

7. HVAC Part 3

7.2 HVAC trouble shooting and testing



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- HVAC trouble shooting 暖通空調故障排除
- Direct expansion (DX) systems 直膨式系統
- Testing & commissioning 測試和調試
- Inspection & regulations 檢驗與法規

3 Steps for HVAC Troubleshooting



1. Know the Normal

Is the HVAC unit functioning the way it should be?



2. Eliminate Unnecessary Work

Find the problem quickly so you don't waste time.



3. Discuss with the Customer

Tell your client exactly what you need to do and why.

HVAC trouble shooting



- General trouble shooting steps:
 - 1. Customer communication
 - 2. Inspect using your senses
 - 3. Verifying power
 - 4. Heat exchange medium (e.g. air, water, glycol)
 - 5. Full system diagnoses
- Technicians should consider themselves skilled trades “detectives”



HVAC trouble shooting



- To diagnose the problems, start with the easy, visible items and work your way to the hidden components

故障排除



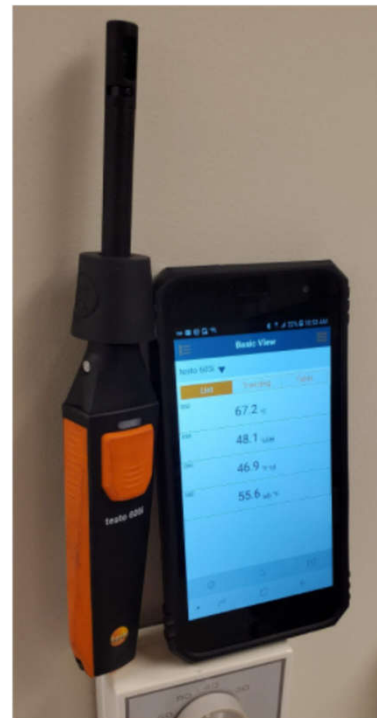
HVAC trouble shooting



- HVAC diagnosis tools
 - Manifold gauges
 - Temperature probe or clamp
 - Multi-meter
 - Dual port manometer
 - Electronic refrigerant leak detector
 - Hygrometer, rotating vane or hot wire anemometer
 - Combustion analyzer
 - Infrared temperature gun, thermal imager



Examples of HVAC diagnosis tools



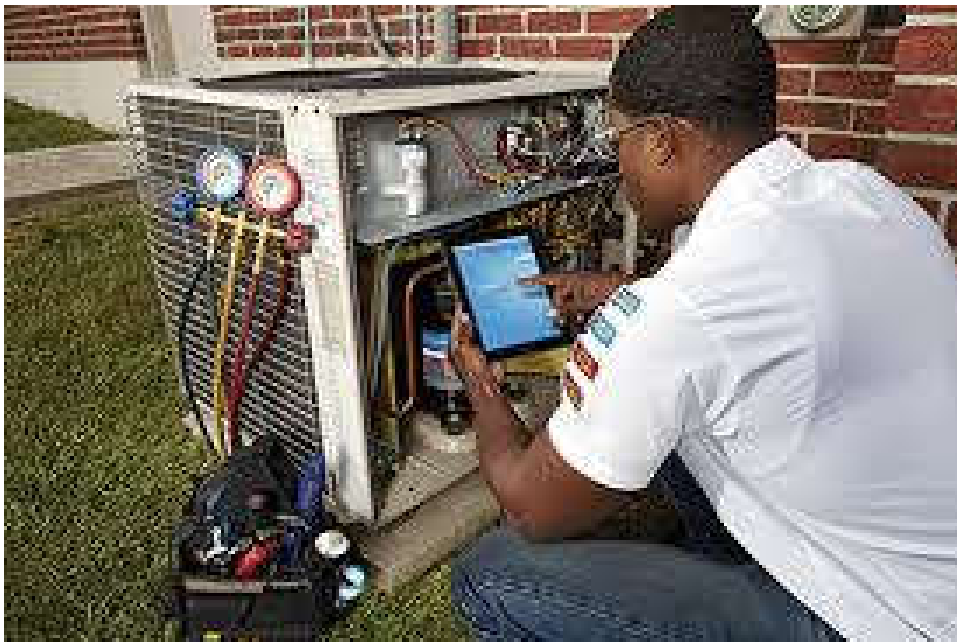
HVAC troubleshooting & diagnostic tips

5 troubleshooting tips:

- 1. Observe
- 2. Think locally
- 3. Establish a pattern
- 4. Accept help
- 5. Practice

5 diagnostic tips:

- 1. Be safe
- 2. Start at the beginning
- 3. Always check the thermostat
- 4. Look and listen
- 5. Mechanical or Electrical?



HVAC trouble shooting



- HVAC repair & troubleshooting process
 - Preparation
 - Observation
 - Define the problem area
 - Identify possible causes
 - Determine the most probable cause
 - Repair and test
 - Follow-up



HVAC trouble shooting



- Common HVAC problems & possible reasons
 - HVAC equipment won't turn on (lack of power)
 - The thermostat is not working (setting/calibrated)
 - The system is not cool (low refrigerant)
 - Condenser problems (dirt deposition)
 - Evaporator problems (frozen coil)
 - Leaking or dirty ducts (lack of checking/cleaning)
 - Drainage difficulties (clogged drain)
 - Noisy fan system (worn belts, bearings, fan motor)



HVAC Air / Refrigerant Diagnostic Quick Sheet

Fixed Metering	Suction Pressure	Head Pressure	Super heat	Subcool	Comp. Amps	Δt
Low Charge	↓	↓	↑	↓	↓	↓
Over Charge	↑	↑	↓	↑	↑	Norm ↓
Low Indoor Airflow/Low R/A Temp	↓	Norm ↓	↓	Norm ↓	Norm ↓	↑
Dirty Condenser	↑	↑	Norm ↓	Norm ↓	↑	↓
Liquid Line Restriction*	↓	Norm ↓	↑	↑ Norm	↓	↓
Oversized Piston	↑ Norm	Norm ↓	↓	↓	↓	Varies
High R/A Temp	↑	↑	↑	Norm ↓	↑	Norm ↓

TXV =
thermostatic
expansion
valve

TXV System	Suction Pressure	Head Pressure	Super heat	Subcool	Comp. Amps	Δt
Liquid Line Restriction*	↓	Norm ↓	↑	↑ Norm	↓	↓
Overfeed / Loose Bulb Bulb Insulated	↑	↓	↓	↓	↓	↓
Low Charge Slightly	Norm	↓	Norm	↓	↓	Norm
Over Charge Slightly	Norm	↑	Norm	↑	↑	Norm
Low Indoor Airflow/Low R/A Temp	↓	Norm ↓	↓	Norm ↓	Norm ↓	↑

Refrigeration system symptoms & diagnostic

Symptom	SUCTION PSI	SUPER HEAT	HEAD PSI	SUB COOL	AMPS
Restricted Cond. Coil	↑	↓	↑	↓	↑
Restricted Evap. Coil	↓	↓	↓	↓	↑
Heavy Load	↑	↑	↑	↑	↑
Light Load	↓	↓	↓	↓	
Noncondensable	↑	↓	↑	↓	↑
Undercharge	↓	↑	↓	↓	↓
Overcharge	↑	↓	↑	↑	↑
Bad Valves	↑	↔	↓	↔	↓
Liquid Line Restriction	↓	↑	↓	↑	↓
Suction Line Restriction	↓	↑	↓	↑	↓
Overfeeding Metering Device	↑	↓	↓	↓	↑
Missed Refrigerants	↓	↔	↓	↔	
Underful Metering Device	↓	↑	↓	↑	↓
Low Outdoor Ambient	↓	↑	↓	↑	↓

HVAC trouble shooting



- Common problems in HVAC controls
 - A sensor or actuator may fail due to aging, stress or physical damage
 - Setups fail as a result of communication cabling or downstream devices
 - A field controller is not receiving an acceptable value from a sensor
 - A DDC panel is not communicating
 - A workstation becomes disconnected



HVAC trouble shooting



- How to identify & determine problem in HVAC controls & BMS
 - Controller checks
 - Ethernet checks
 - Cabling checks
 - Signal checks
- Intermittent problems
 - Happens randomly; most difficult to troubleshoot
 - May use a logging multimeter or oscilloscope
- Power problems & analog checks



HVAC trouble shooting



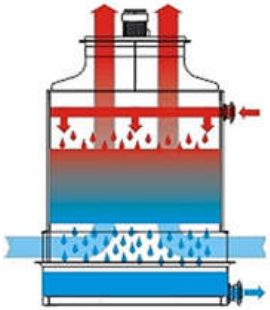
- Verification of BMS system components
 - Wiring & cabling verification
 - Input & output verification/test
 - System sequence test/phase test
 - Software functionality, backup, archiving, and version verification
 - Software structure verification
 - IT infrastructure verification IT



HVAC trouble shooting



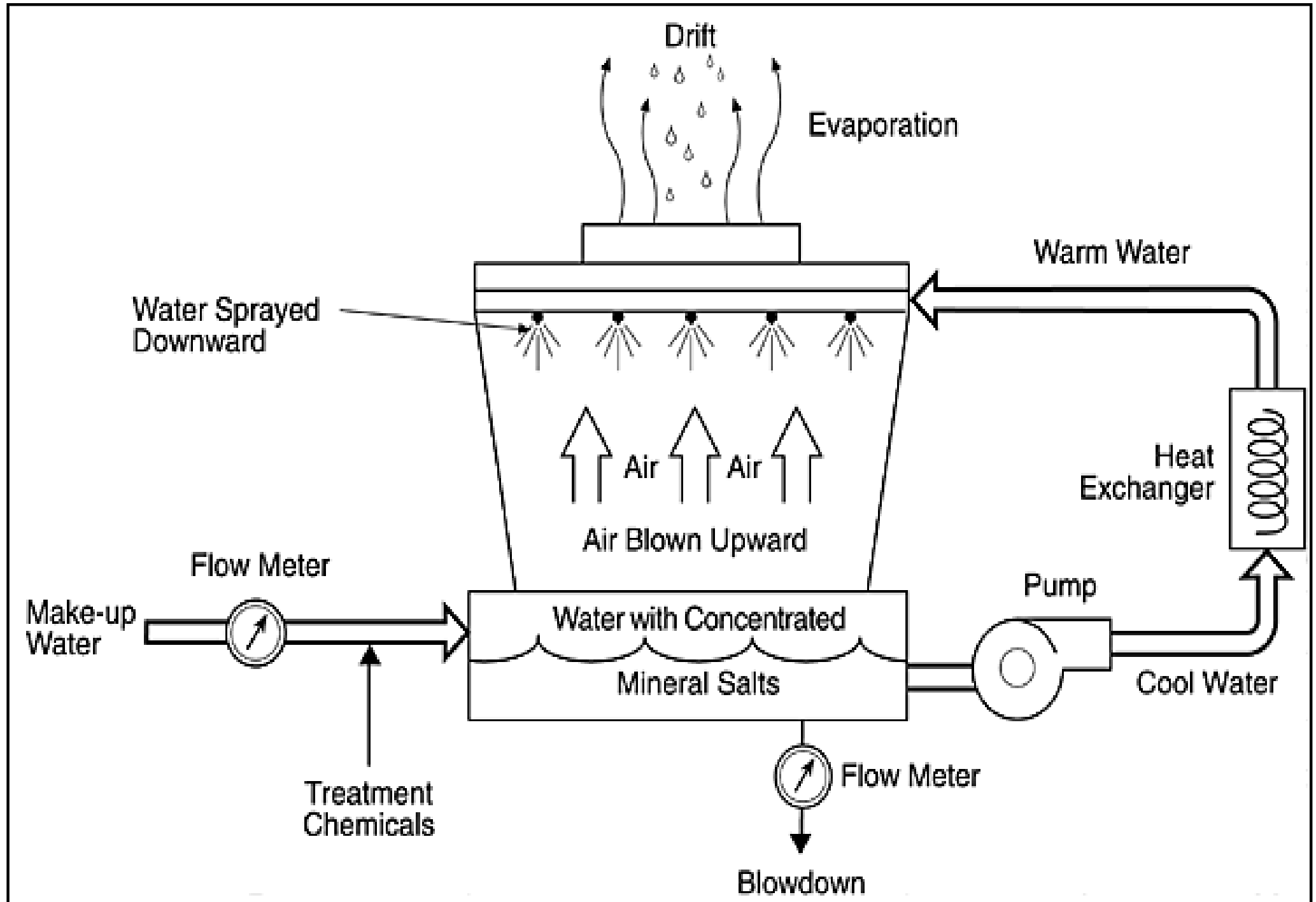
- Cooling towers 冷卻塔



- Operation and maintenance (O&M) work mainly comprise routine checking and upkeeping of conditions of components (e.g. water basin and drift eliminator) and associated equipment (e.g. pumps and valves), water treatment, and cleaning, desludging and disinfection of cooling towers
- Fresh water cooling towers could be sources of spreading Legionnaires' disease 退伍軍人症



Main features of cooling towers



HVAC trouble shooting



- Troubleshooting of cooling towers
 - Water dissolves many things (especially hot water)
 - Water is cooled and results in deposits in tower
 - Solid concentrate in cooling tower basin
- Problems faced by operators
 - Scale formation – suspended solids from deposits
 - Corrosion – electrochemical reactions with metals
 - Fouling – due to sit, debris, algae
 - Wood decay - fungi



Direct expansion (DX) systems

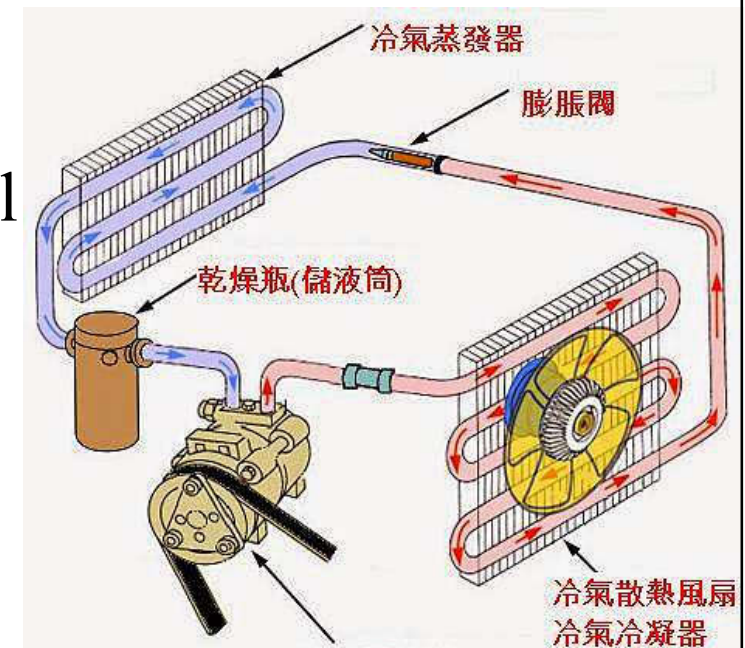


- Direct expansion (DX) system in HVAC
 - Growing rapidly due to its ability to get rid of most duct work & piping
 - Installation work is made easier hence reducing the cost of the overall system
 - The evaporator is located in the space to be refrigerated (vs chilled water system)
 - Examples:
 - Window air conditioner, split system, packaged units, and variable refrigerant flow (VRF)

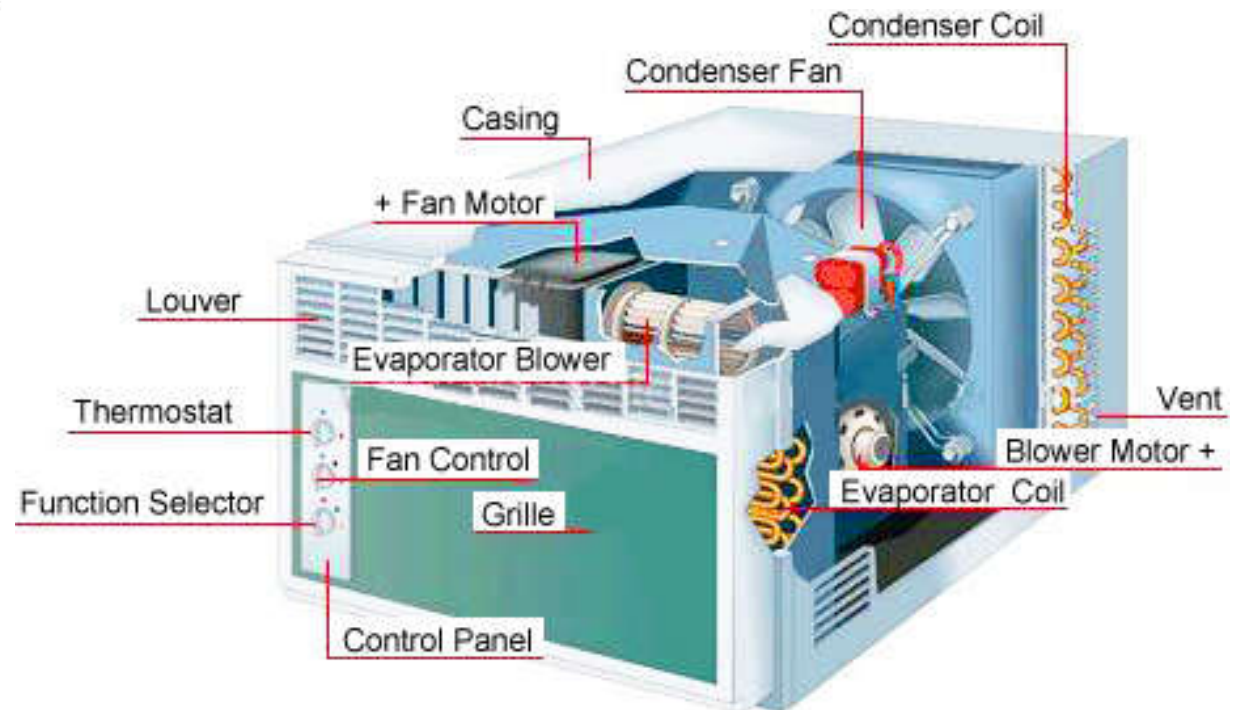
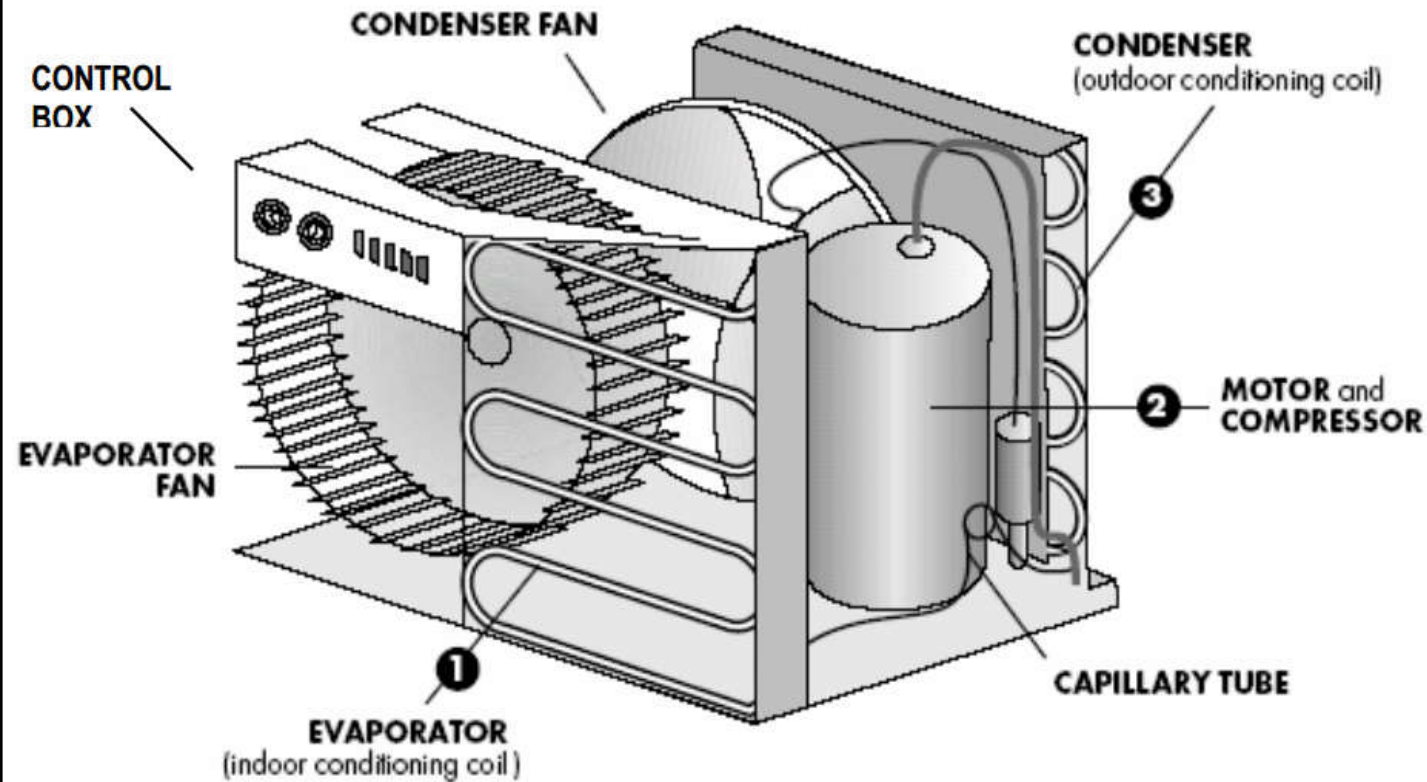
Direct expansion (DX) systems



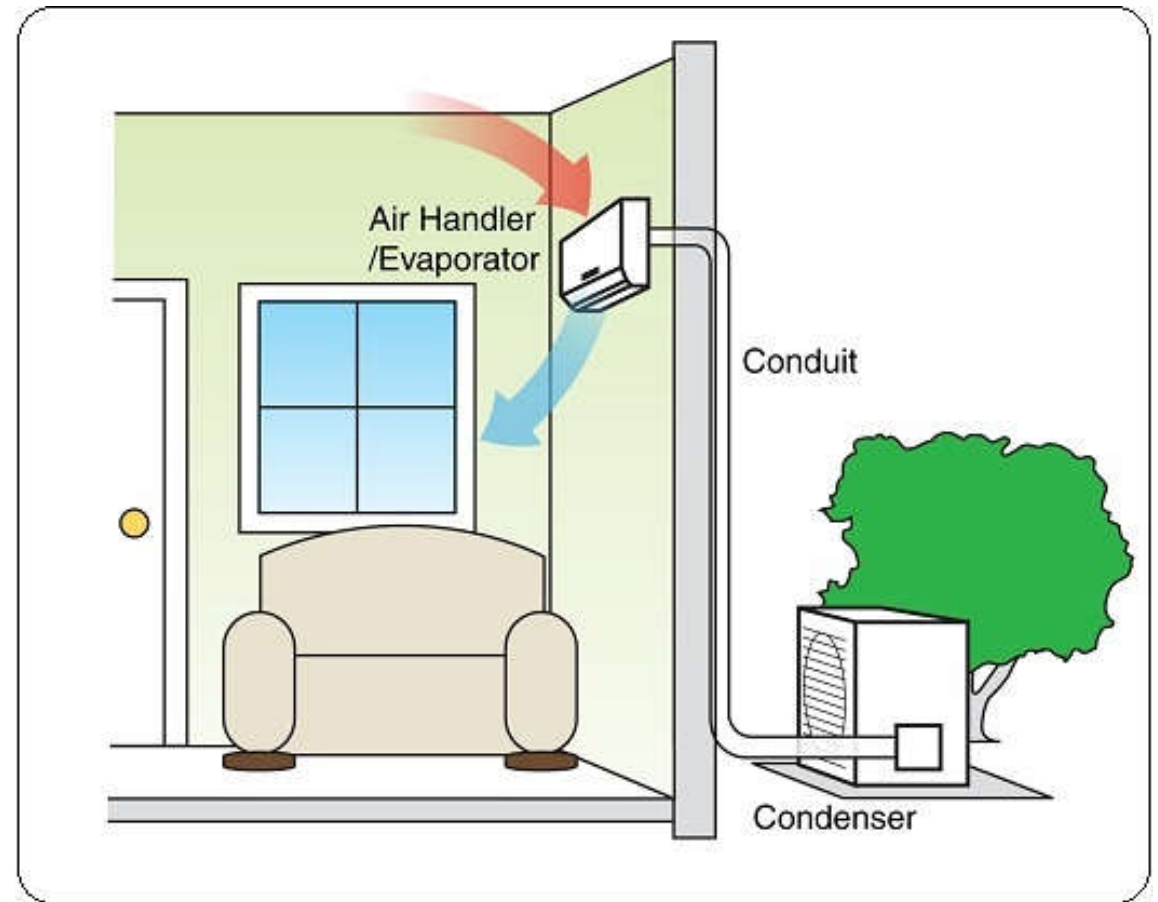
- Direct expansion (DX) systems
 - Part of the packaged air-conditioning system
 - R-22 & R-134a widely used, also new refrigerants e.g. R-32
 - Typical range: 3-100 TR
 - Components & accessories
 - Compressor(s): reciprocating/scroll
 - Condensers
 - Refrigeration feed
 - Oil lubrication
 - Refrigerant piping



A typical window type room air conditioner

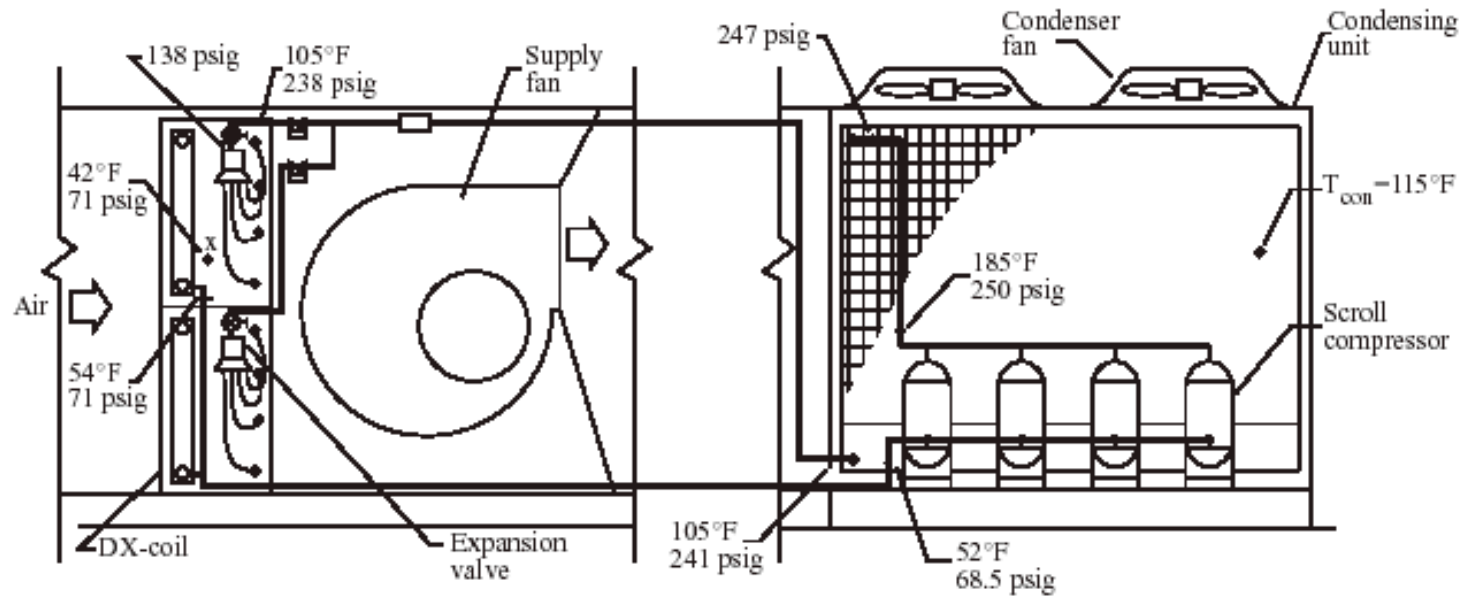


Split type air conditioning system



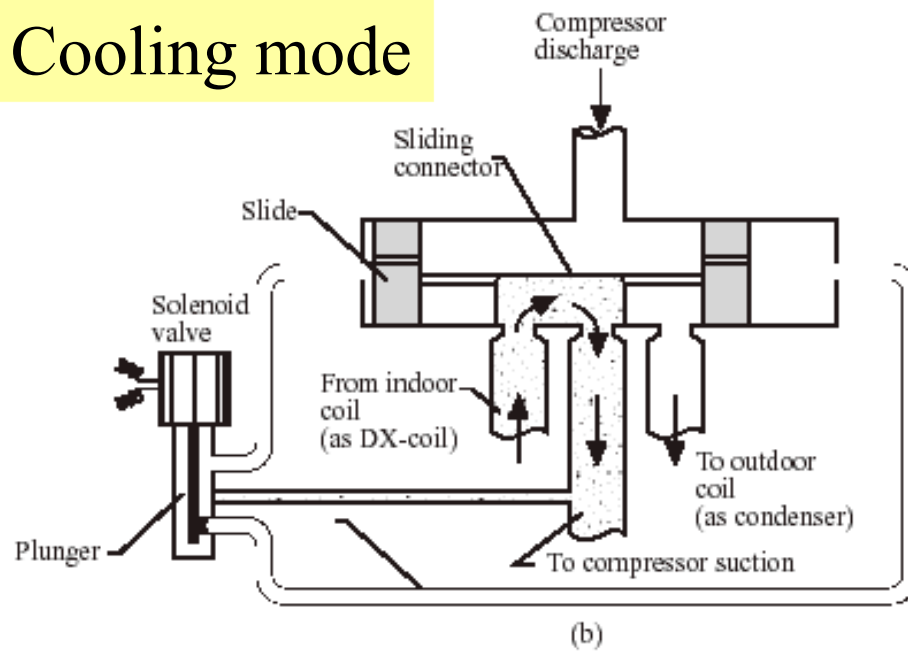
Outdoor Unit

Direct expansion (DX) system (air-cooled condenser)

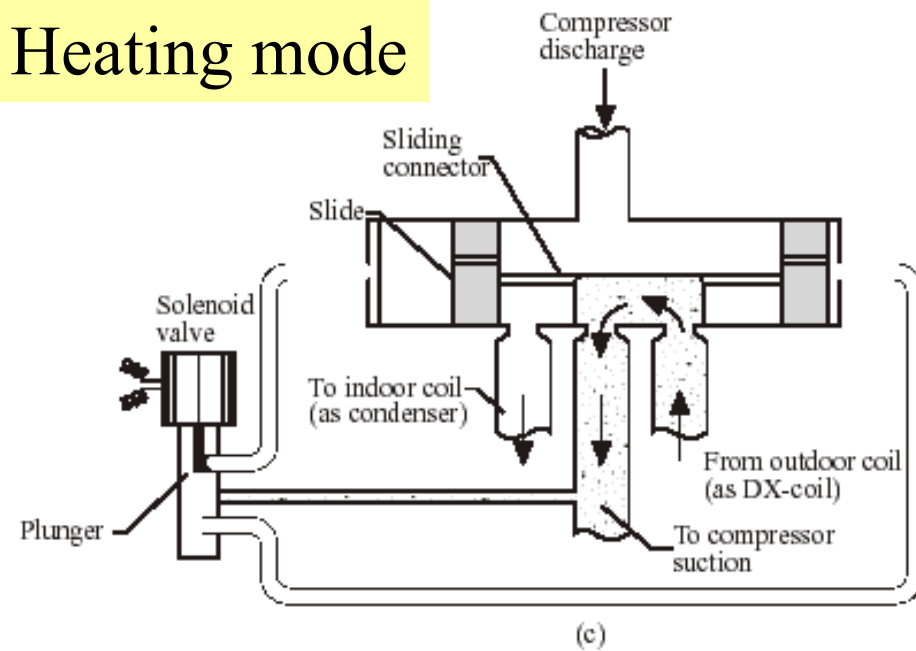


(a)

Cooling mode



Heating mode

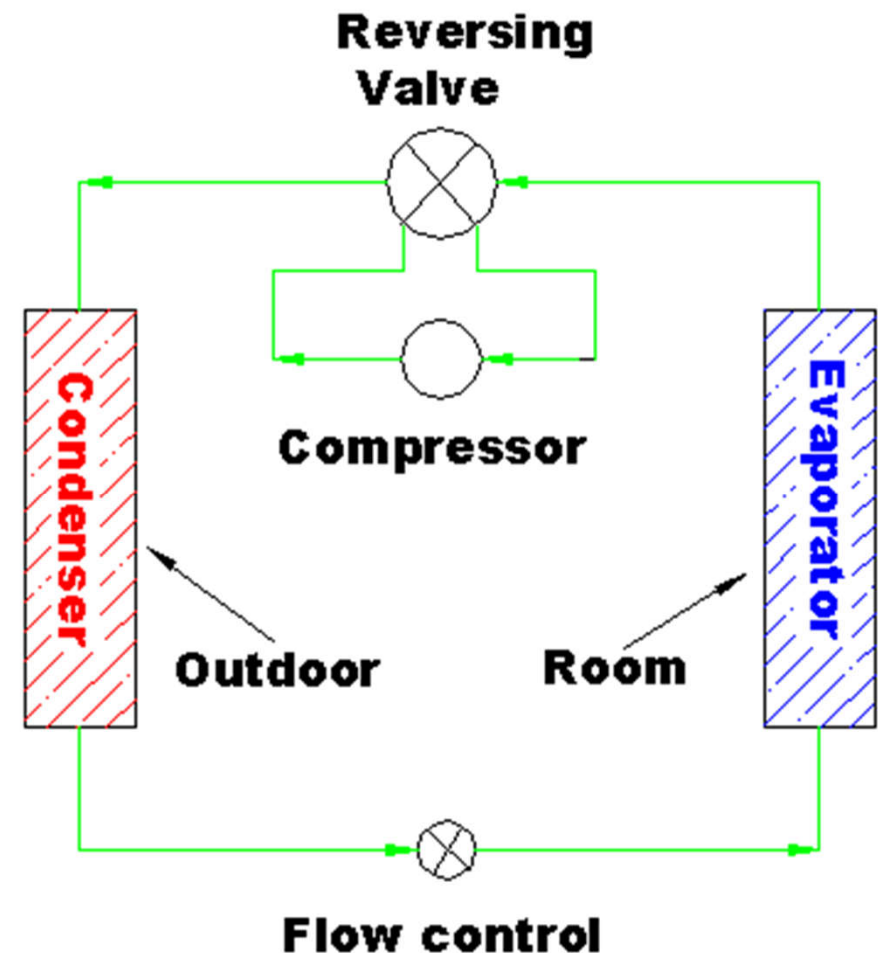




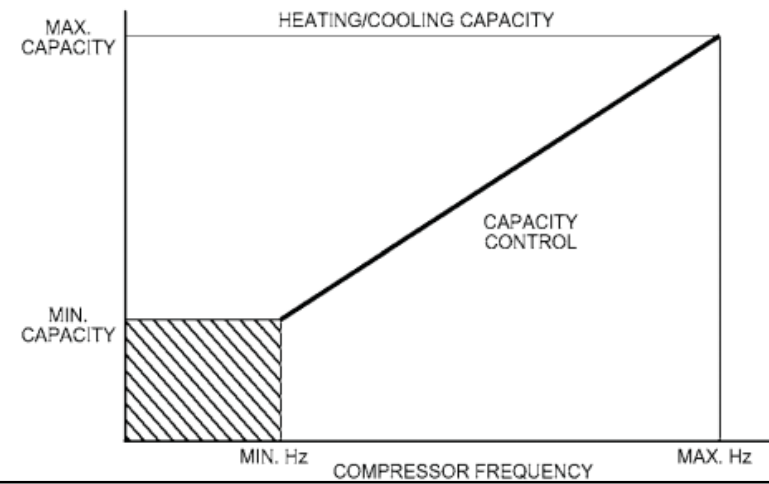
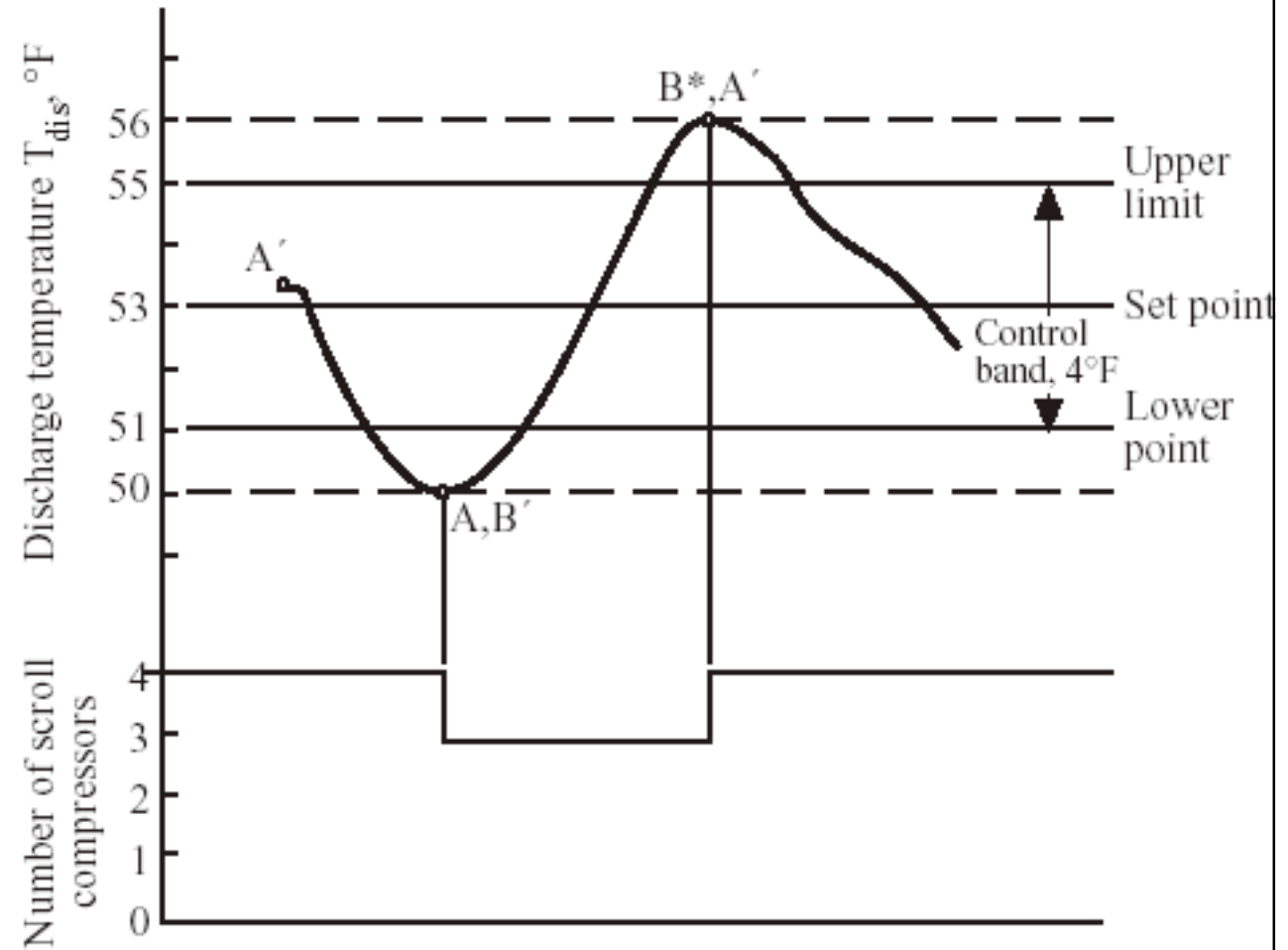
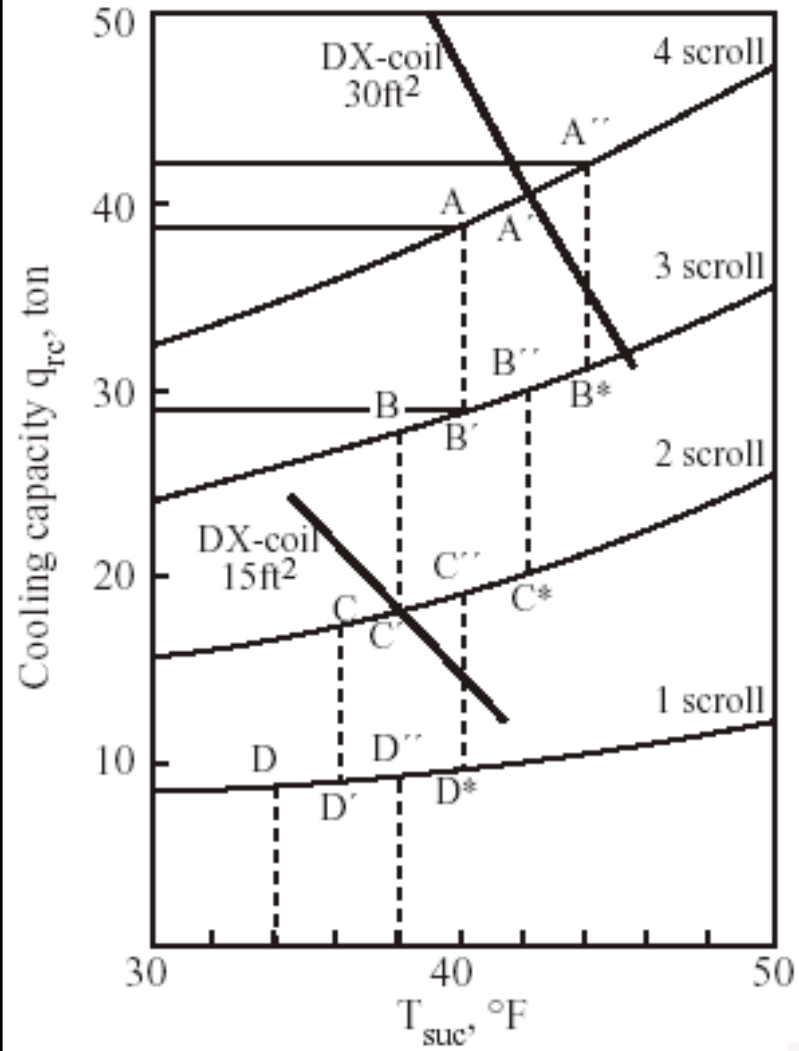
Direct expansion (DX) systems

- Direct expansion (DX) systems (cont'd)

- Capacity control
 - On-off control
 - Cylinder unloader
 - Speed modulation
- Safety control
 - Low- & high-pressure control
 - Low-temperature control
 - Motor overload control
 - Pump-down control
- Full- and part-load operation



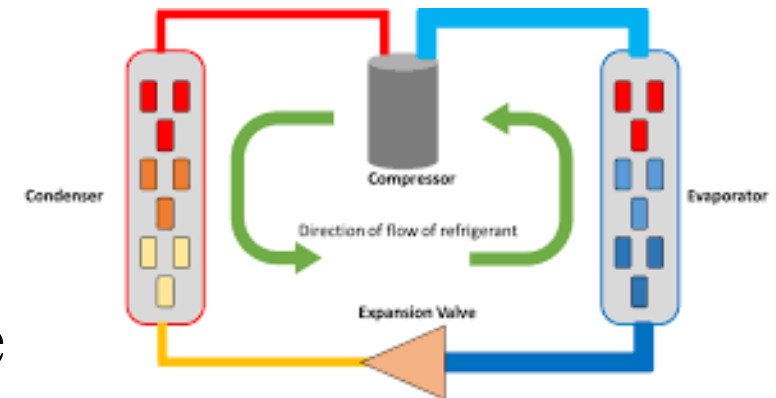
Capacity control of a DX system



Direct expansion (DX) systems



- Advantages of DX systems
 - Low installation costs
 - Ease to test, adjust and balance
 - Minimum ceiling or wall space needed
 - Low energy consumption & maintenance costs
 - Individual section can be operated without running the entire system in the building
 - Low noise level (NC 35)
 - Good relative humidity control

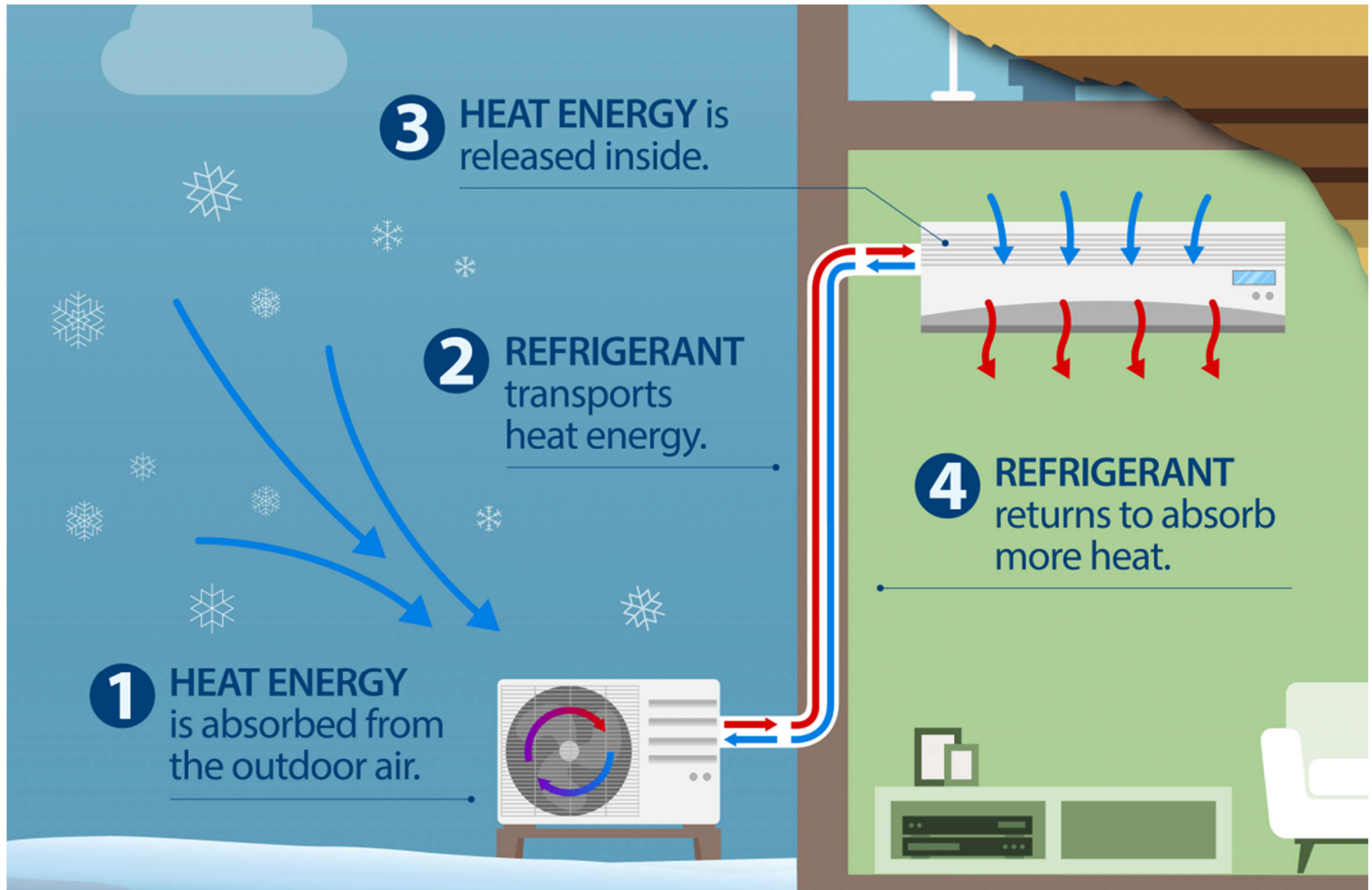


Direct expansion (DX) systems



- Limitations of DX systems
 - Since the localized DX units are smaller in size, the coefficient of performance (COP) is low
 - Multiple DX units may spoil the exterior elevations & aesthetics of the building
 - Most maintenance works occur directly in occupied building spaces
 - Not suitable for areas requiring high degree of cleanliness or large positive pressurization

Heat pump air conditioning system



Direct expansion (DX) systems



- Heat pump technology
 - High-efficiency heating & cooling
- Common problems & reasons in heat pumps
 - Freezing up (refrigerant leak, clogged filter, or very dirty coils)
 - Running constantly in summer (faulty controls, leaky ducts, wrong-sized system)
 - Running constantly in winter (refrigerant leak, frozen outdoor unit, or compressor problem)



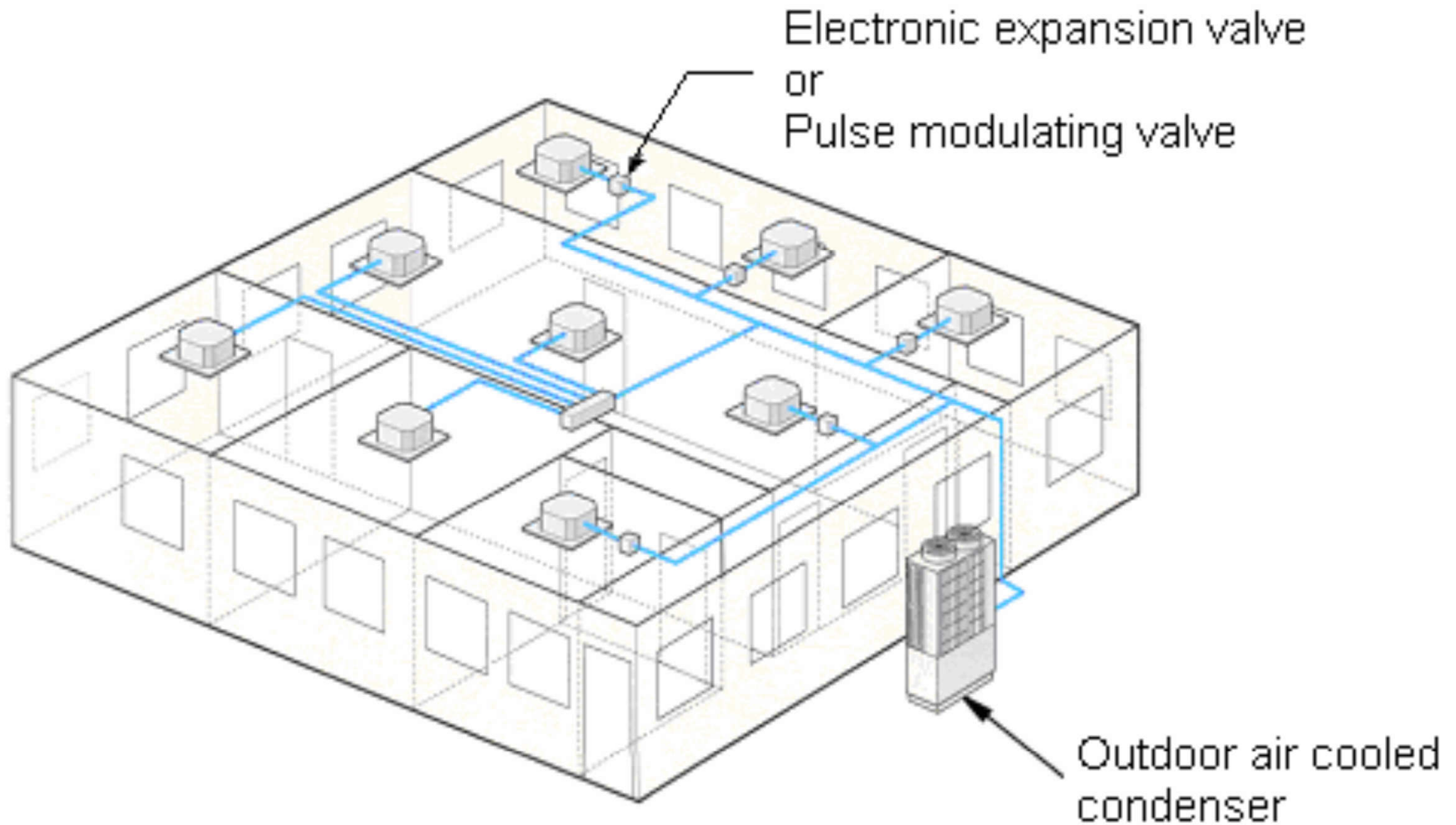


Direct expansion (DX) systems

- Variable refrigerant flow (VRF) systems*
 - Direct expansion (DX), similar to **multi-split** systems; widely used in Japan and Europe
 - Able to control the amount of **refrigerant** flowing to the **multiple evaporators** (indoor units), enabling the use of many evaporators of differing capacities and configurations connected to a single condensing unit
 - Provides an **individualized** comfort control, and **simultaneous cooling & heating** in different zones

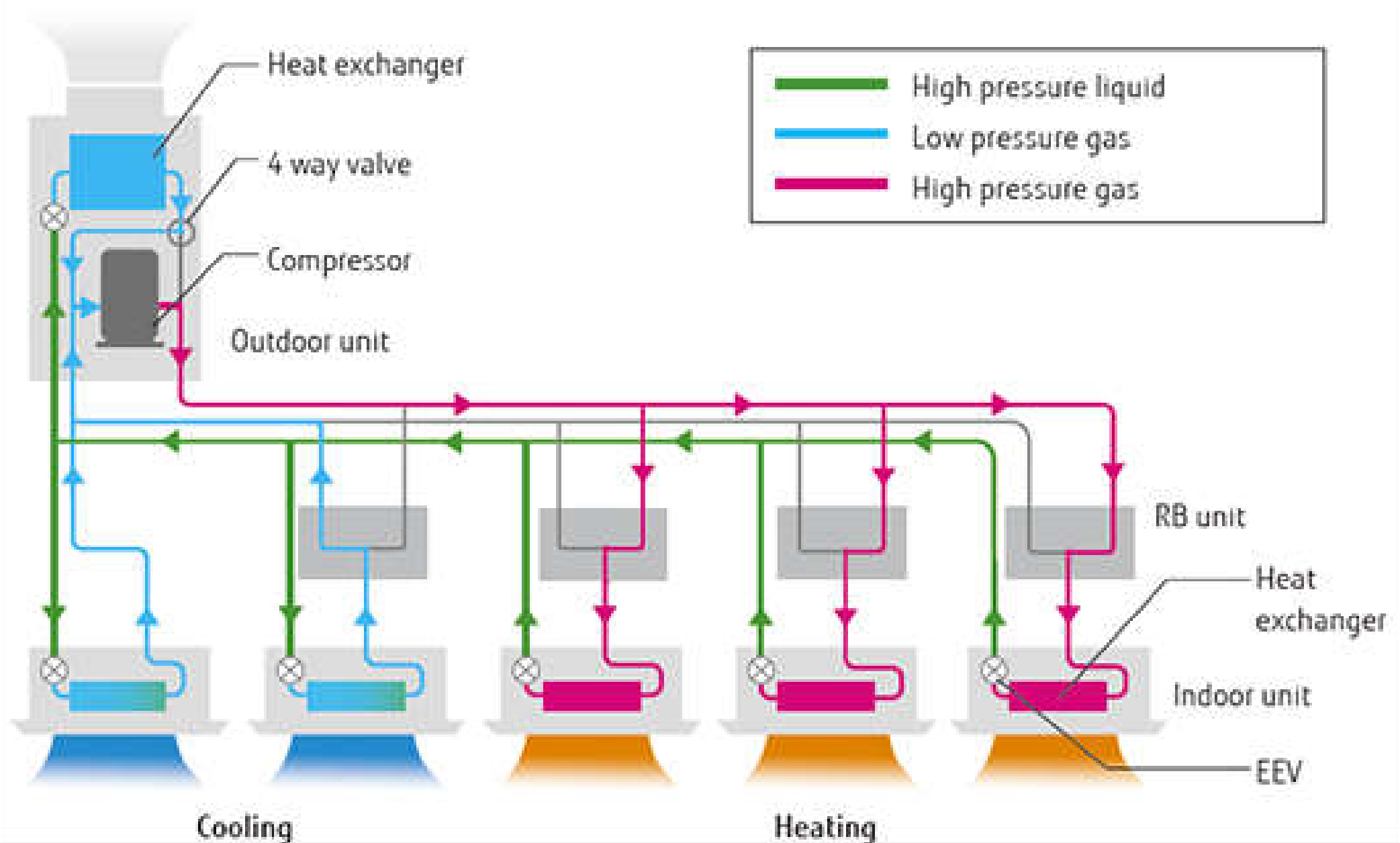
(*See also: http://en.wikipedia.org/wiki/Variable_refrigerant_flow)

An example of variable refrigerant flow (VRF) system

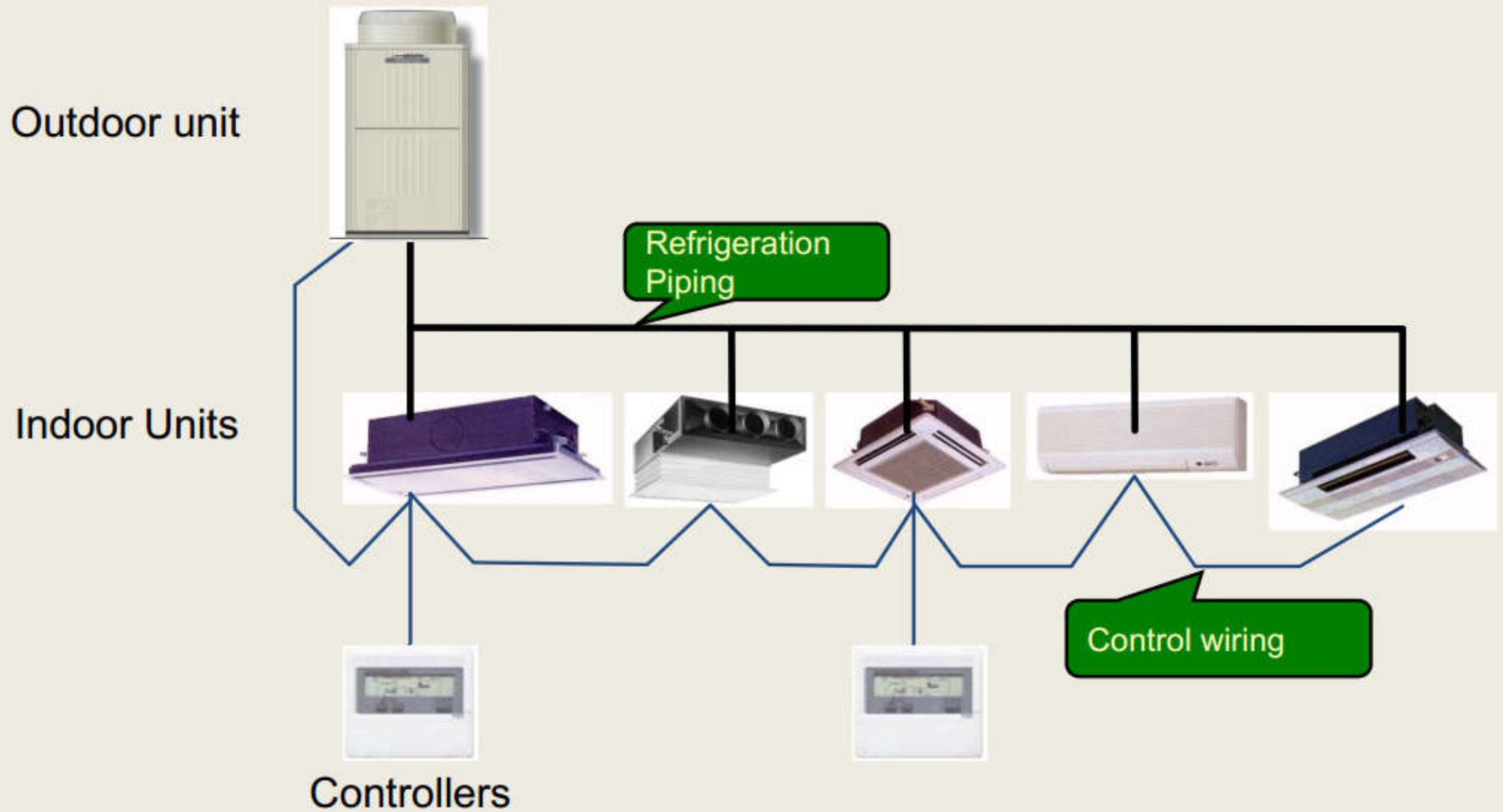


VRF System with Multiple Indoor Evaporator Units

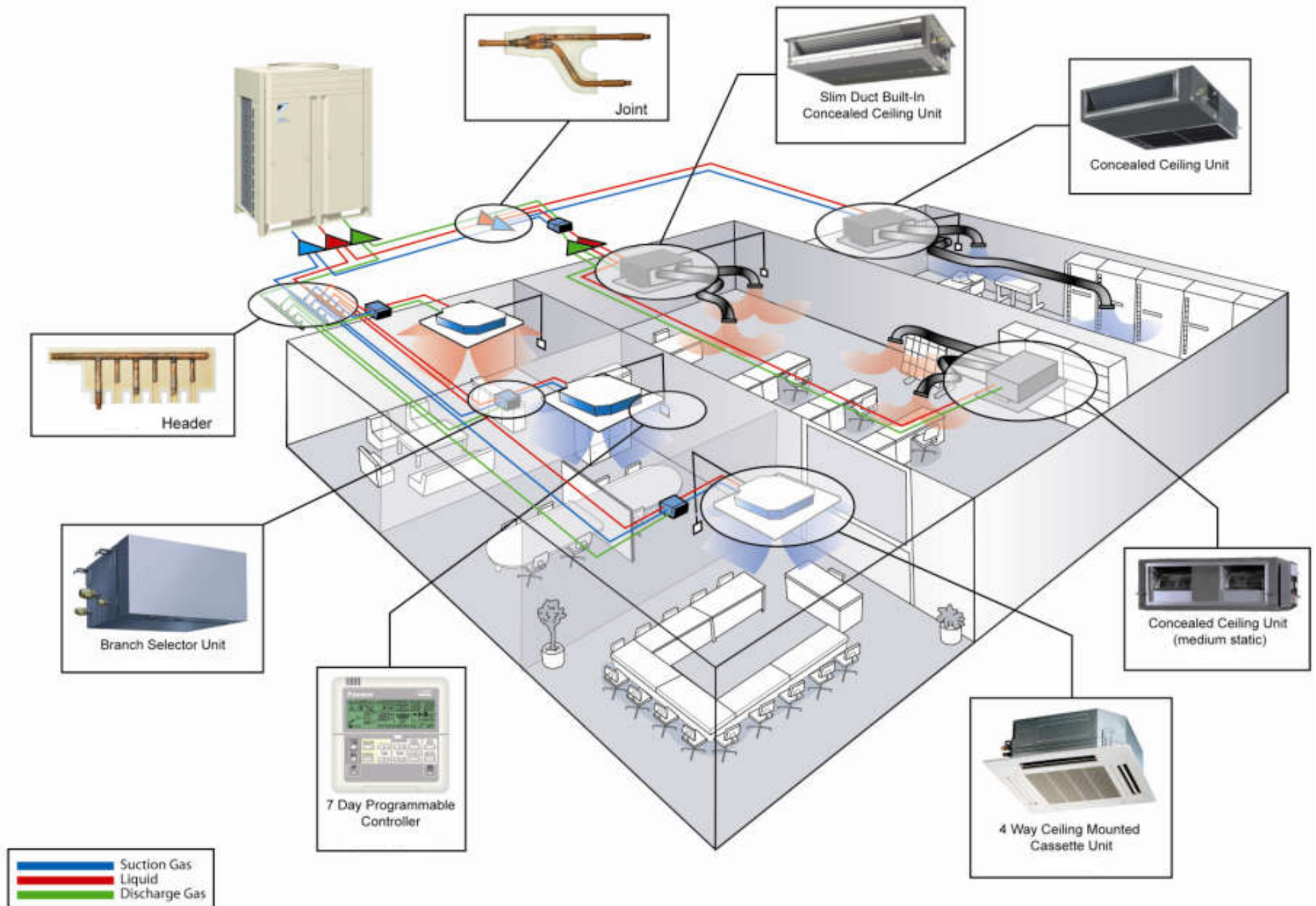
VRF system with simultaneous cooling & heating (by heat recovery)



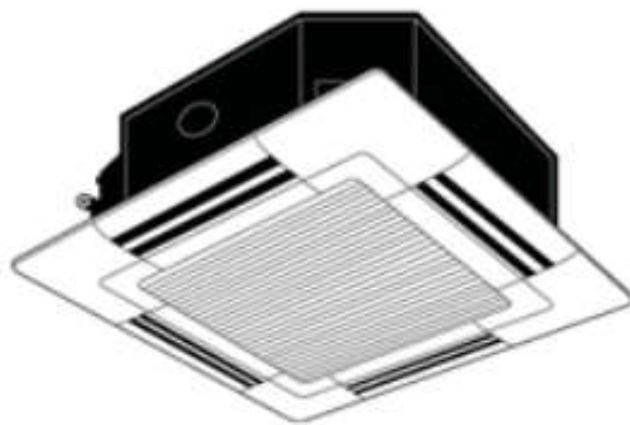
Basic components of a VRF system



Variable refrigerant flow (VRF) system with mixed indoor units



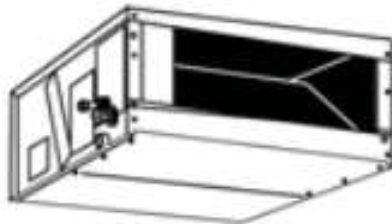
(Source: Daikin)



A. FOUR-WAY CEILING
RECESSED CASSETTE



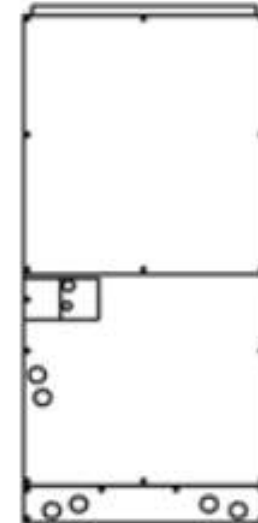
B. CEILING
SUSPENDED



C. CEILING CONCEALED
DUCTED



D. WALL MOUNTED



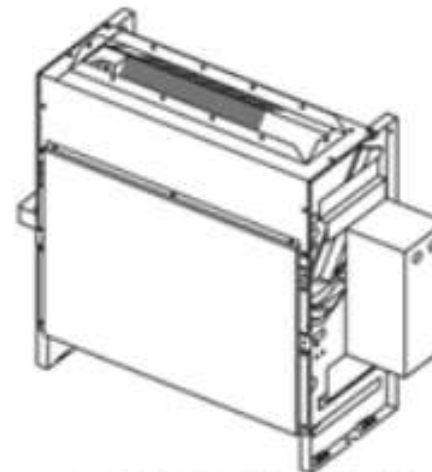
E. VERTICAL
AIR HANDLER



F. ONE-WAY CEILING
RECESSED CASSETTE



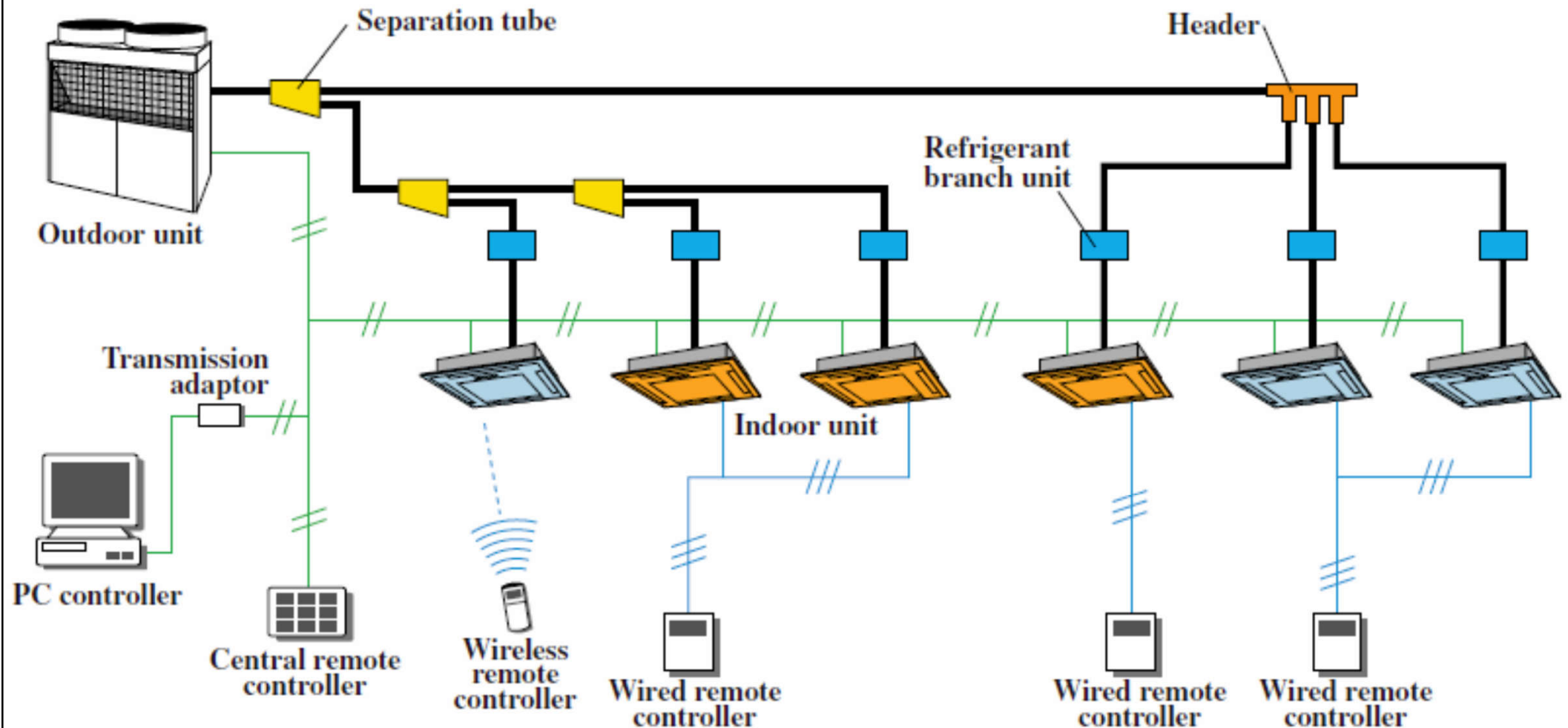
G. FLOOR-STANDING
EXPOSED



H. FLOOR-STANDING
CONCEALED

Common
types of VRF
indoor units

Variable refrigerant flow (VRF) system --- refrigerant circuit and control communication devices



Testing & commissioning



- Objectives of testing & commissioning (T&C):
 - To verify proper functioning of the equipment/system after installation
 - To verify that the performance of the installed equipment/systems meet with the specified design intent & statutory requirements, if any, through a series of tests & adjustments
 - To capture & record performance data of the whole installation as the baseline for future operation & maintenance

Testing & commissioning



- Scope of T&C works:
 - Tests & inspections during construction
 - Functional performance tests
 - Statutory tests & inspections
 - Documentation & deliverables (test records & T&C reports)



Examples of HVAC testing & commissioning (T&C) works

Functional Performance Test

[Project]

System: AHU-33

Tag: AHU-33

Service: 3rd & 4th Floors - D Tower

<i>Functional Performance Test</i>	<i>Pass</i>	<i>Fail</i>	<i>Remarks</i>
FPT Test Prerequisites			
SVC forms completed and signed and dated			
Start-Up Report received	✓		
Point to Point checks completed	✓		
Point calibration completed	✓		
TAB completed and pencil copy received	✓		



HVAC testing & commissioning procedures

1. General Test & Inspection Requirements

- Work tests
- Weld in piped services
- Pressure testing of piped services
- Air leakage test for ductwork
- General electrical checks
- Pre-commissioning checks of water distribution system & air distribution system

2. Other Relevant Tests & Inspections

- Indoor air quality (IAQ)
- Energy efficient equipment & systems
- Control systems
- Noise & sound tests
- Vibration tests
- Electrical tests
- Final air conditioning system performance tests

Major HVAC sub-systems:

- (a) Water distribution system
- (b) Air distribution system
- (c) Refrigeration systems



[Source: T & C Procedure for Air-Conditioning, Refrigeration, Ventilation and Central Monitoring & Control System Installation <https://www.archsd.gov.hk/en/publications-publicity/t-c-procedure-for-air-conditioning,-refrigeration,-ventilation-and-central-monitoring-control-system-installation.html>]

Testing & commissioning



- Typical HVAC T&C activities:
 - Pre-commissioning & setting to work
 - Air systems balancing & regulation
 - Water systems balancing & regulation
 - VAV system testing
 - Performance testing
 - Temperature & humidity analyses
 - Environmental checks & sound level readings



Testing & commissioning

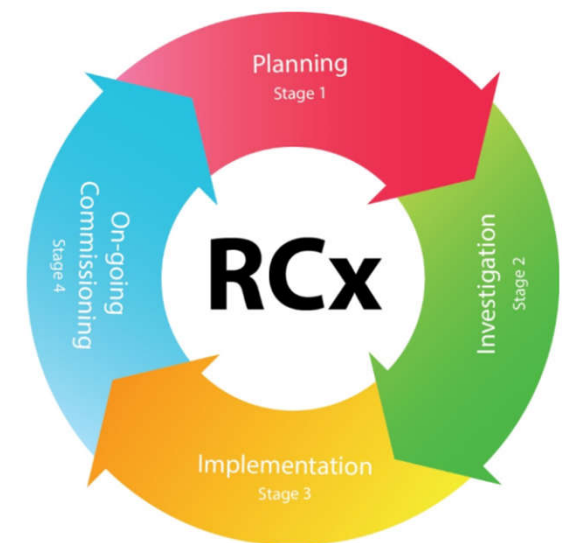


- Three main types of HVAC commissioning:
 - 1. **Initial commissioning**: occurs during the production of a new building or on a new HVAC system within an existing building
 - 2. **Retro-commissioning**: implemented first in an existing building on existing HVAC equipment
 - 3. **Re-commissioning**: commissioning HVAC systems that were already commissioned during the initial commissioning process, so as to verify, improve & document the system performance

Testing & commissioning



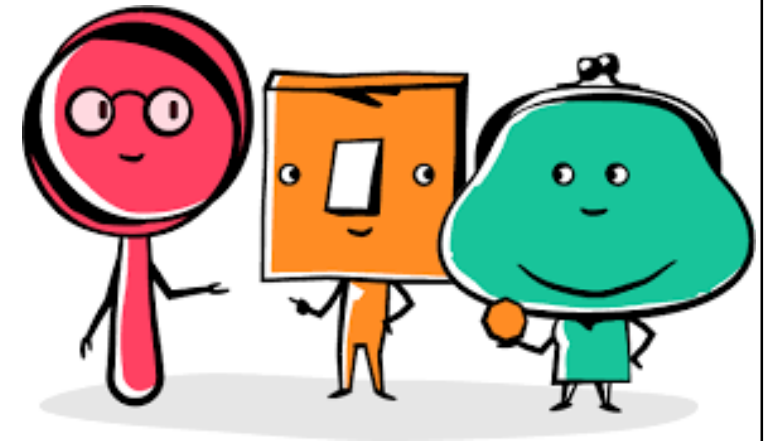
- Retro-commissioning (RCx) 重新校驗
 - To promote energy saving for existing building
 - A systematic process to periodically check an existing building's performance to identify operational improvements that can save energy and thus lower energy bills and improve indoor environment
 - Four stages in RCx:
 - Stage 1 - Planning
 - Stage 2 - Investigation
 - Stage 3 - Implementation
 - Stage 4 - Ongoing commissioning



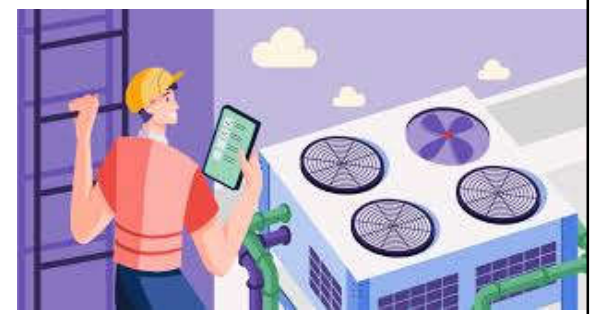
Testing & commissioning



- Essential parties involved in RCx Team:
 - (1) Building Owner (or Building Owner's representative)
 - (2) Building Manager
 - (3) O&M staff
 - (4) Contractor
 - (5) RCx service provider (optional)
- Identify energy saving opportunities (ESOs) for implementation

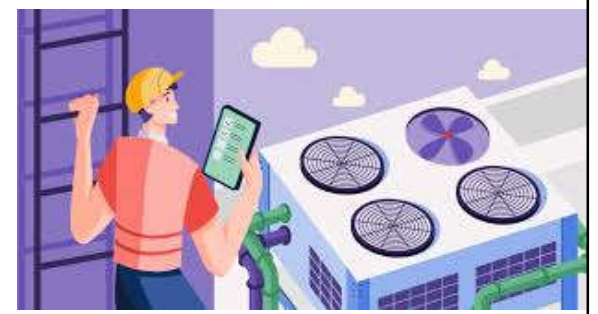


Inspection & regulations



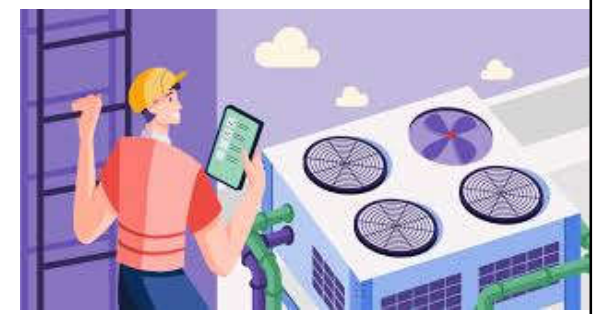
- Major regulations affecting HVAC
 - Cap. 123J Building (Ventilating Systems) Regulations
<https://www.elegislation.gov.hk/hk/cap123J>
 - Cap. 132CE Ventilation of Scheduled Premises Regulation
<https://www.elegislation.gov.hk/hk/cap132CE>
 - Essential fire safety requirements in ventilating system (e.g. fire dampers, smoke control)
 - FS 251 and certification of ventilating systems

Inspection & regulations



- Inspection & certification
 - Letter of compliance for ventilating system
https://www.hkfsd.gov.hk/eng/source/licensing/irregularities_vent.pdf
 - Licensing inspection of ventilating system
 - Annual inspection & certification of damper/filter/precipitator at ventilating system
 - Occupational health & safety requirements (e.g. on flammable refrigerants)

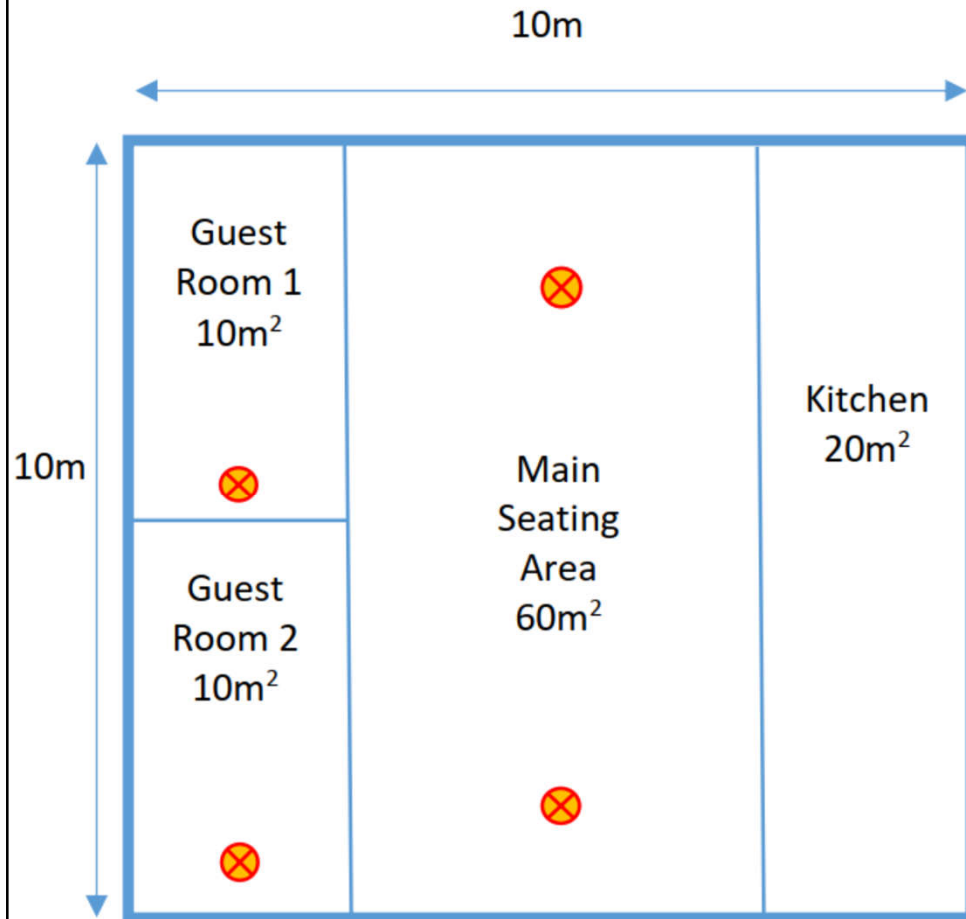
Inspection & regulations



- Air change / air purifier requirement in dine-in restaurants under Cap. 599F
 - Air change per hour (ACH) (fresh air) at 6 or above; OR
 - Air purifiers that meet the specified specifications as an alternative, for example
 - (1) Ultraviolet-C (UV-C) cum High-Efficiency Particulate Arrestance Filter (HEPA) device;
 - (2) UV-C device; or
 - (3) HEPA device



Worked example on air change / air purifier requirement



Distribution of UV-C Air Purifiers



- (1) Air Change per Hour (Fresh Air) = $A \div (B \times C)$
A : capacity of outside fresh air supplied to seating area by the ventilation system (m^3/hr)
B : size of footprint of the seating area (m^2)
C : height from floor to ceiling of the seating area (m)

C is 2.9m

$$\text{ACH (Main Seating Area)} = 900 \div (60 \times 2.9) = 5.17$$

$$\text{ACH (Guest Room 1)} = 150 \div (10 \times 2.9) = 5.17$$

$$\text{ACH (Guest Room 2)} = 150 \div (10 \times 2.9) = 5.17$$

- (2) Owner considers to go for installing air purifiers as the alternative

Case B – UV-C Air Purifier (serving area 35 m^2)

Nos. of purifier in main seating area = $60/35 = 1.7$, so 2 nos. are adopted.

For guest room 1 & 2, no. of purifier = $10/35 = 0.3$ so 1 no for each room is adopted.

[Note : ACH of UVC air purifiers is 7. The total ACH for each compartment, including the fresh air supply and air purifier, is $5.17 + 7 = 12.17$]