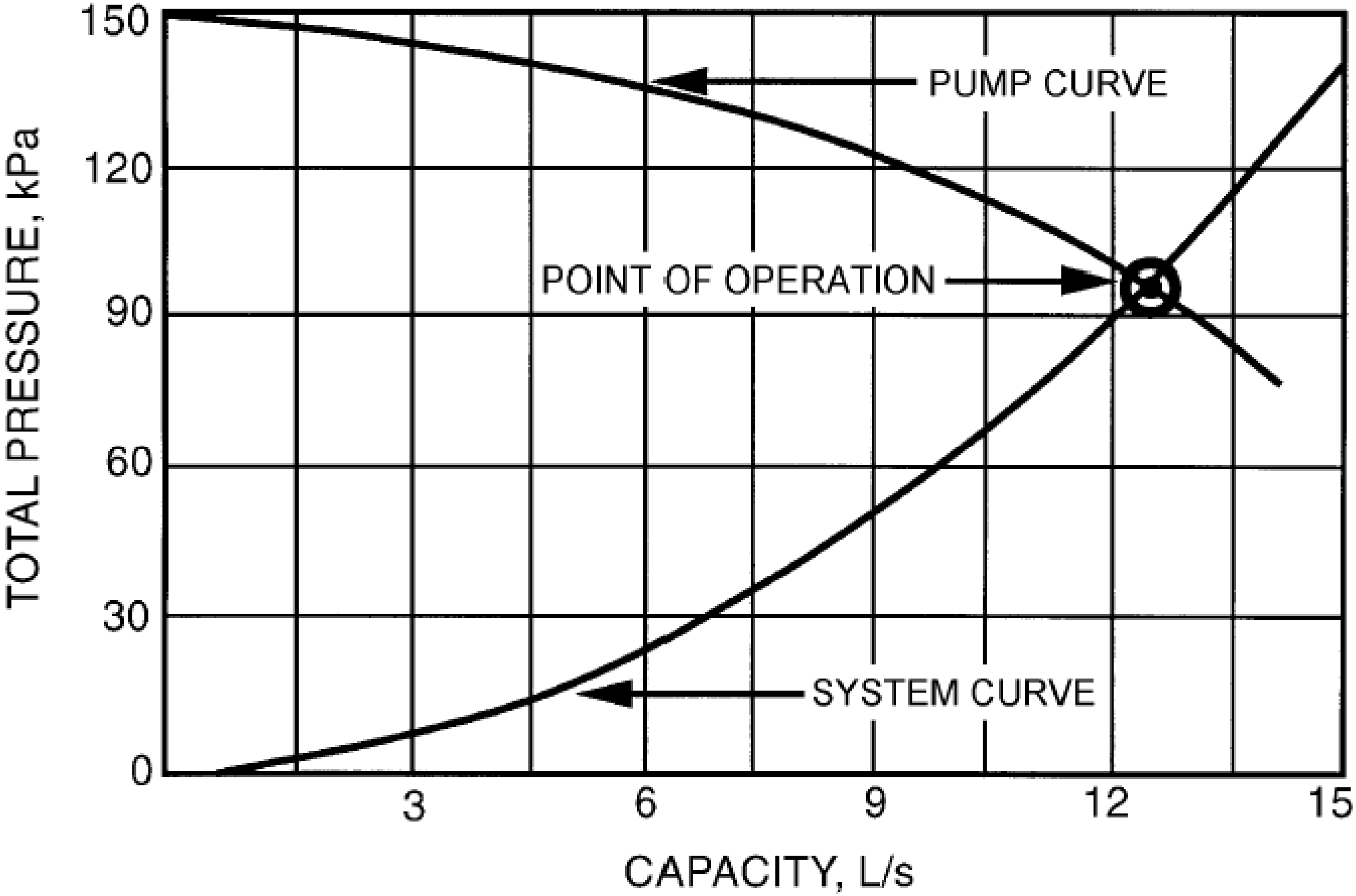
Base plate-mounted centrifugal pump installation



Pay attention to the pump installation details

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

Pump curve, system curve and point of operation

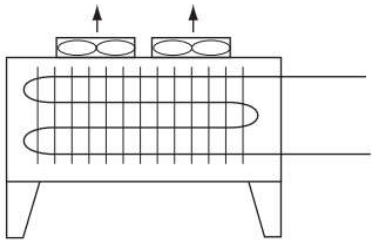
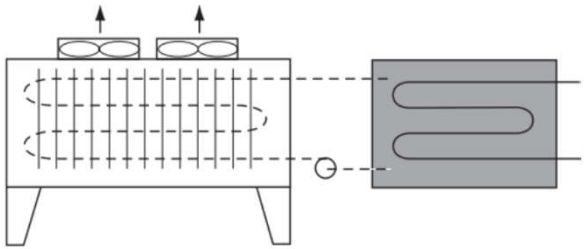
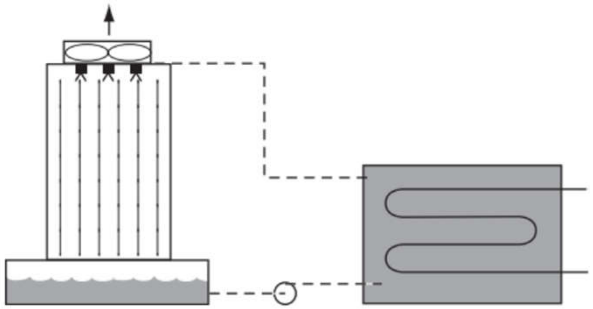
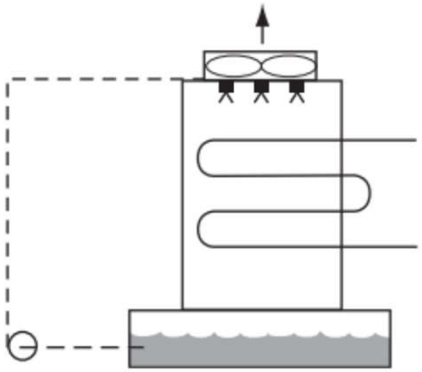


(Source: *ASHRAE HVAC Systems and Equipment Handbook 2004*)

HVAC water-side equipment

- Types of heat rejection system:
  - 1. Air cooled condenser
  - 2. Dry air cooler
  - 3. Cooling tower
  - 4. Evaporative condenser

Types of heat rejection system

(a) Air cooled condenser	Fans induce air flow over finned tubing in which refrigerant condenses.		Convenient and common for chillers up to a few 100 k W. Free of hygiene risks and do not require water piping. Can be adapted to provide free cooling with thermosiphon systems.
(b) Dry air cooler	Similar to (a) but aqueous glycol solution of water is passed through the tubes instead of refrigerant.		Less efficient than (a) because an additional heat transfer process, and pumps, are required to reject heat from a refrigeration plant. May cool water sufficiently in winter to avoid need to operate a refrigeration plant – 'free cooling'.
(c) Cooling tower	Water is sprayed over a packing material. Airflow over the packing evaporates some of the water causing the water to be cooled.		More efficient than (a) or (b) because less air is required because less air is required and water is cooled to a few degrees above the wet bulb temperature. May cool water sufficiently to avoid need to operate a refrigeration plant – 'free cooling'. High maintenance requirement.
(d) Evaporative condenser	Water is sprayed over tubing in which refrigerant condenses. Airflow across the tubing evaporates some of the water causing the water and the tubes to be cooled.		Most efficient method of rejecting heat from a refrigeration plant. Similar maintenance requirements as (c). Can be adapted to provide free cooling with thermosiphon systems.

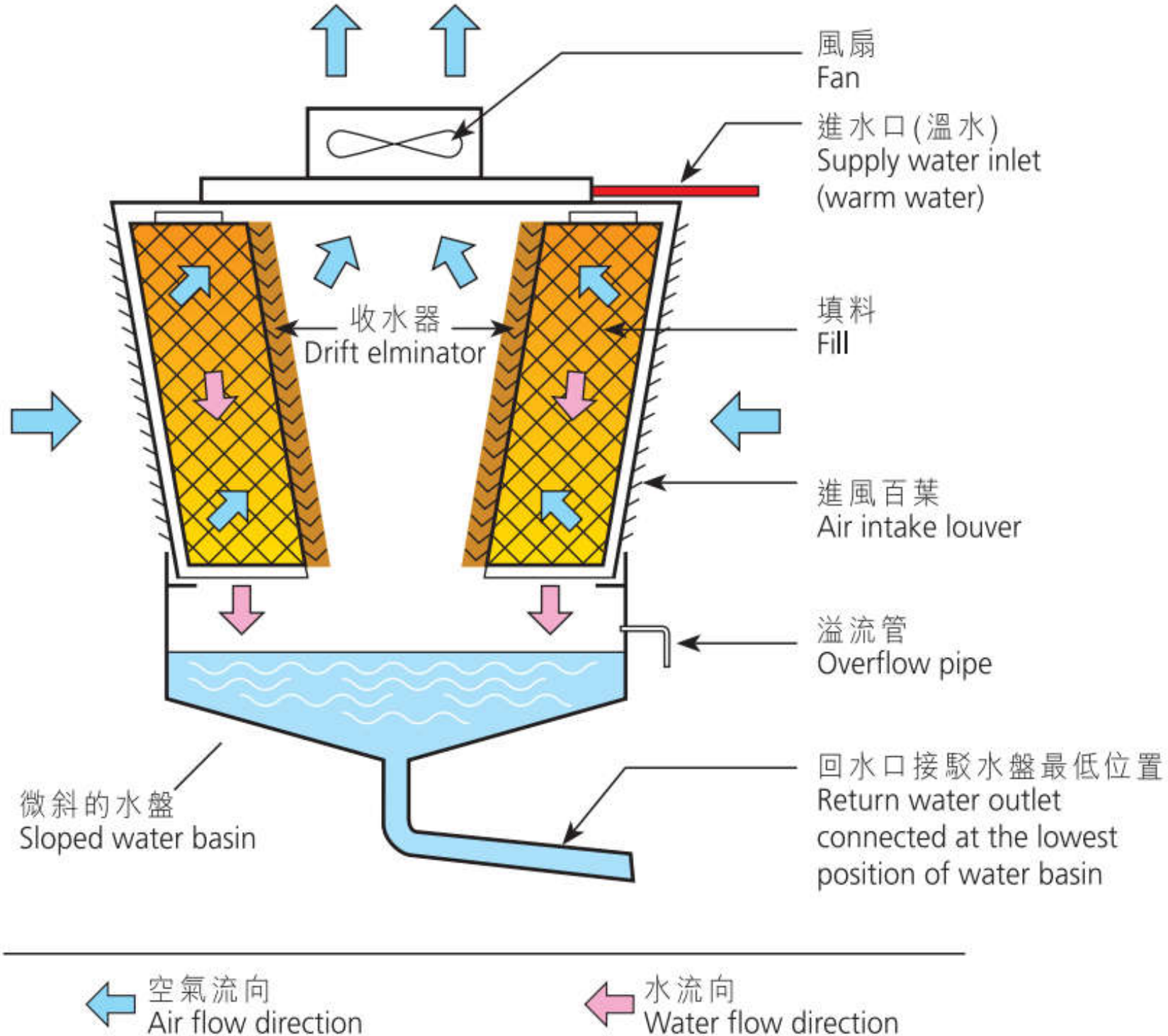
(Source: CIBSE, 2003. *Refrigeration and Heat Rejection*, CIBSE Guide B4, Chartered Institution of Building Services Engineers, London.)

Examples of air-cooled condensers

Advantages of air-cooled over water-cooled system:

- No problem of water freezing
- No water treatment required
- No condensing water pump required
- Lower initial cost

A typical cooling tower configuration

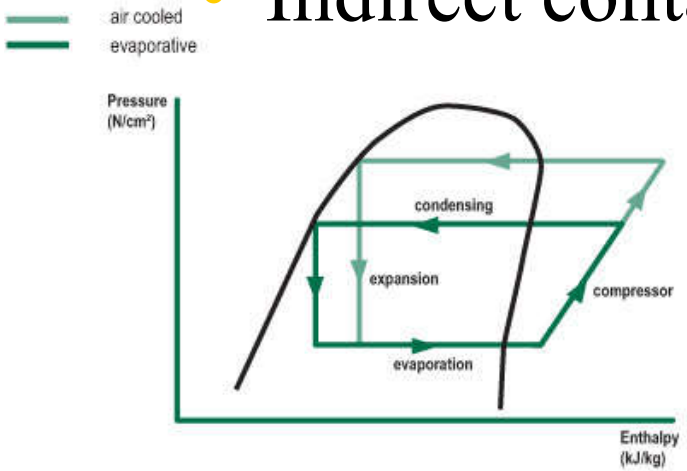


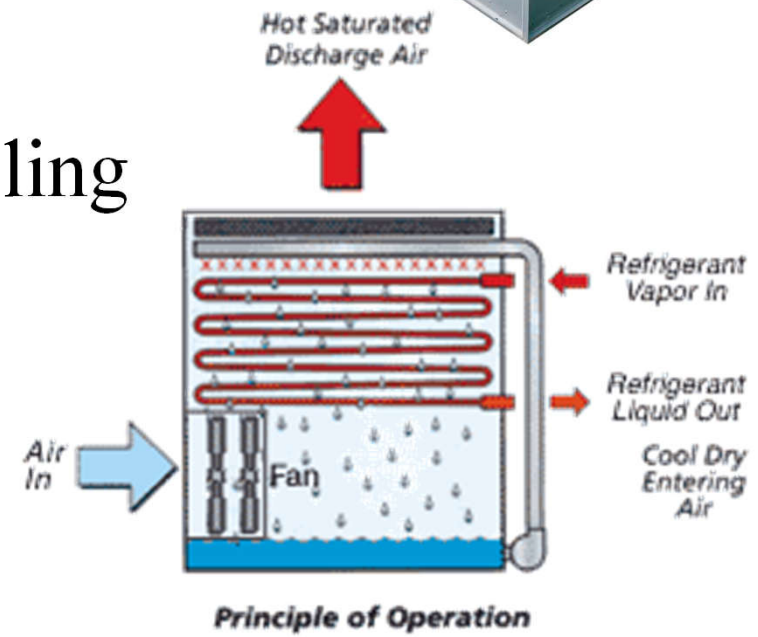
(Source: EMSD)

Structure of an induced draft, counterflow cooling tower

HVAC water-side equipment

- Evaporative condensers
  - Uses both air and water
  - Air flows over the refrigerant coil
  - Water flows over the coil when needed
  - Water remains in the condenser
  - Indirect contact evaporative cooling





Operation & maintenance

- HVAC operation & maintenance (O&M)
  - Keep the systems working at peak performance during the life of the building
  - Good design can make the HVAC systems easier to operate & maintain
- System performance
  - Thermal comfort (e.g. temperature, humidity)
  - Energy use (e.g. electricity consumption)
- Proper commissioning is important

HVAC operation & maintenance

清洗, 保養, 維修, 通去水喉及入雪種

Typical issues of a HVAC maintenance plan

- Periodic maintenance to be performed in accordance with the manufacturer's instructions, including details of all inspections that will be carried out
- A determination of the budget required for maintenance
- Establishing the availability of recommended parts
- Establishing proper documents for the maintenance system, including work orders, cost of each part, etc.
- Training for the technicians concerning maintenance
- The availability of operator manuals for all the HVAC equipment

Strategies for O&M:

- Contract services (by outside contractors or agencies)
- In-house maintenance (by its own technicians & staff)

HVAC components:

- Filters
- Evaporator & condenser coils
- Compressor
- Fan, bearings & belts

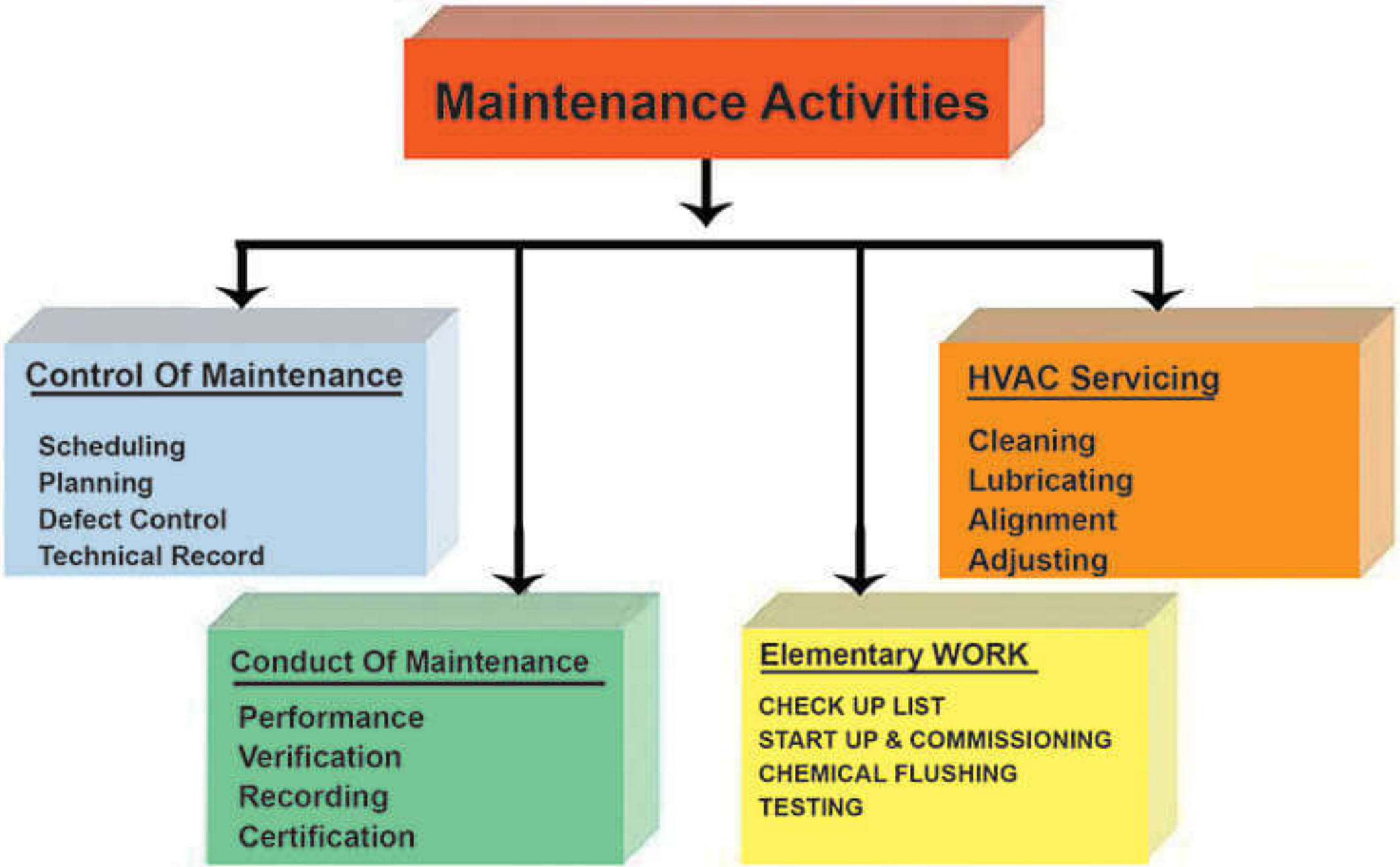
Operation & maintenance

- Operation manuals
  - High quality operations are ensured by good design process & regular maintenance
  - O&M manuals for the operating staffs which specifies the design intent, maintenance list, replacement schedule, etc.
    - The manual should clearly explain the parameters that are conducted during commissioning
    - Without a manual, operations staff are left to troubleshoot systems through piecemeal guesswork

Operation & maintenance

- Maintenance schedules
  - For cleaning ducts, filters & other components
  - For replacing filters
  - For measuring energy use & comfort
  - Performance measurements should be done monthly or at least quarterly, to provide operators with enough data to tell when systems are beginning to perform poorly
    - Building automation systems can provide hourly data on temperature, humidity, and energy use

Major maintenance activities for HVAC systems



Operation & maintenance

- Occupant behaviour & flexibility
  - When building occupants bring in their own space heaters or desk fans, it may be an indication that the HVAC system is not working as designed, or was not designed to meet the current users' needs
  - Have the flexibility to work with users to meet their needs while ensuring energy efficiency
    - This may mean changes to the original design, or helping occupants choose efficient products for their personal use

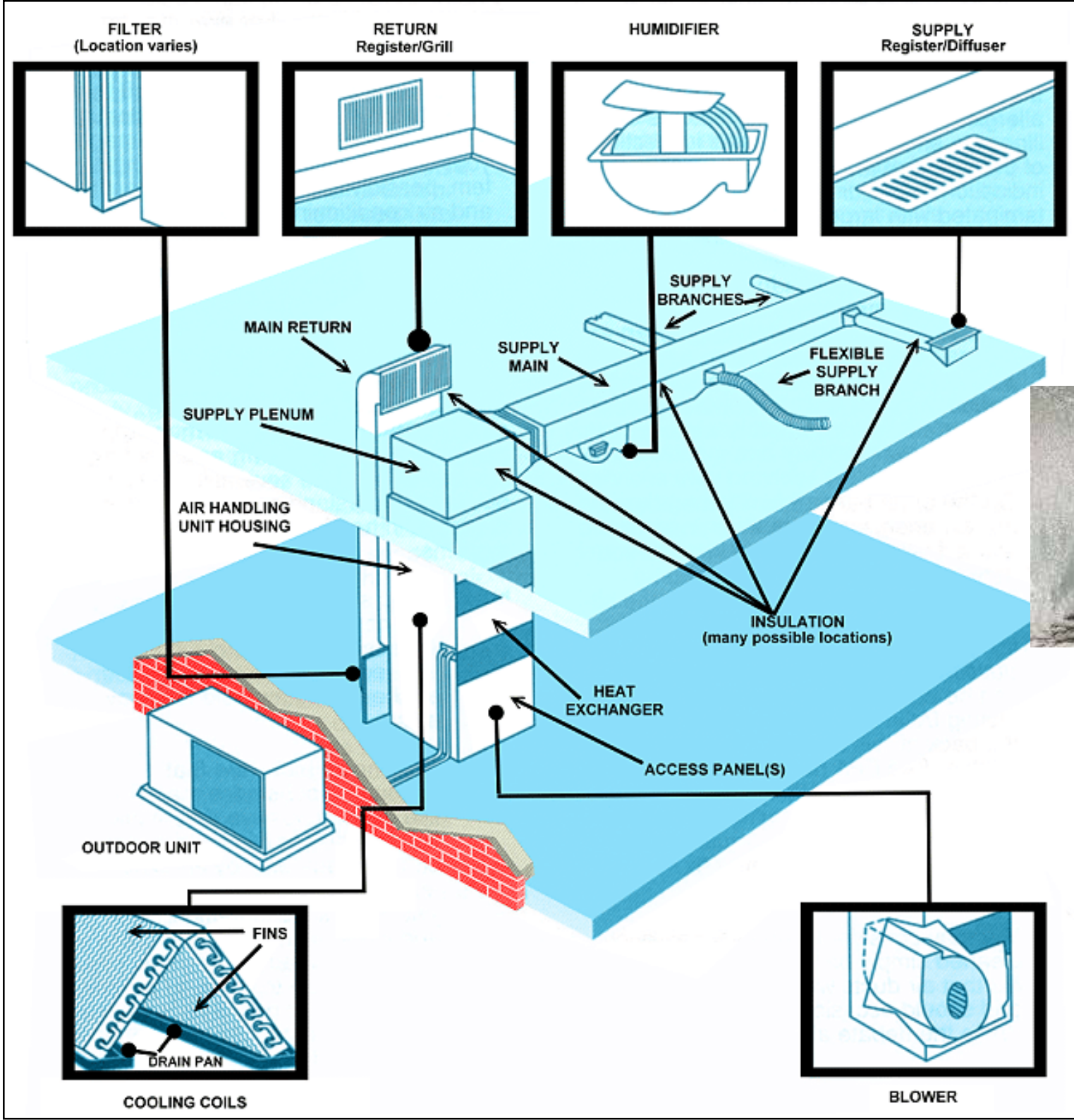
Operation & maintenance

- Filter cleaning & replacement
  - Keeping filters clean is an important factor in energy performance & indoor air quality
    - This is the most frequently neglected aspect of HVAC operations, because HVAC machines do not break down often but filters do require regular attention
  - Some filters are designed to be cleaned by spraying with water or vacuuming; others should simply be replaced
    - Not only filters in ducts, but filters in furnaces, heat pumps, and other devices

Operation & maintenance

- Cleaning components
  - Other components require periodic cleaning too
    - Ducts must be kept clean of dust, mould, and other contaminants for good indoor air quality
    - Dirt & dust that settles on coils acts as an insulator
    - Crooked or crushed fins restrict air flow, reducing the effectiveness of convective cooling
  - Dehumidifiers & air conditioners should have their condensate drains checked
    - Blocked drains will cause condensed water to pool up and possibly causing leakage, mould & mildew

Cleaning HVAC components



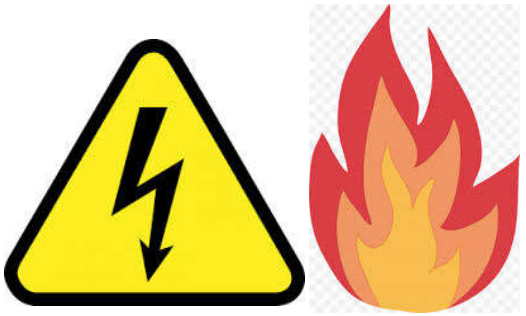
Operation & maintenance

- Operation of control systems
  - Programmable thermostats schedule the heating and cooling of HVAC systems
    - Those schedules must match the occupancy & activity of the system and must be changed in accordance to the age of the building
    - Temperature, occupancy, humidity sensors should be checked regularly for the proper operation
  - Control systems that function but are not tuned according to occupant preferences may get manually disabled by them

Examples of maintenance service for cooling tower

Type of Service	Monthly	Quarterly	Start-Up	Shutdown	Annually
Inspect General Condition of Tower	X		X		
Inspect and Clean as Necessary:					
A) Cold Water and Hot Water Basins	X		X	X	
Flush Cold Water Basin to Remove Silt		X			
B) Optional BALANCE CLEAN® Chamber Inlet Strainer	X		X	X	
C) Air Inlet Louvers	X		X	X	
Check and Adjust Water Level in:					
Cold Water Basin/ Hot Water Basin ·	X		X		
Check Operation of Make-Up Valve	X		X		
Check Bleed Rate and Adjust	X		X		
Power Train:					
A) Check Condition of Belt	X		X		
B) Readjust Tension on Belt		X			
C) Drive Alignment					X
Lubricate Fan Shaft Bearings		X	X	X	
Lubricate Motor Base Adjusting Screw		X	X	X	
Clean Outside of Fan Motor		X	X	X	
Inspect Protective Finish					X

HVAC safety tips



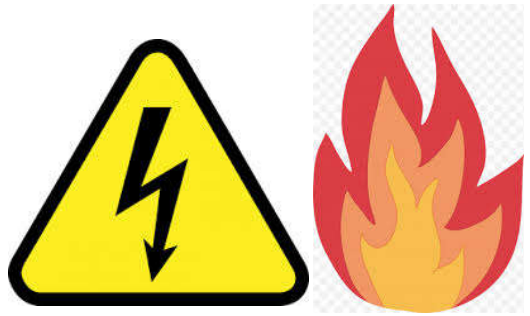
- Common HVAC work safety & health issues:
  - Work at height
    - Safe use of working platforms, scaffolds, and truss-out scaffolds (with brackets & anchor bolts)

  - Electrical safety
    - Safe use of electrical installation & equipment, tools
  - Refrigerants (& gas cylinders)
    - Safety in transport & storage of refrigerants
    - Safe use of refrigerants

  - Fire safety & smoke control

(Source: https://www.labour.gov.hk/eng/public/pdf/GN_for_Air_conditioning_Works_ENG.pdf)

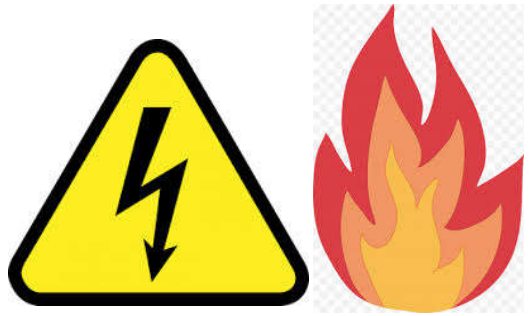
HVAC safety tips



- HVAC electrical & fire hazards:
  - Overload of HVAC appliances
  - Malfunction in the wires or protective devices
  - Bad electrical connections & broken parts
  - Overheat of heating equipment
  - Highly flammable substance (e.g. oil & gas) is coming into contact with hot elements inside the HVAC unit
  - Clean chemicals, solvents & construction materials may react to heat or catch fire
  - Refrigerant leak & flammable refrigerant
  - Handling of compressed gas cylinders (explosion risk)

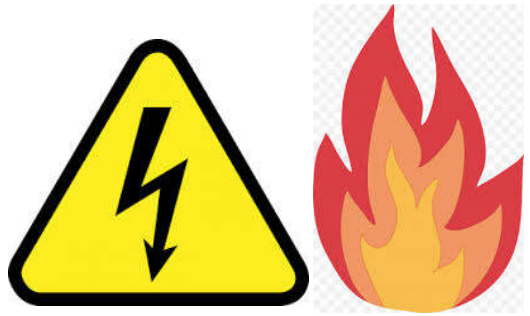
HVAC electrical & fire hazards

HVAC safety tips



- How to avoid the hazards:
  - Regular maintenance to prevent instances of damage, leakage, or circuitry problems
  - Prioritize control of any HVAC equipment used for smoke control (e.g. staircase pressurization fans, smoke exhaust fans)
  - Coordinate zoning of HVAC equipment with the smoke control zoning
  - Ductwork that penetrates fire-resistance rated walls to be protected with fire/smoke dampers

HVAC safety tips



- HVAC safety precautions:
  - Proper HVAC safety training
  - Evaluate the work environment before starting the work
  - Take electrical safety precautions
  - Use proper personal protective equipment (PPE)
  - Protection against falling from height or ladder
  - Follow chemical & refrigerant safety best practices