CHAPTER 3
AIR CONDITIONING SYSTEMS AND EQUIPMENT

1. INTRODUCTION TO AIR CONDITIONING

• Air conditioning may be required in buildings which have a high heat gain and as a result a high internal temperature.

• The heat gain may be from solar radiation and/or internal gains such as people, lights and business machines.

• The diagram below shows some typical heat gains in a room.

INTRODUCTION TO AIR CONDITIONING (CONT.)

If the inside temperature of a space rises to about 25^{o}C then air conditioning will probably be necessary to maintain comfort levels.

This internal temperature (around 25^{o}C) may change depending on some variables such as:

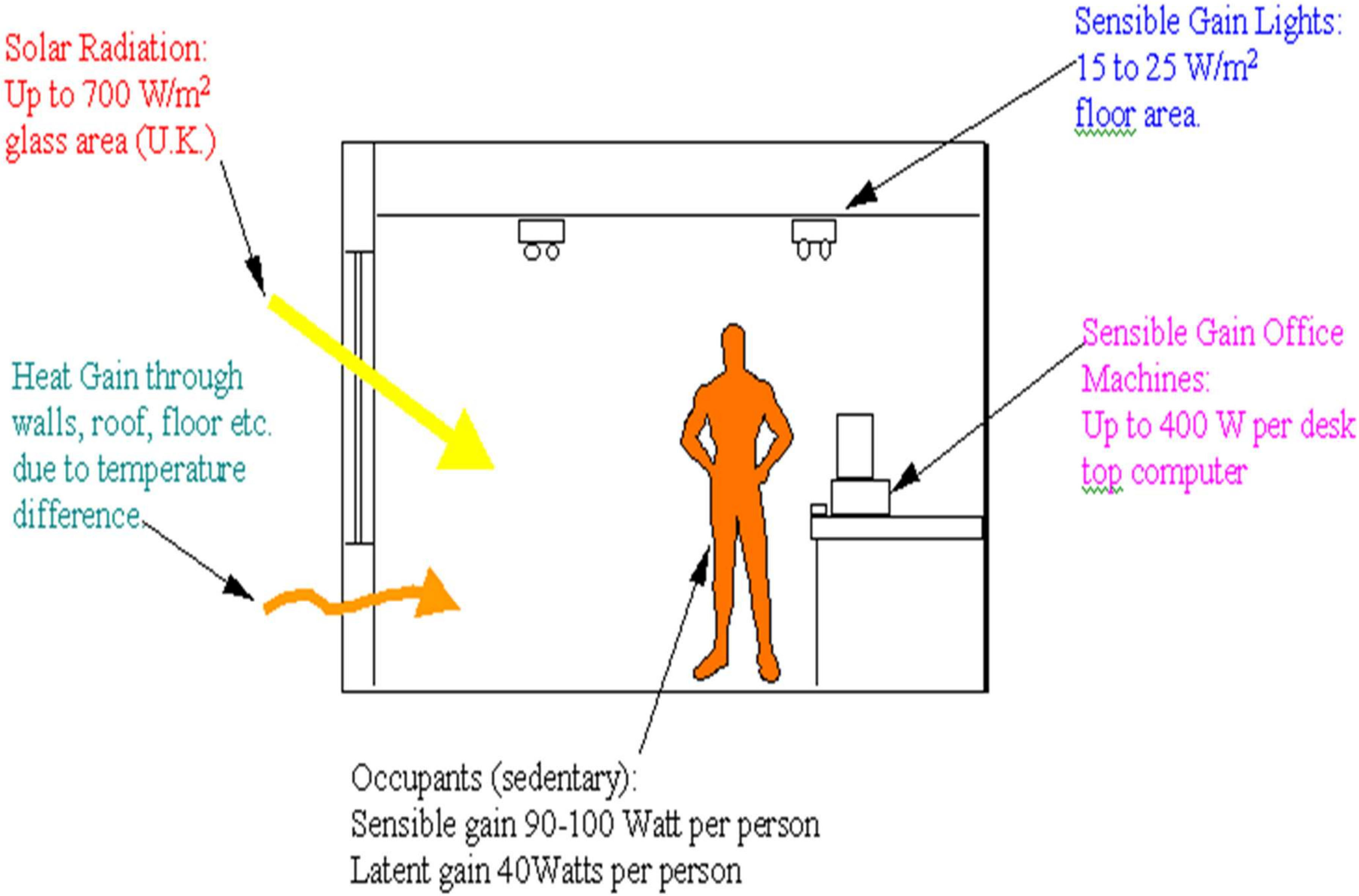
- type of building
- location of building
- duration of high internal temperature
- expected comfort conditions.
- degree of air movement
- percentage saturation.

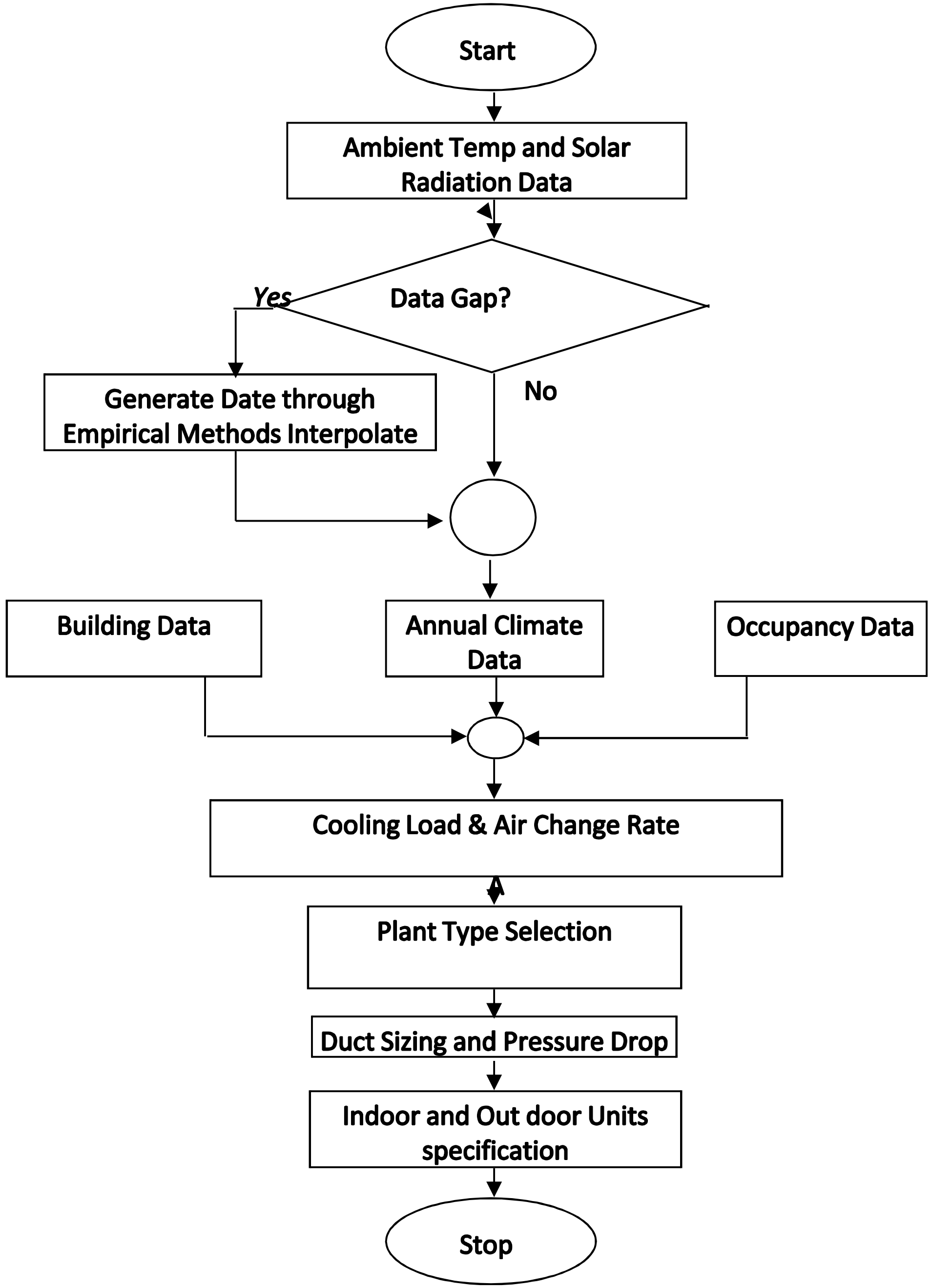
INTRODUCTION TO AIR CONDITIONING (CONT.)

In some buildings it may be possible to maintain a **comfortable environment** with mechanical ventilation but the air change rate will tend to be high (above about 8 air changes per hour) which can in itself cause air distribution problems. Since air conditioning is both **expensive** to install and maintain. It can be reduced by careful building design and by utilising methods such as:

- window blinds or shading methods
- heat reflecting glass
- openable windows
- higher ceilings
- smaller windows on south facing direction
- alternative lighting schemes.

Cooling Load in a Building




Start
Ambient Temp and Solar Radiation Data
Data Gap?
Yes
No
Generate Date through Empirical Methods Interpolate
Building Data
Annual Climate Data
Occupancy Data
Cooling Load & Air Change Rate
Plant Type Selection
Duct Sizing and Pressure Drop
Indoor and Out door Units specification
Stop

COOLING/HEATNG LOAD CALCULATION

1. Sensible Transmission Through Glass

This is the Solar Gain due to differences between inside and outside temperatures. In very warm countries this can be quite significant.

This gain only applies to materials of negligible thermal capacity i.e. glass.

$$Qg = Ag \, . \, Ug \, (T_o - T_r)$$

Where;

Qg	=	Sensible heat gain through glass (W)
Ag	=	Surface area of glass (m2)
Ug	=	'U' value for glass (W/m2 oC)
To	=	outside air temperature (oC)..
Tr	=	room air temperature (oC)

COOLING/HEATNG LOAD CALCULATION

2. Solar Gain Through Windows

This gain is when the sun shines though windows.

The cooling loads per metre squared window area have been tabulated in stanadrds. for various; locations, times, dates and orientations.

These figures are then multiplied by correction factors for; shading and air node correction factor.

Heat load is found from;

$$Q_{sg} = F_c \cdot F_s \cdot q_{sg} \cdot A_g$$

where Q_{sg} = Actual cooling load (W)

q_{sg} = Tabulated cooling load (W/m^2)

F_c = Air node correction factor from Table below.

F_s = Shading factor.

A_g = Area of glass (m2)

COOLING/HEATNG LOAD CALCULATION

3. Solar Gain Through Windows

Aa slightly different formula as follows;

$Q_{sg} = \quad S \cdot q_{sg} \cdot A_g$

where Qsg = Actual cooling load (W)

qsg = Tabulated cooling load (W/m^2)

S = Mean solar gain factor

A_g = Area of glass (m2)

COOLING/HEATNG LOAD CALCULATION

4. Mean gain through wall,

$$Q_q = A \cdot U (T_{em} - T_r)$$

where,	Q_q	=	heat gain through wall at time q
	A	=	area of wall (m^2)
	U	=	overall thermal transmittance (W/m^2 oC)
	Tem	=	24 hour mean sol-air temperature (oC)
	Tr	=	constant dry resultant temperature (oC). dry bulb is used.

COOLING/HEATNG LOAD CALCULATION

5. Heat Gain Through Roof

The heat gain through a roof uses the same equation as for a wall as shown below.

Q q+f Roof = A U [(Tem - Tr)

COOLING/HEATNG LOAD CALCULATION

6. Ventilation and/or Infiltration Gains

Heat load is found from;

$$Qsi = n \cdot V \ (T_o - T_r) \ / \ 3 \quad \ldots\ldots\ldots$$

Where	Qsi	=	Sensible heat gain (W)
	n	=	number of air changes per hour (h-1) (see note below)
	V	=	volume of room (m3)
	To	=	outside air temperature (oC)
	Tr	=	room air temperature (oC)

COOLING/HEATNG LOAD CALCULATION

7. Internal Heat Gains –

$Q_{int.}$ = Heat from Occupants + Heat from Lighting + Heat from Electrical Equipment + Heat from Cooking

Conditions	Typical building	Sensible Heat Gain (Watts)	Latent Heat Gain (Watts)
Seated very light work	Offices, hotels, apartments	**70**	45
Moderate office work	Offices, hotels, apartments	**75**	55
Standing, light work; walking	Department store, retail store	**75**	55
Walking standing	Bank	**75**	70
Sedentary work	Restaurant	**80**	80
Light bench work	Factory	**80**	140
Athletics	Gymnasium	**210**	315

INTRODUCTION TO AIR CONDITIONING (CONT.)

Total Room Load From Heat Gains

$$Q_{total} = Qg + Qsg + Qint. + Q_{q+f\,Wall} + Q_{q+f\,Roof} + Qsi$$

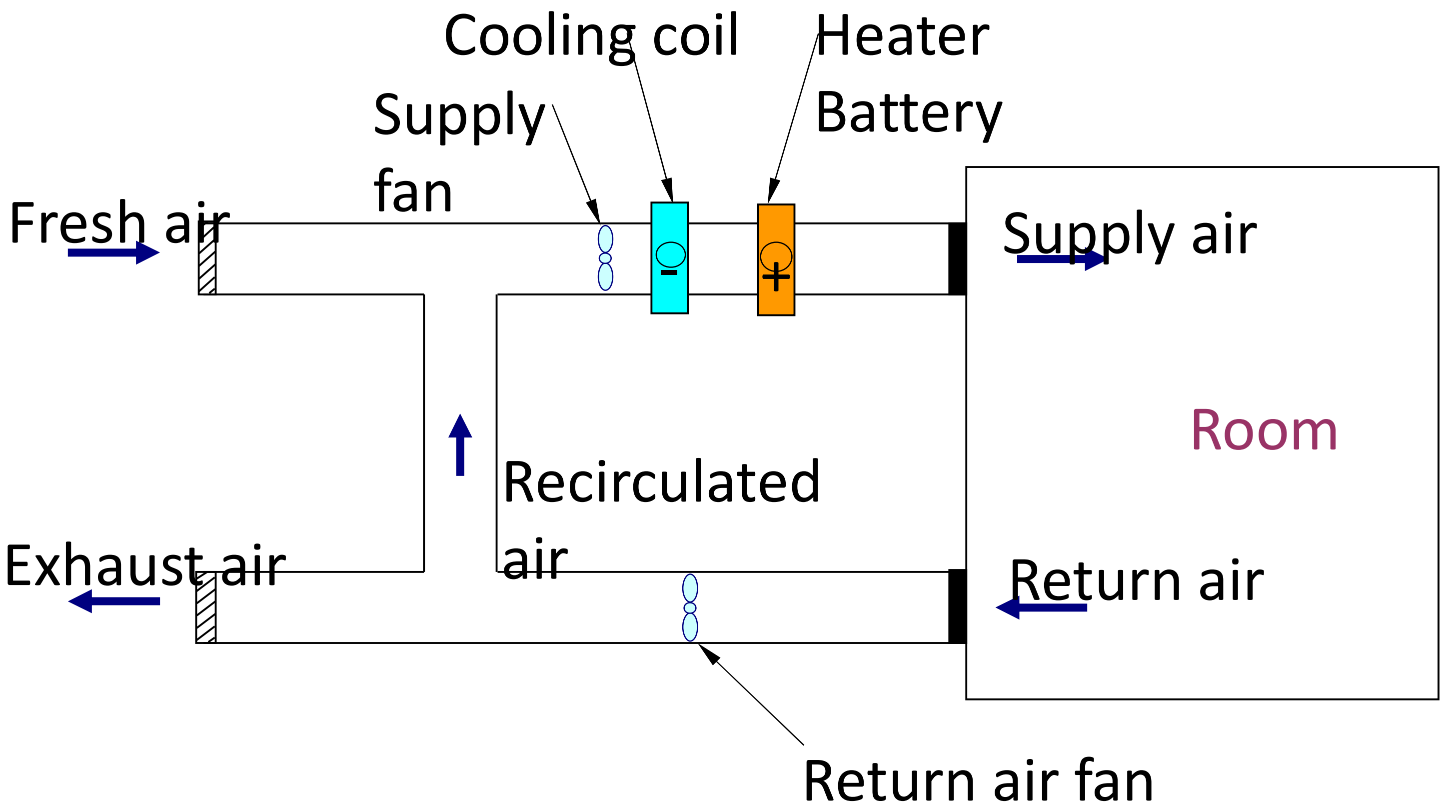
Q total	=	Ag . Ug (To - Tr)	1. Sensible Glass
	+	Fc . Fs . qsg . Ag	2. Solar Glass.
	+	Qint.	3. Internal
	+	A.U [(Tem - Tr) + f (Teo - Tem)]	4. Walls
	+	A.U [(Tem - Tr) + f (Teo - Tem)]	5. Roof
	+	n . V (To - Tr) / 3	6. Ventilation

INTRODUCTION TO AIR CONDITIONING (CONT.)

Total Room Load From Heat Gains

Heat Gain from	Watts	%
1. Sensible transmission through glass		
2. Solar gain through glass		
3. Internal		
4. External walls		
5. Roof		
6. Ventilation		
Total		100%
Heat gain per m^2 floor area =		
Heat gain per m^3 space =		

Schematic Diagram of Central Plant Air Conditioning System



INTRODUCTION TO AIR CONDITIONING (CONT.)

- If air conditioning is the only answer to adequate comfort in a building then the main **choice of system** can be considered.
- **Full comfort air conditioning** can be used to provide cool air (approx. 13^{o}C to 18^{o}C) for cooling and warm air (approx. 28^{o}C to 36^{o}C) for heating and the air is cleaned by filters, dehumidified to remove moisture or humidified to add moisture.
- Air conditioning systems fall into three main categories, and are detailed in the following pages;

  1. **Central plant systems.**
  2. **Room air conditioning units.**
  3. **Fan coil units.**

INTRODUCTION TO AIR CONDITIONING (CONT.)

- **Central plant** systems have one central source of conditioned air which is distributed in a network of ductwork.
- **Room air conditioning units** are self-contained package units which can be positioned in each room to provide cool air in summer or warm air in winter.
- **Fan coil units** are room units and incorporate heat exchangers piped with chilled water and a fan to provide cool air.

2. ROOM AIR CONDITIONER

- These units use refrigerant to transfer cooling effect into rooms.
- Room air conditioning units fall into two main categories:

1. **Split type** with indoor and outdoor unit
2. **Window/wall units** with evaporator at inside and condenser at the outside face.

2.1 SPLIT AIR CONDITIONER

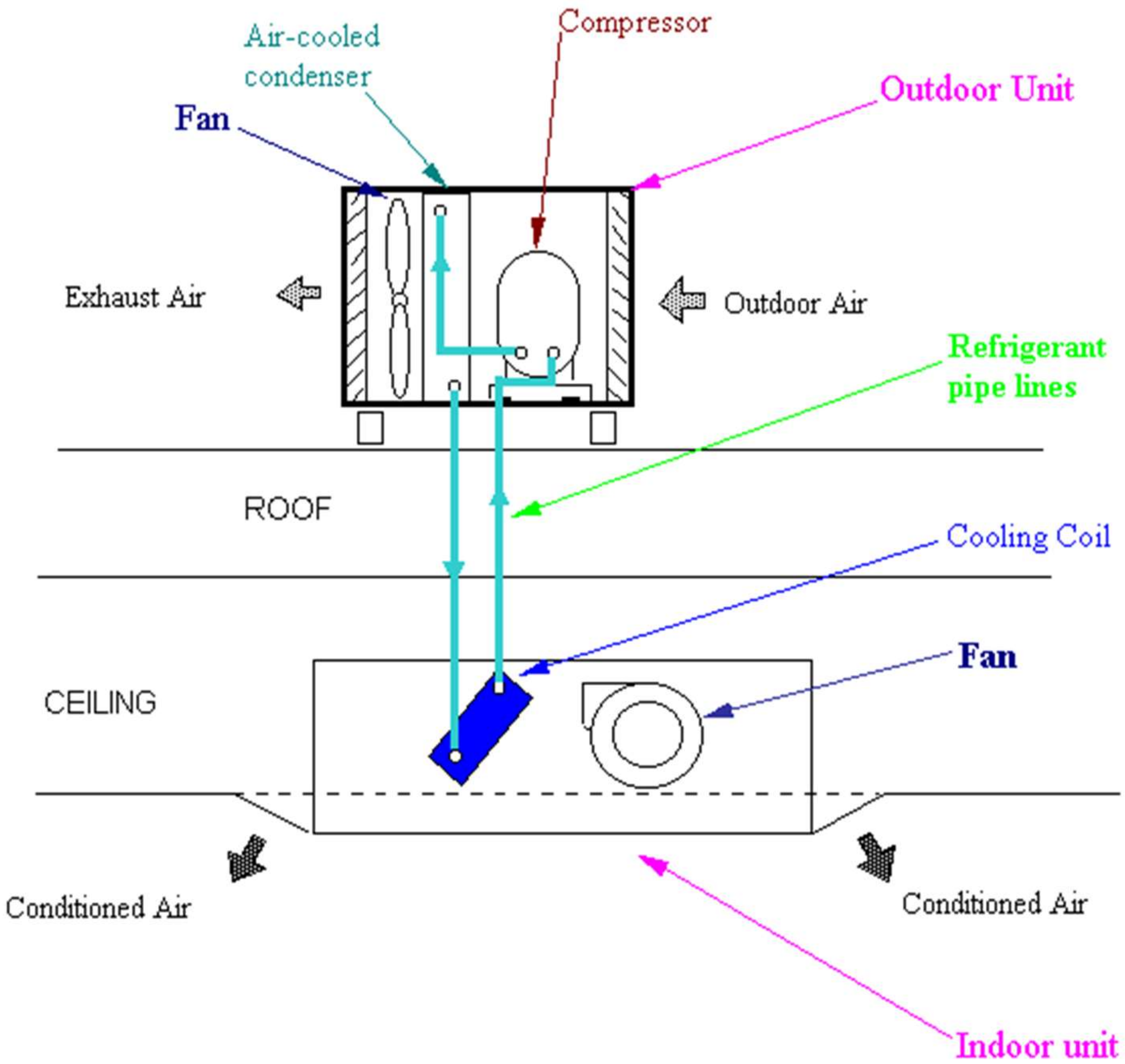
- Split air conditioners have two main parts, the **outdoor unit** is the section which generates the cold refrigerant gas and the **indoor unit** uses this cold refrigerant to cool the air in a space.

- The outdoor unit uses a compressor and air cooled condenser to provide cold refrigerant to a **cooling coil** in the indoor unit.

- A fan then blows air across the cooling coil and into the room.

- The indoor unit can either be ceiling mounted **(cassette unit**), floor mounted or duct type.

- The drawing below shows a ceiling mounted (cassette unit).



SPLIT AIR CONDITIOING UNIT

Ceiling 4 way Cassette Unit
Indoor Unit

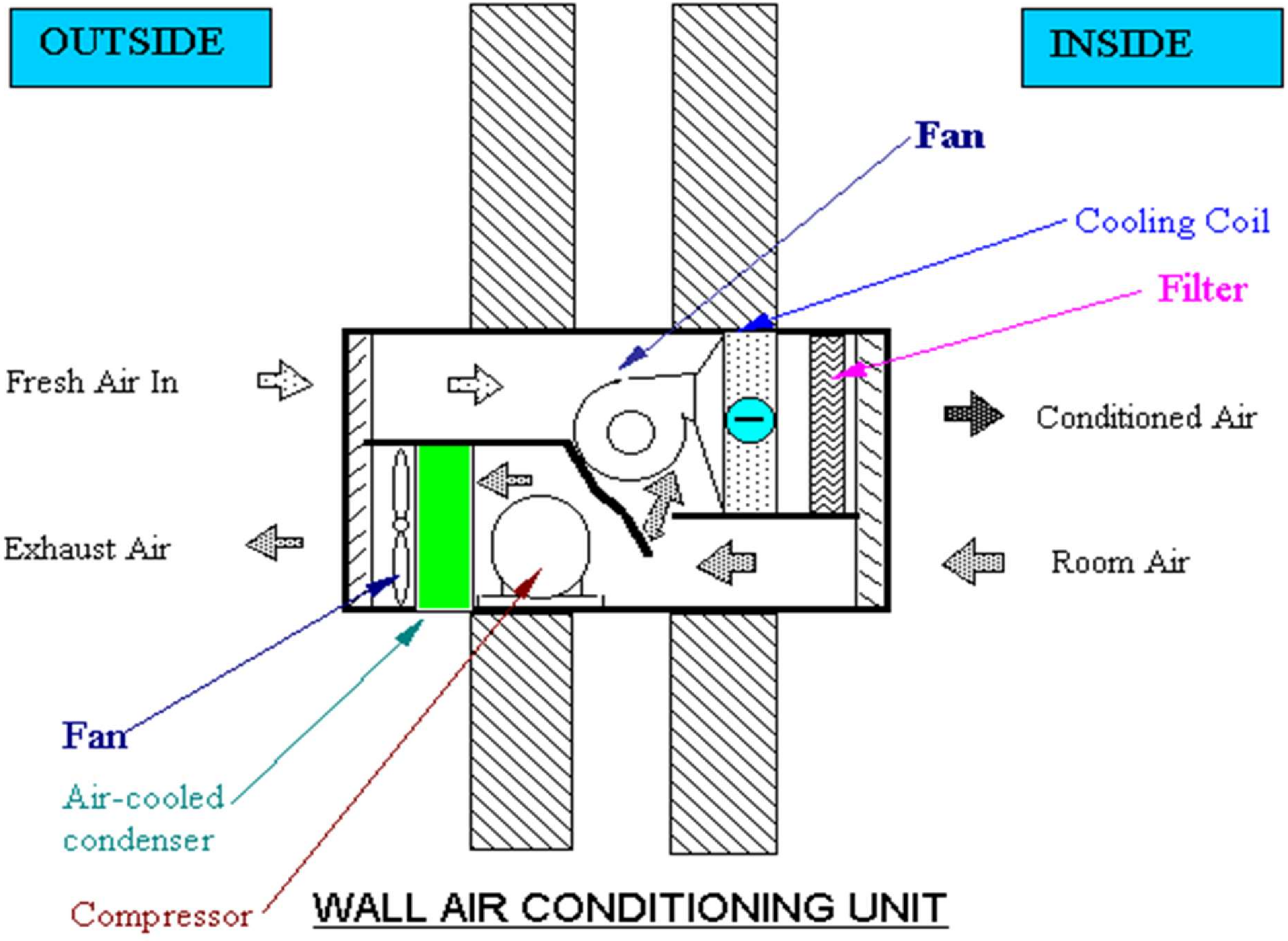
Out door Unit

Different Type of Split Units

VARIOUS TYPES OF ROOM AIR CONDITIONERS – INDOOR UNITS

2.2 WINDOW / WALL UNITS

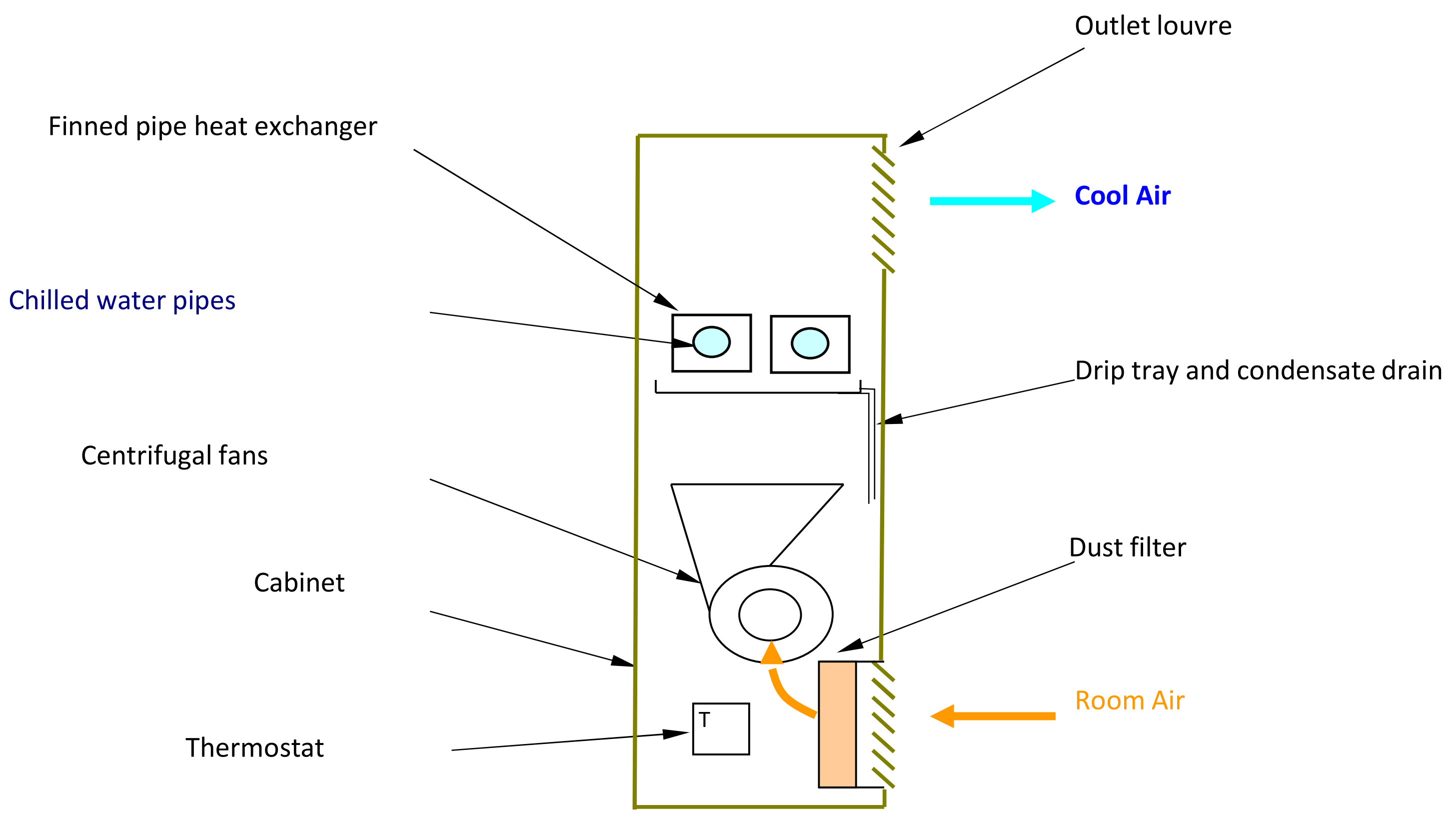
- Window or wall units are more **compact** than split units since all the plant items are contained in one box.
- **Window units** are installed into an appropriate hole in the window and supported from a metal frame.
- **Wall units** like the one shown below are built into an external wall and contain all the necessary items of equipment to provide cool air in summer and some may even provide heating in winter.



WALL AIR CONDITIONING UNIT

3. FAN COIL UNITS

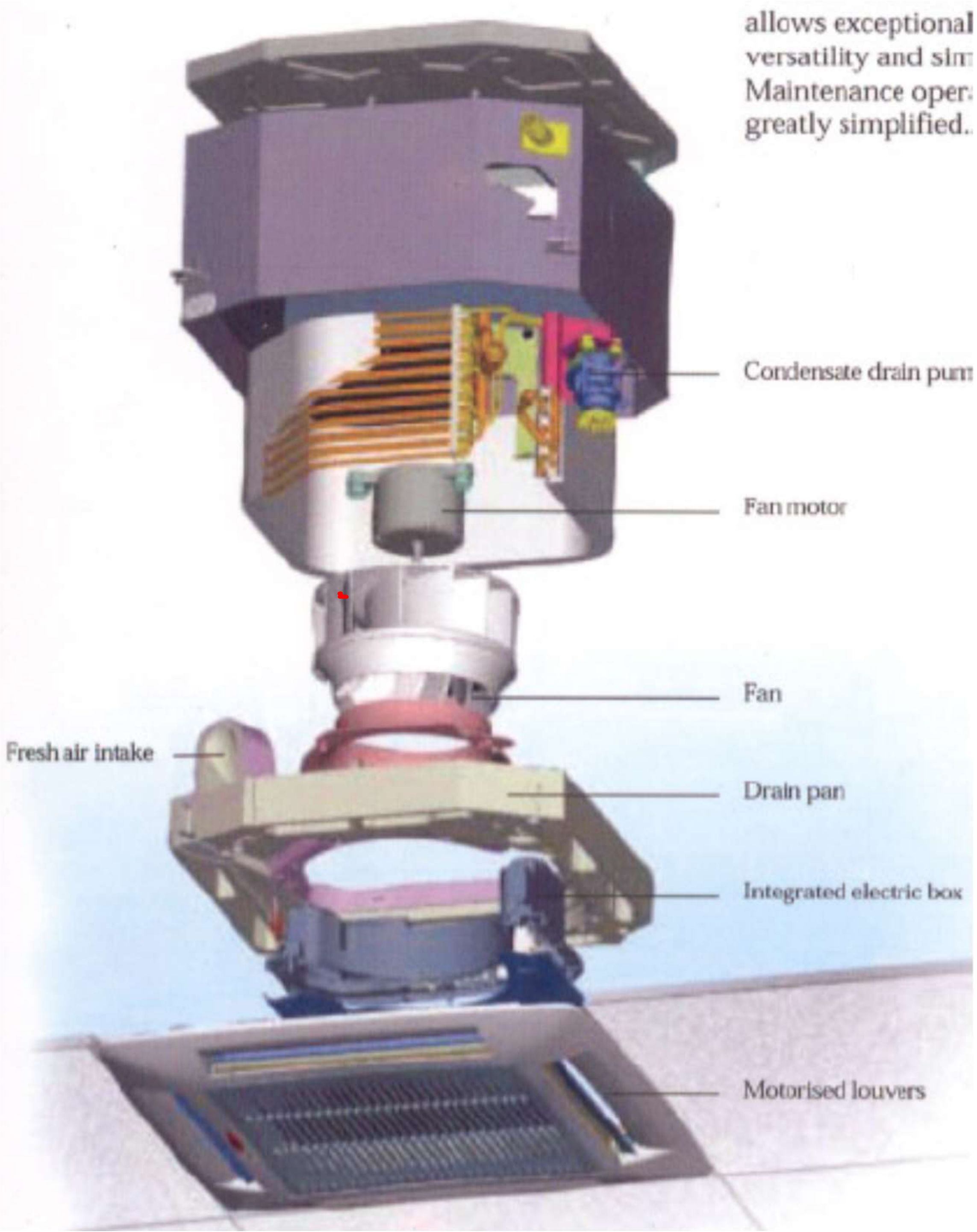
- These are room air conditioners but use chilled water instead of refrigerant.
- Units can be floor or ceiling mounted.
- The chilled water is piped to a finned heat exchanger as in a fan convector.
- A fan blows room air across the heat exchanger and cool air is emitted into the room, as shown below.

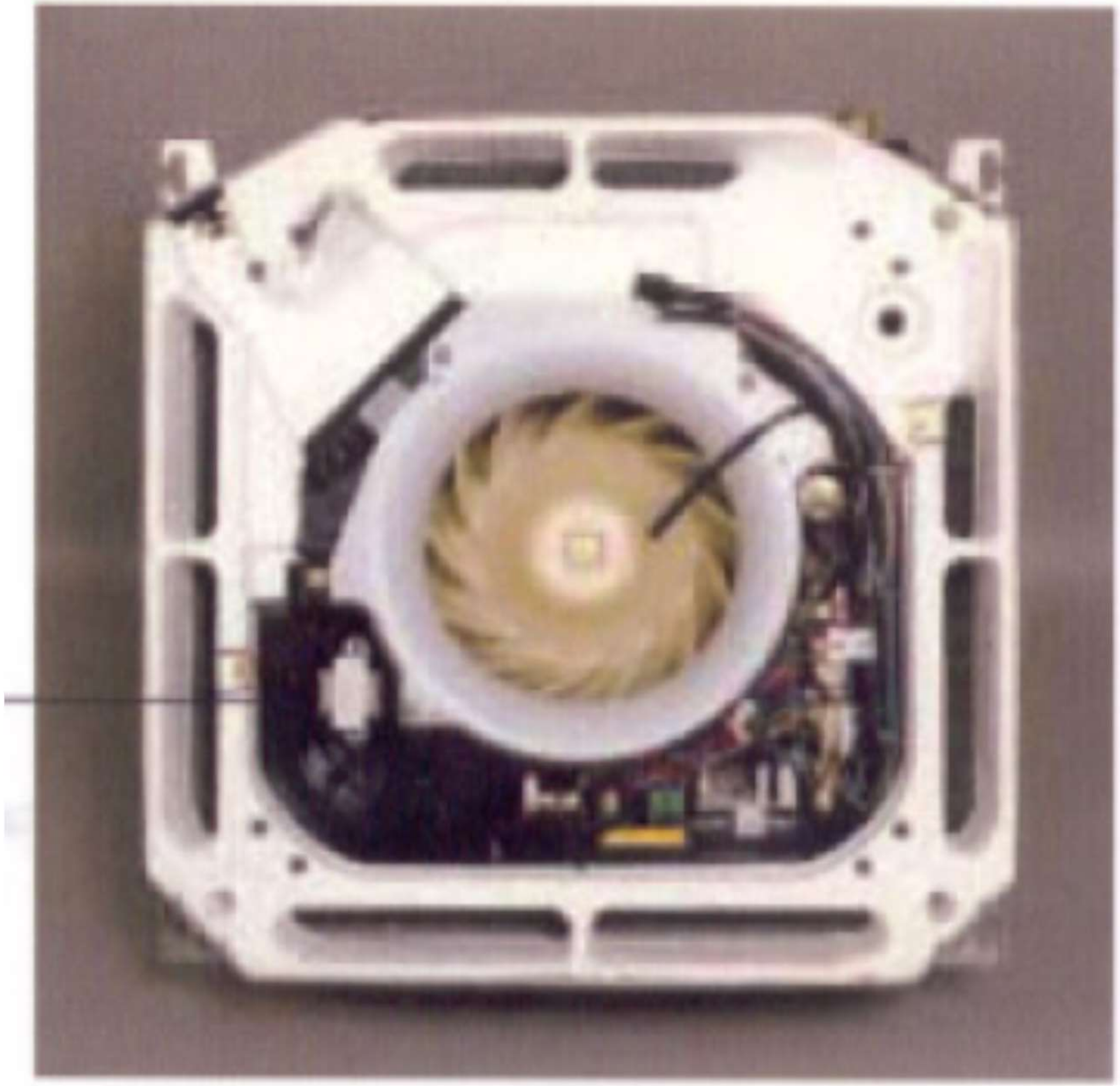


FAN COIL UNIT

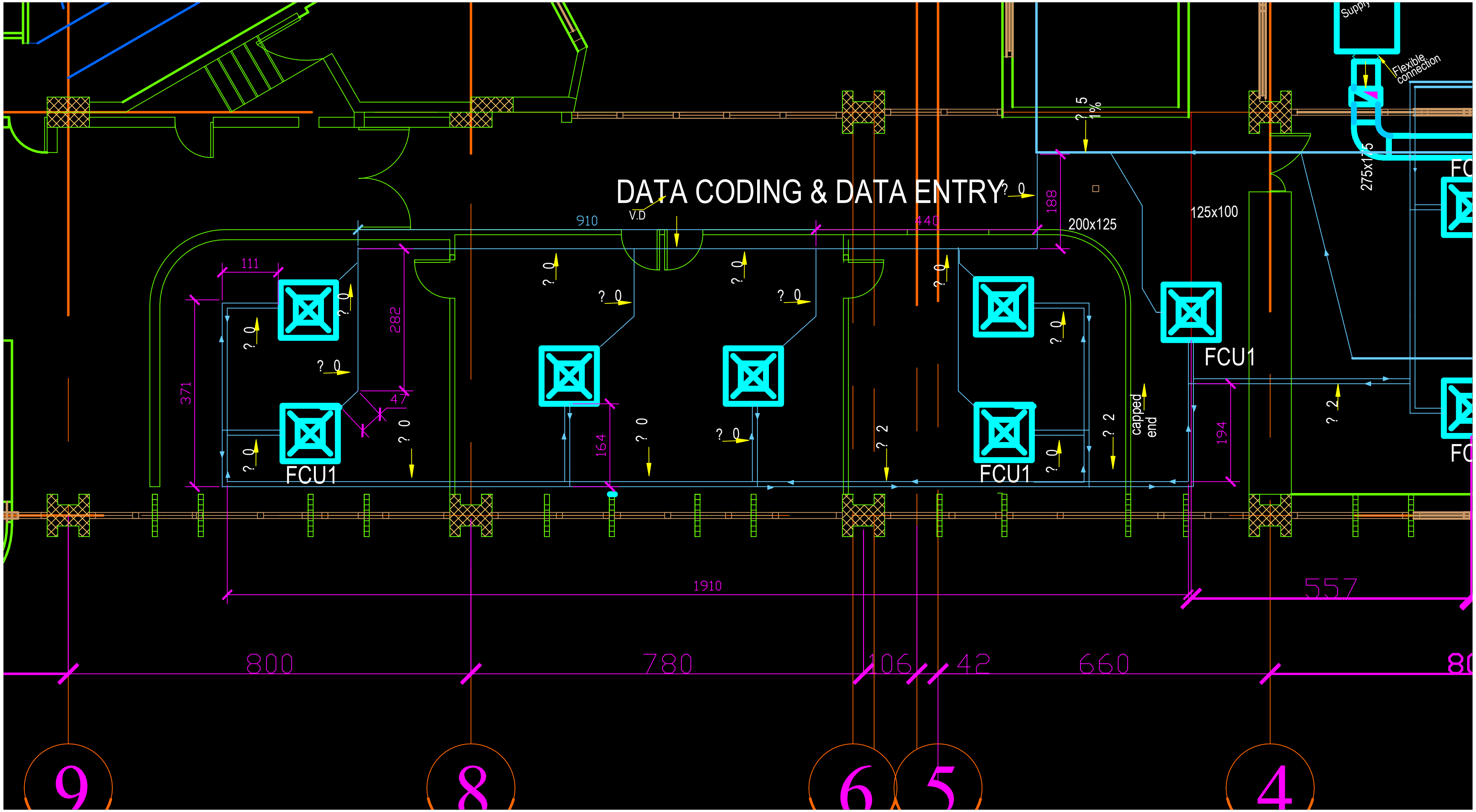
- Fan coil units may be looked upon as being small air handling units located in rooms and they can be piped with chilled water for cooling and low temperature hot water (LTHW) for heating if necessary.
- The room temperature can be controlled with low, medium and high fan speeds and chilled water flow is varied with a two-port or three-port motorised valve.
- Two-pipe, three-pipe and four-pipe systems have been used.
- The four-pipe system has two heating and two cooling pipes and may have a single heat exchanger or two separate heat exchangers for heating and cooling.
- It is useful to have a summer/winter changeover switch in the main control system to avoid both heat exchangers being on at the same time.
- A three-pipe system used heating flow, cooling flow and common return pipework.

allows exceptional
versatility and sim
Maintenance oper
greatly simplified.

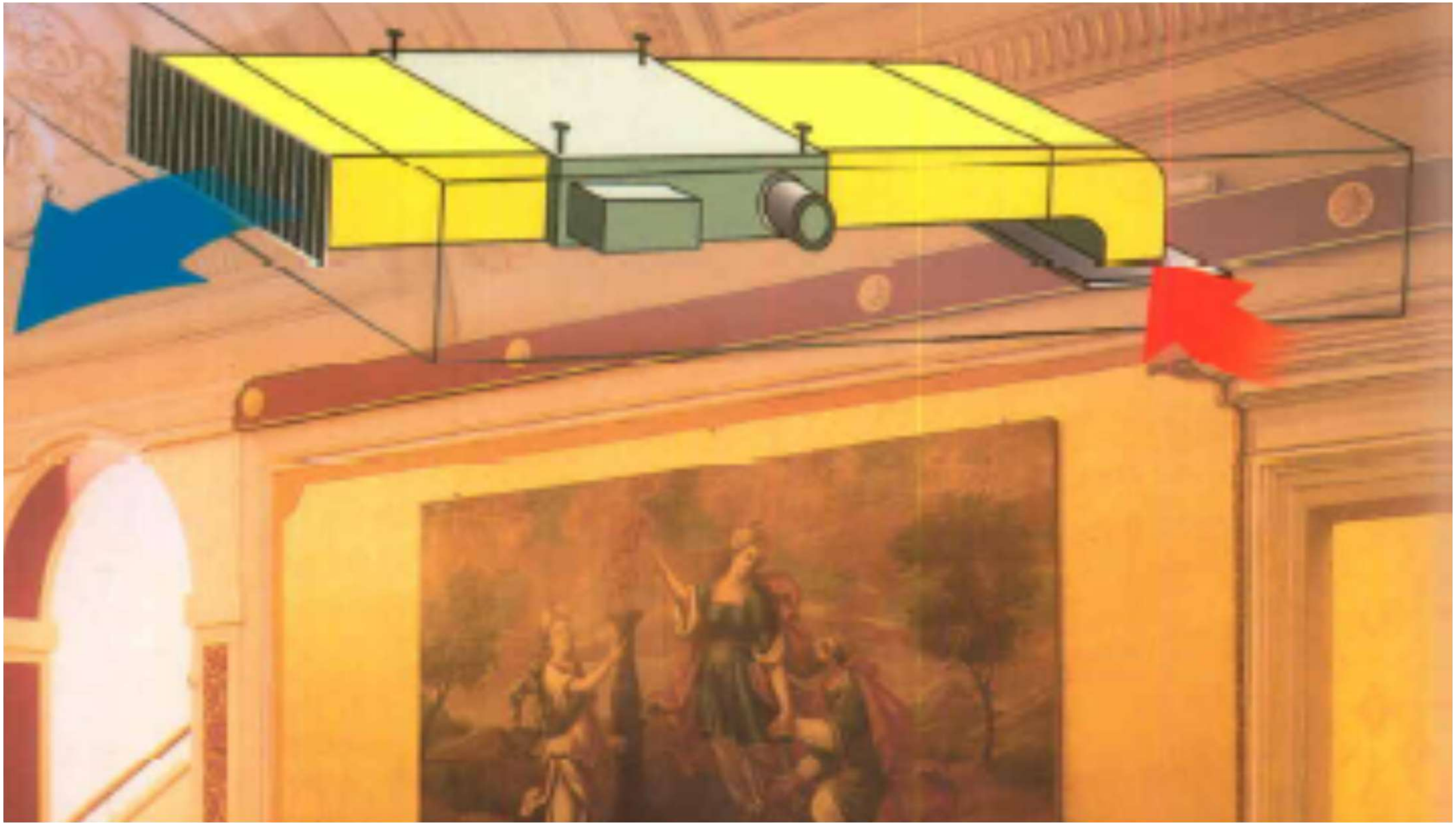




CHILLED WATER FAN COIL UNIT ISTALLATION

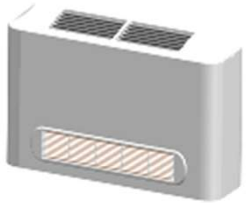


DUCTED CHILLED WATER FAN COIL UNIT



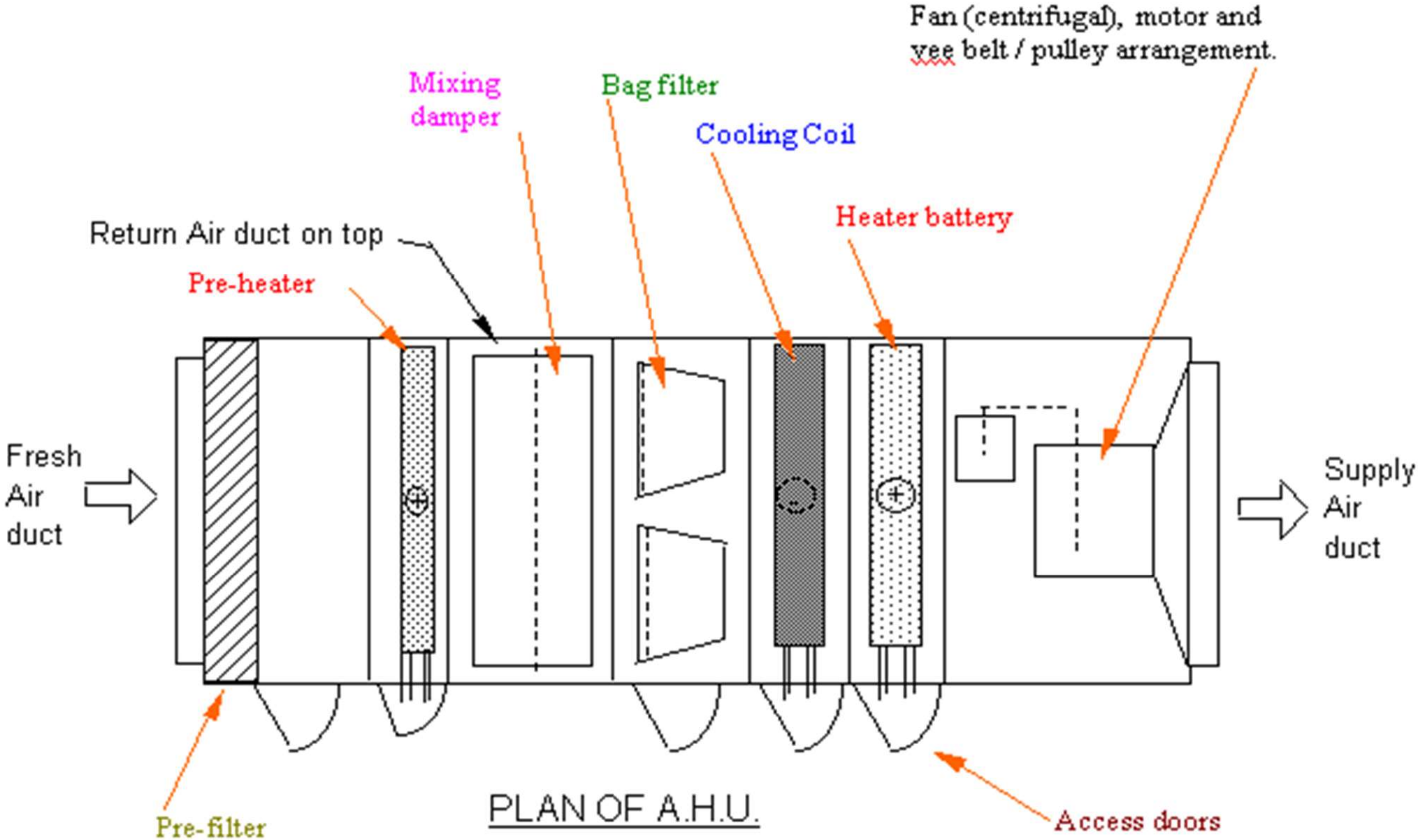
Fan Coil Indoor Units Choice

Fan coil unit



4. AIR HANDLING UNIT

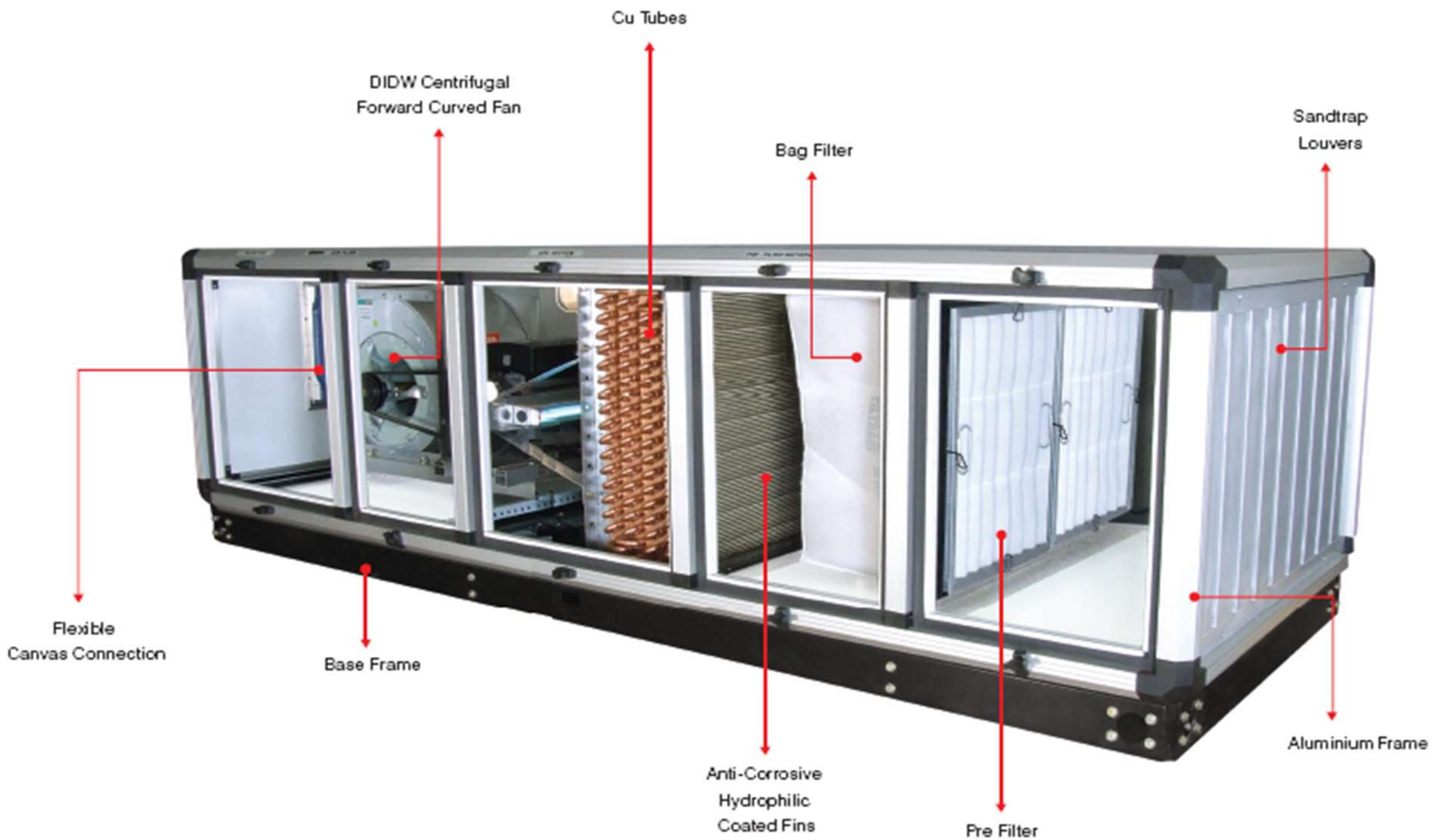
- Air handling units (**A.H.U**.) are widely used as a package unit which incorporates all the main plant items as shown below.
- Pipework, ductwork and electrical connections are made after the unit is set in place on site.
- Since air conditioning plant rooms tend to be at roof level, the larger **A.H.U.'s** are lifted into place by crane before the roof is fixed.



Fan (centrifugal), motor and
vee belt / pulley arrangement.
Mixing
damper
Bag filter
Cooling Coil
Heater battery
Return Air duct on top
Pre-heater
Fresh
Air
duct
Supply
Air
duct
Pre-filter
PLAN OF A.H.U.
Access doors

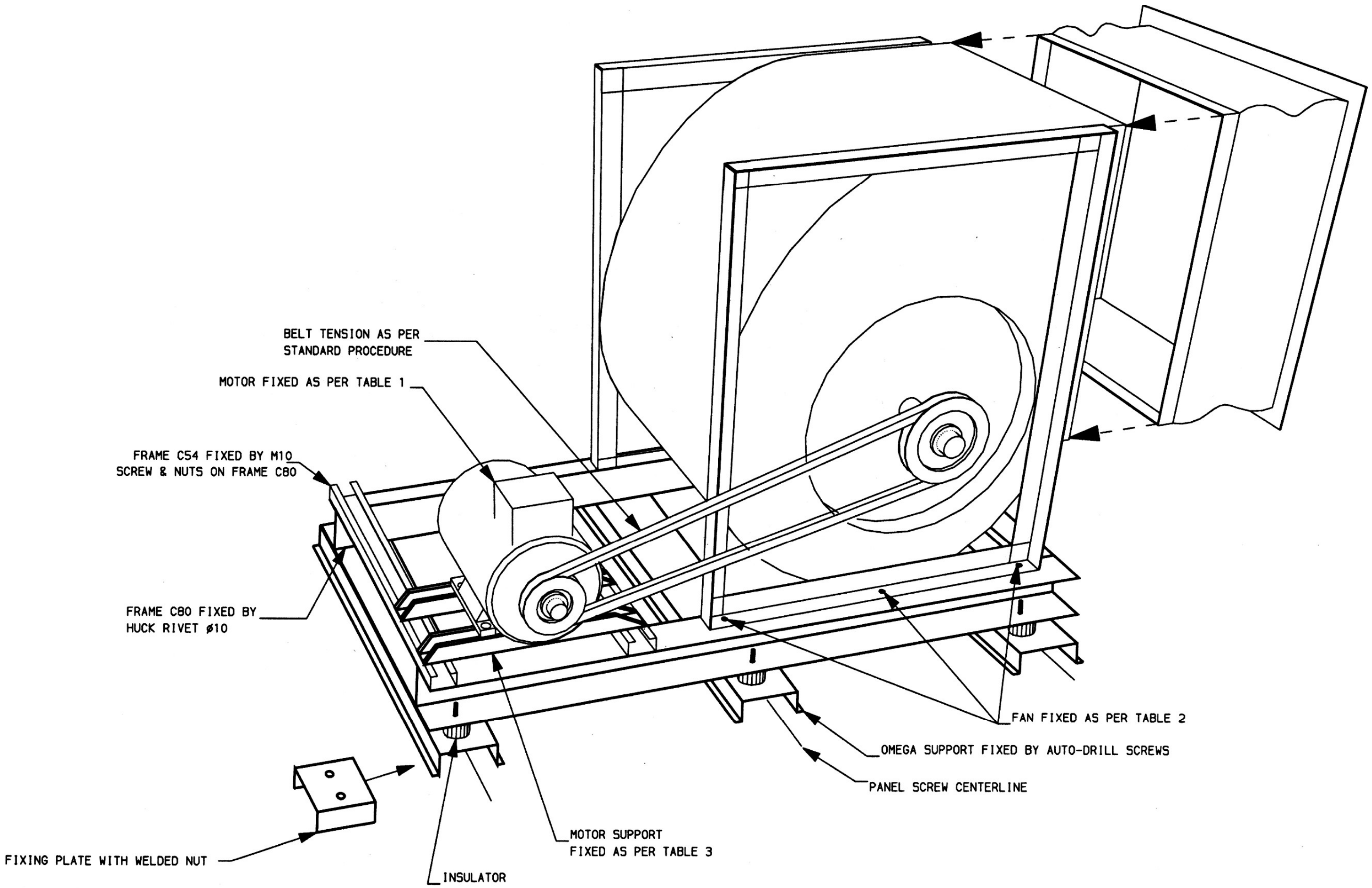
TYPICAL AIR HANDLING UNIT

STANDARD AHU LAYOUT :



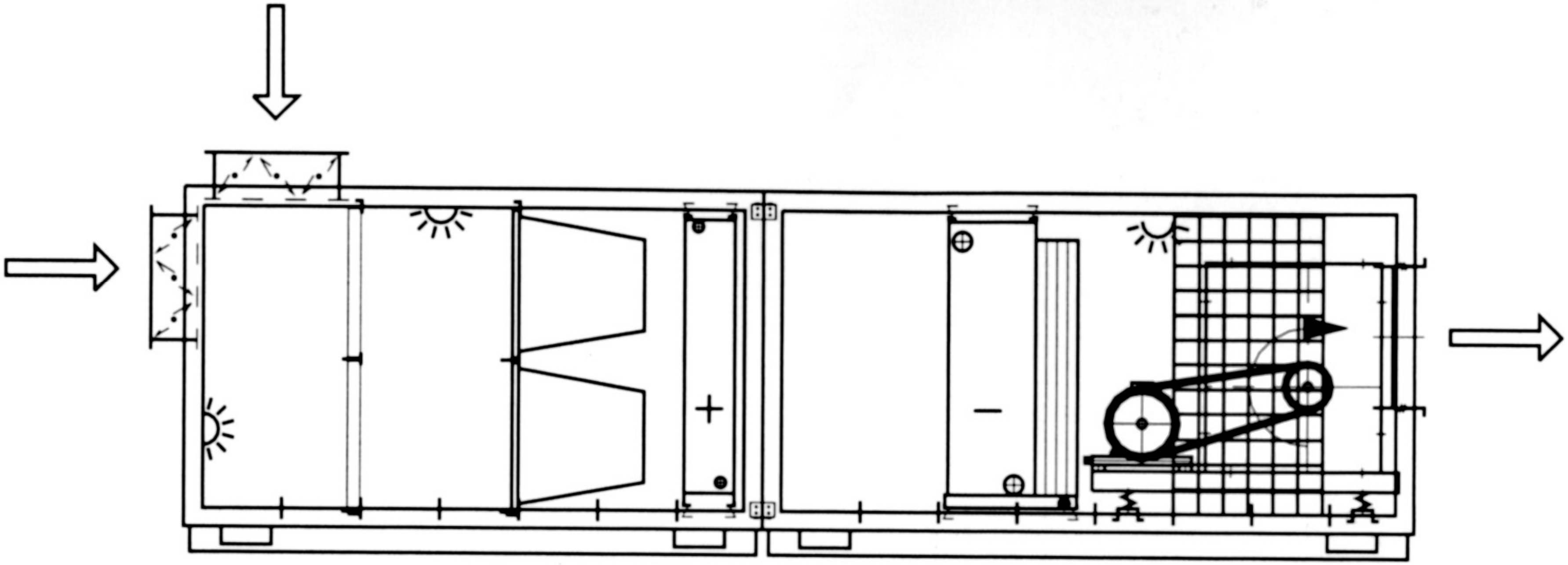
-:Double Skin Air Handling Unit Internal Features.:-

AHU FAN



BELT TENSION AS PER
STANDARD PROCEDURE
MOTOR FIXED AS PER TABLE 1
FRAME C54 FIXED BY M10
SCREW & NUTS ON FRAME C80
FRAME C80 FIXED BY
HUCK RIVET ø10
FAN FIXED AS PER TABLE 2
OMEGA SUPPORT FIXED BY AUTO-DRILL SCREWS
PANEL SCREW CENTERLINE
FIXING PLATE WITH WELDED NUT
MOTOR SUPPORT
FIXED AS PER TABLE 3
INSULATOR

Air Handling Unit Dampers



CONTROL OF AHU

- Three way valve installed between inlet and outlet of chilled water can by-pass the chilled water without entering into the cooling coil to return to the chiller when the air doe not require cooling.

- The AHU Fan can be turned on and off depending on room temperature.
- The air volume flow rate can be controlled proportional to the room temperature by regulating the fan speed of AHU.

5. CHILLERS

30KW module

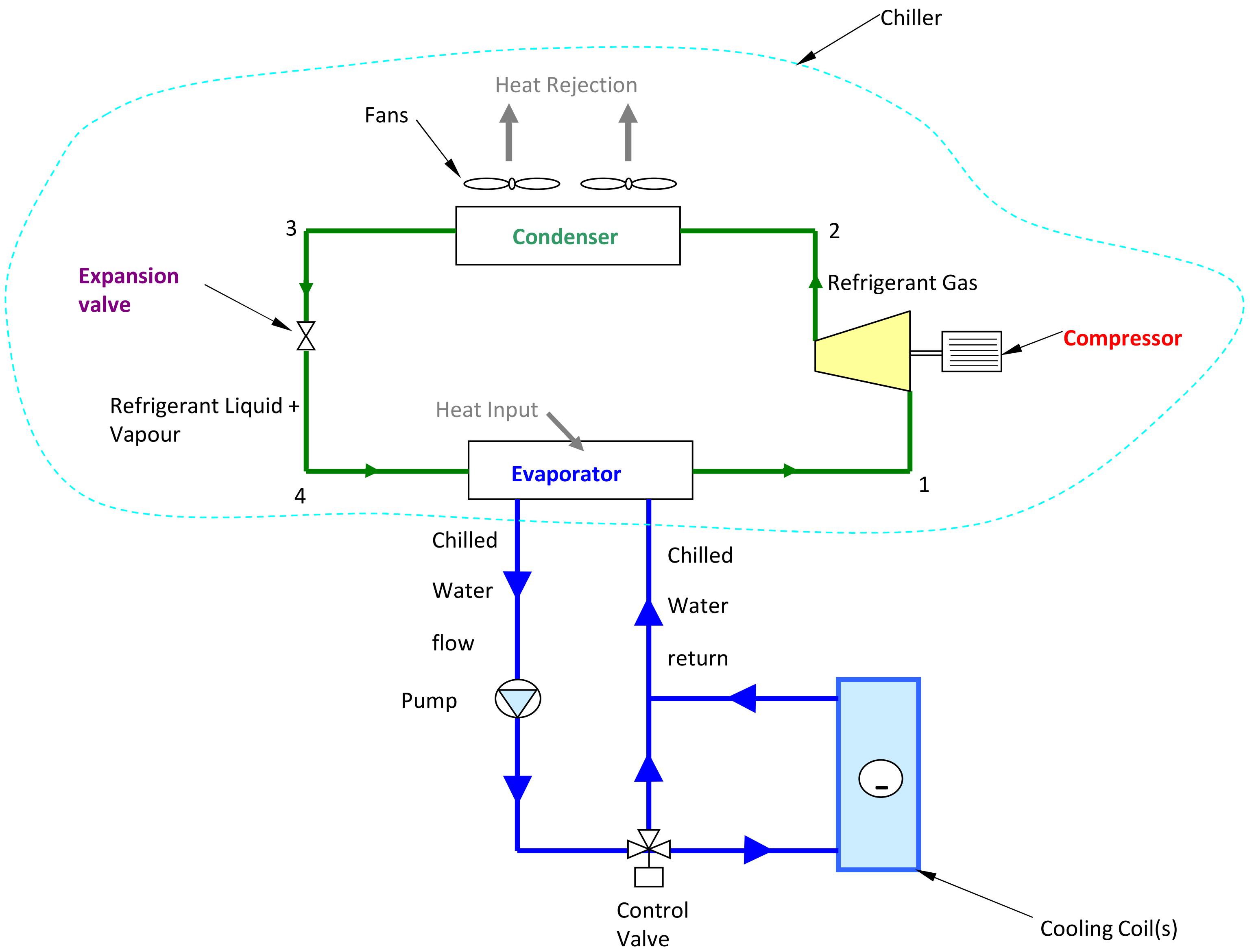
65KW module

200KW module

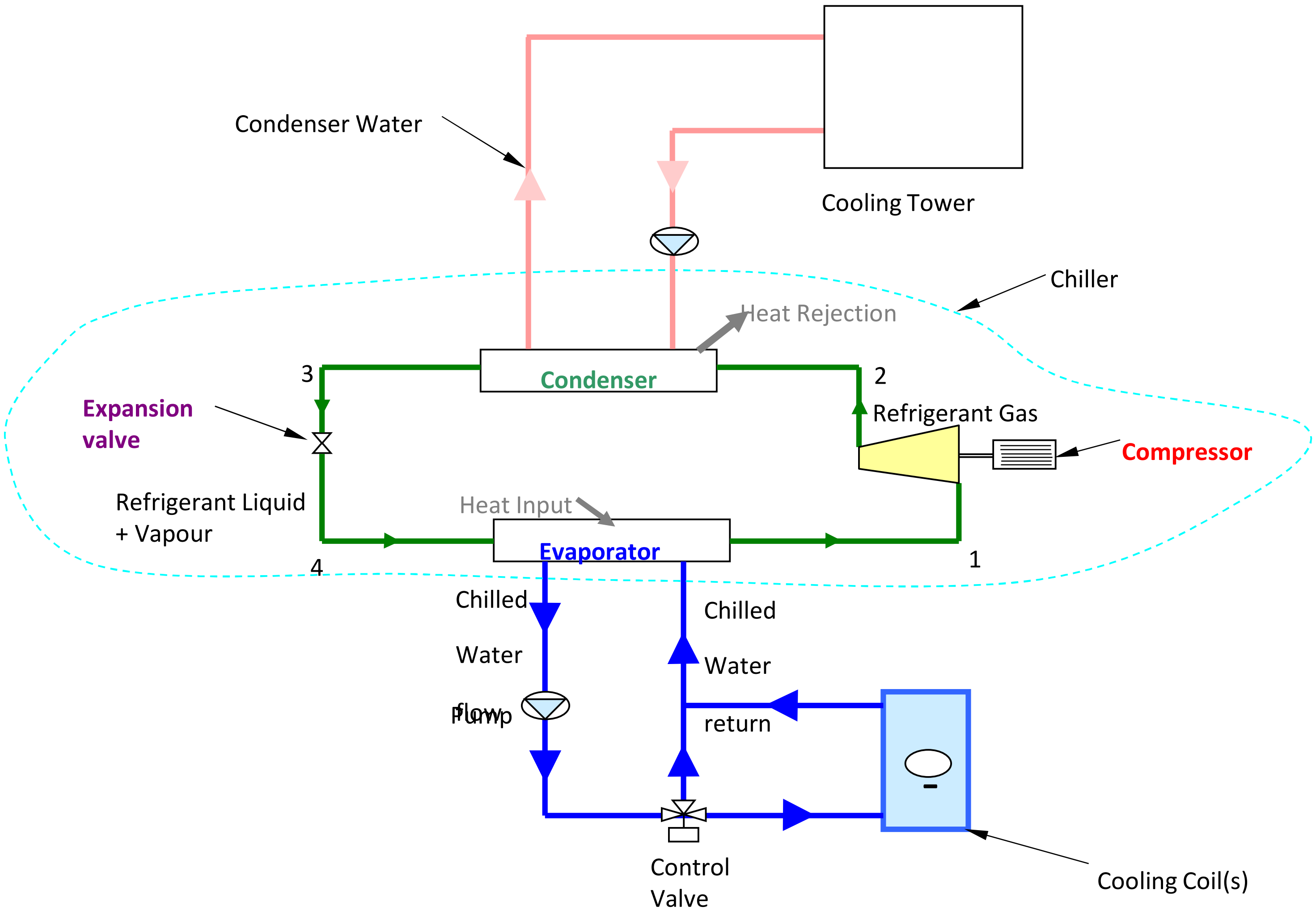
Chillers

For large installations the Condenser, Evaporator, Compressor and Expansion device can be purchased as a package unit, known as a **Chiller.**

The usual package consists of electrically driven Fans mounted on top of two shell and tube or plateheat exchangers, one for the evaporator and the other for the condenser.



Chiller Schematic Diagram with Air Cooled Condenser



Chiller Schematic Diagram

with Cooling Tower

CHILLED-WATER SYSTEM

In larger buildings and particularly in multi-story buildings, the split-system approach begins to run into problems. Either running the pipe between the condenser and the air handler exceeds distance limitations (runs that are too long start to cause lubrication difficulties in the compressor), or the amount of duct work and the length of ducts becomes unmanageable. At this point, it is time to think about a **chilled-water system**.

- In a chilled-water system, the entire air conditioner is situated on the roof or behind the building.
- It cools water to between 4.0^{o}C and 8.0^{o}C.
- This chilled water is then piped throughout the building and connected to the cooling coils in air handlers as needed.
- There is no practical limit to the length of a chilled-water pipe if it is well-insulated.

CHILLED WATER TEMPERATURES

•Typically chilled water flow and return temperatures to cooling coils is generally between 7^{o}C and 12^{o}C, depending upon the dew point to be maintained.
•When this water is pumped through the evaporator section of the chiller this water temperature will be lowered by about 4^{o}C to 6^{o}C.
•In order that the necessary heat transfer may take place, the refrigerant must be at some temperature below that of the leaving water but, at the same time, it must generally be slightly above freezing point.

In a typical case, the following water temperatures may be used:

- Cooling coil inlet 10°C
- Cooling coil outlet 6°C
- Water at evaporator outlet 5.5°C

The refrigerant in the evaporator would in this case be maintained at about **1°C** giving a differential for **4.5°C** for heat transfer.

AIR-COOLED SCREW CHILLER

250kW

350kW

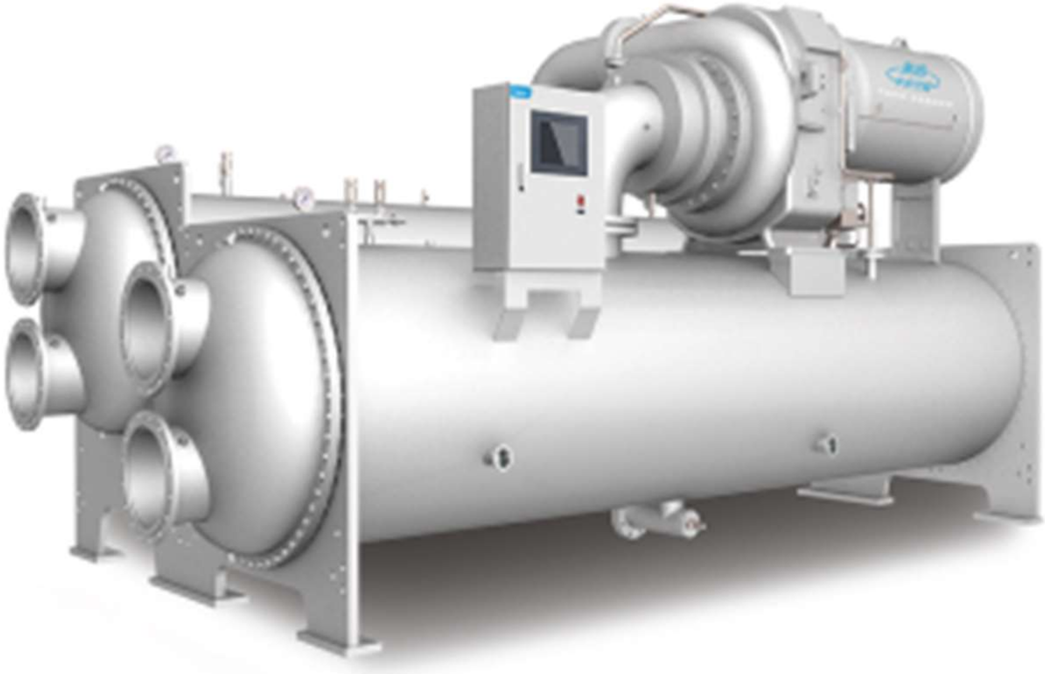
600kW

- 250+250=500Kw
- 250+350=600Kw
- 350+350=700Kw

2 units factory assembled

WATER COOLED CHILLER

Centrifugal chiller



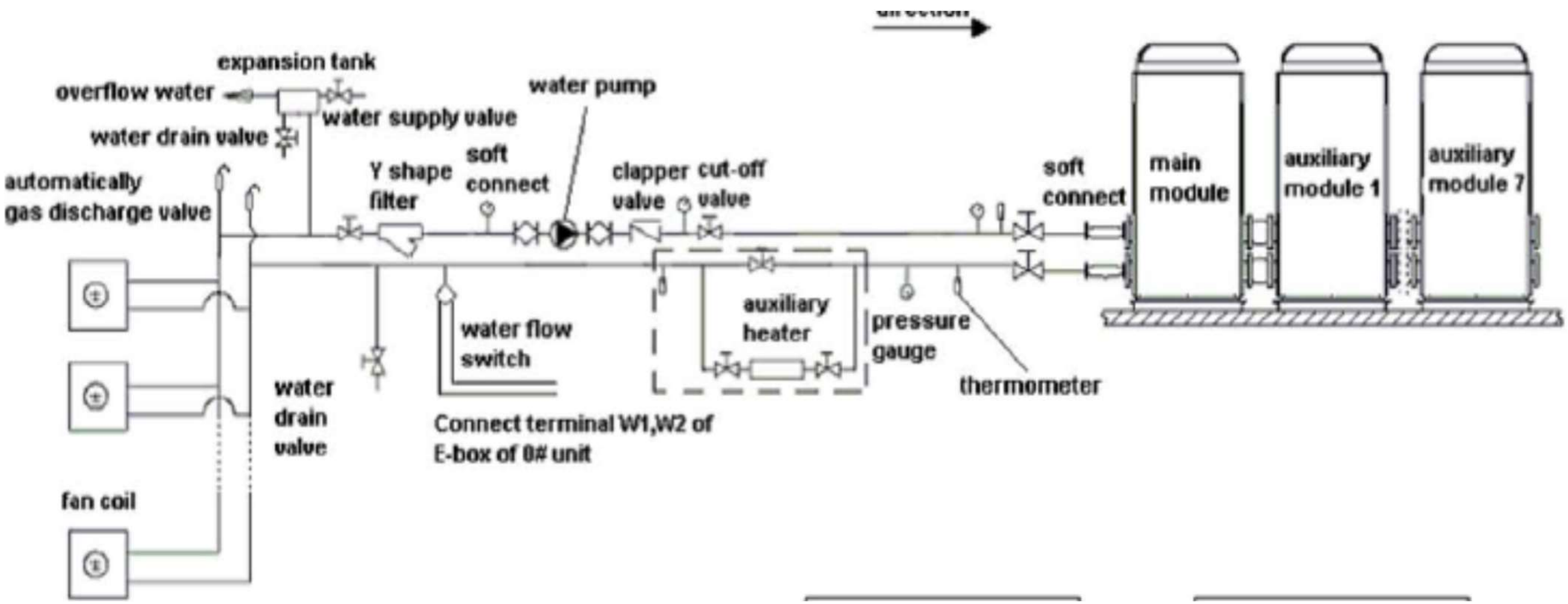
R134A
350-1800 Ton

Refrigerant	R134a													
Compression	one stage									dual stage				
Capacity (RT)	350	400	450	500	550	600	650	700	750	1200	1350	1500	1650	1800
	800	850	900	950	1000	1100								
Power supply	380V/3P/50Hz									6,000V		10,000V		

CHILLER INSTALLATION

- The water passage is narrow due to the adoption of plate heat exchanger, so it is easily jammed by particles or dust, which may cause freezing and damage the system. To prevent this problem, the users should try to install a Y shape filter or strainer at the inlet of chilled-water or cooled-water near the module.
- The water pipeline should be cleaned before connecting to the unit, then dismantle the filter and install again. After confirming the water pipeline is clean, the connection can be done.
- The soft connector should be used at the inlet (outlet) water pipe to avoid vibration.

CHILLED WATER PIPING



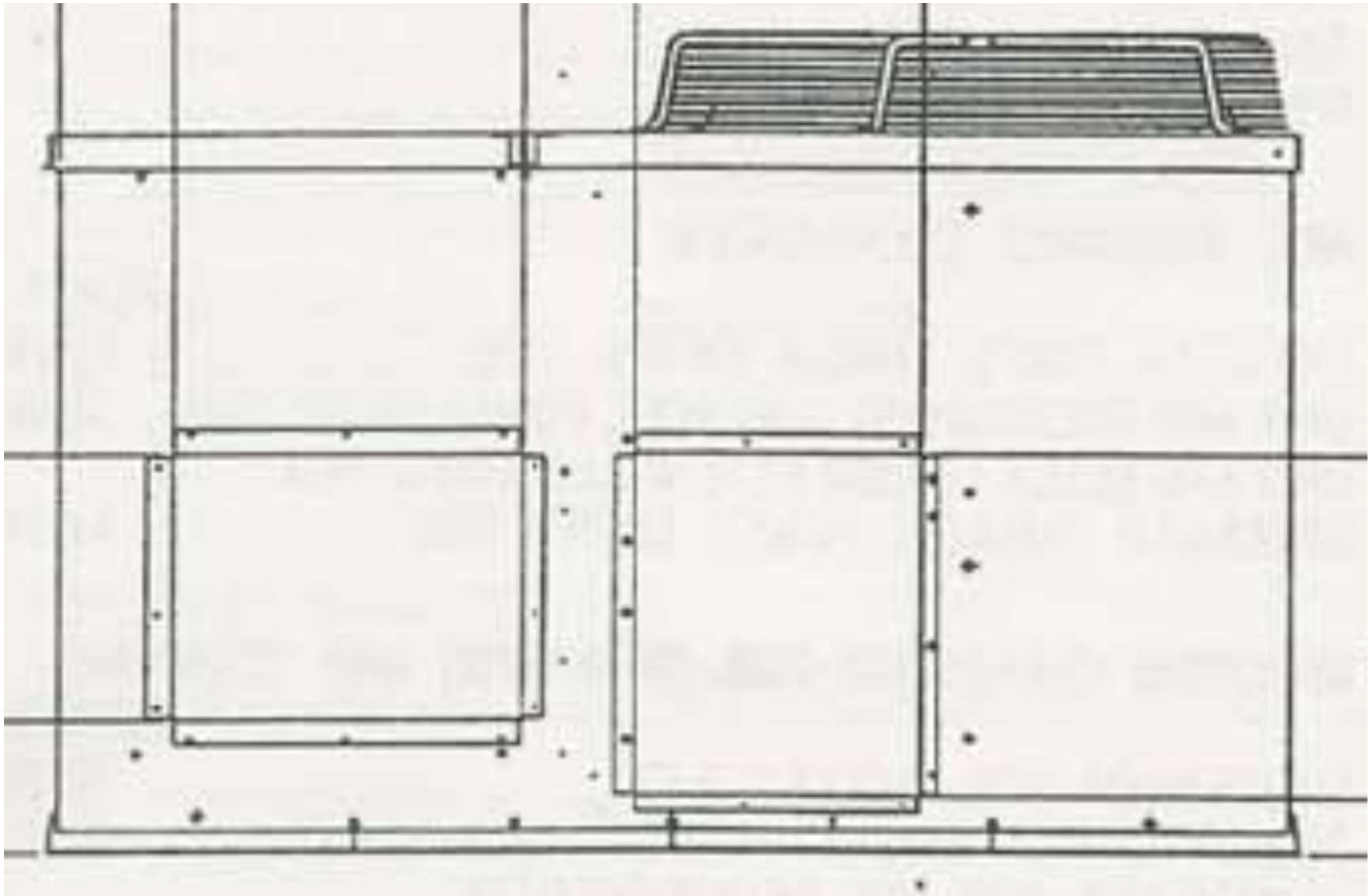
6. ROOF TOP PACKAGE UNIT

- The Roof Top Package units consist of evaporator and condensers side by side packed together
- The evaporator is used to cool air that is supplied to the room/hall. It has also a fan to pressurize the supply air
- The condenser is cooled by blowing air with fan.
- Compared to AHU, it can be used to cool limited space such small halls.

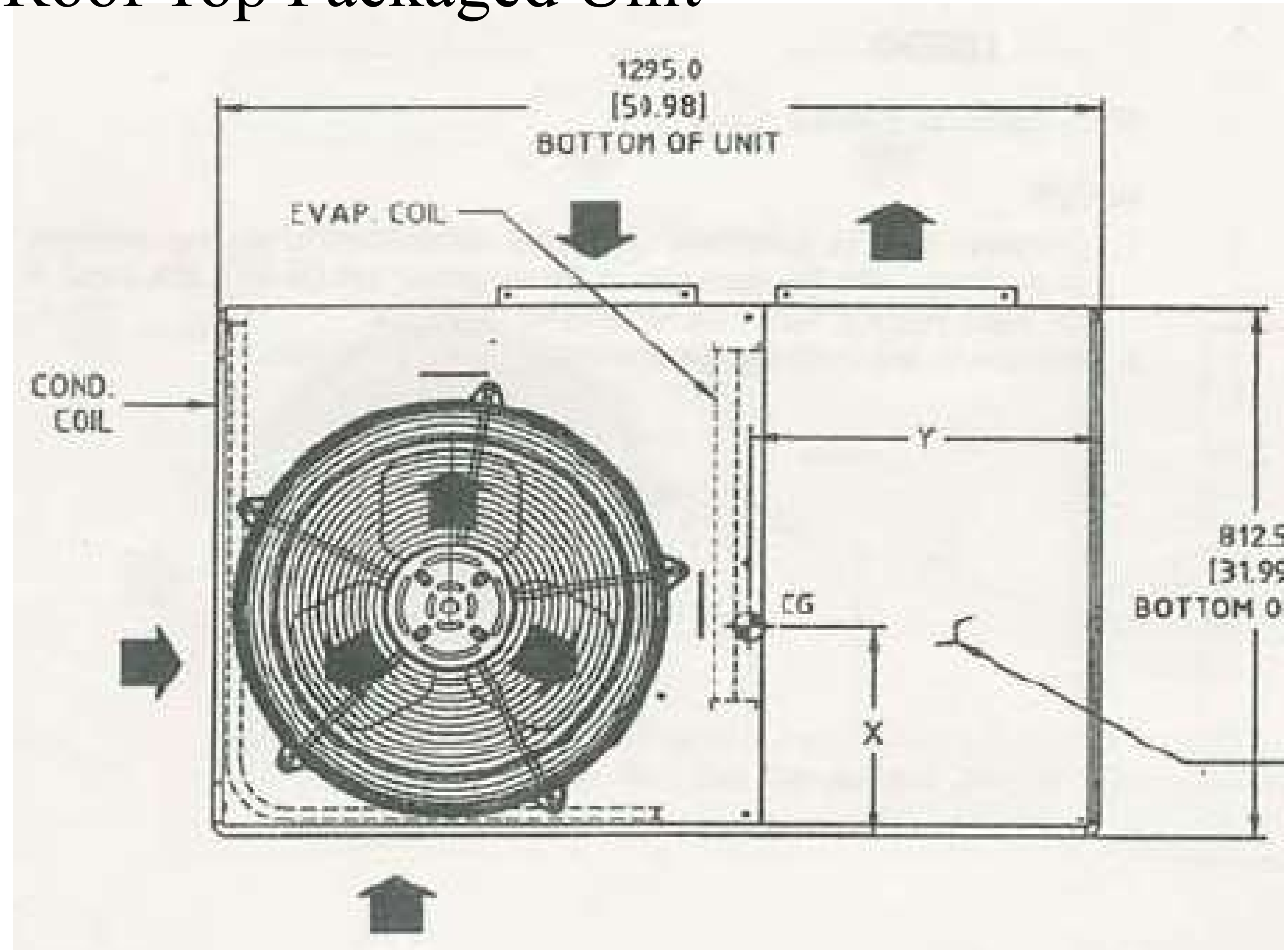
7. ROOF TOP PACKAGE UNIT

- The Roof Top Package fan does not have capacity to pump through long duct work.
- The unit is controlled by thermostat installed inside the room.
- The evaporator is used to cool air that is supplied to the room/hall. It has also a fan to pressurize supply air
- The condenser is cooled by blowing air with fan.
- Compared to AHU, it can be used to cool limited space.

Roof Top Packaged Unit (Top View)



Roof Top Packaged Unit

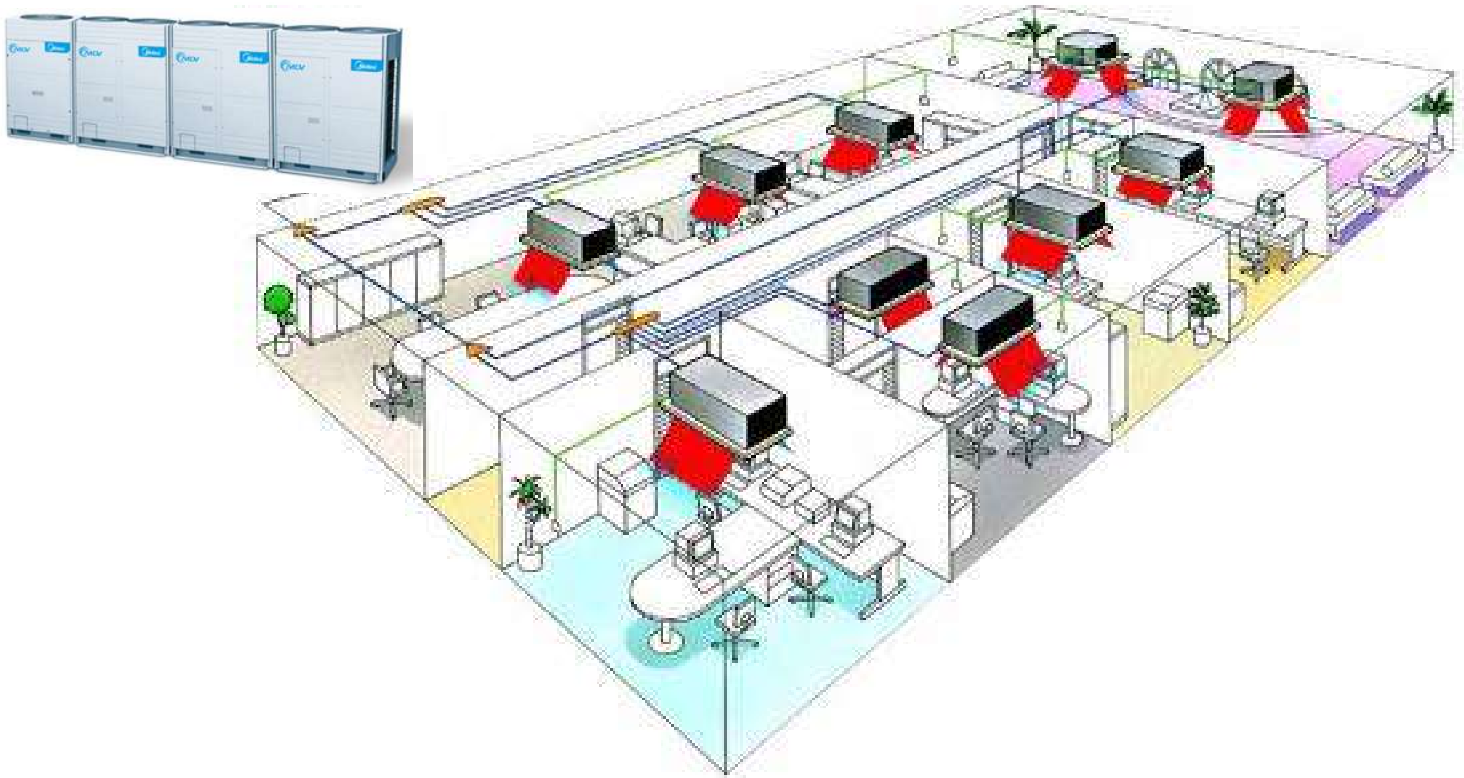


7. VRF SYSTEM

Several Indoor unit sare connected to one out door unit.The combined cooling capacity of the indoor sections can match, exceed, or be lower than the capacity of the outdoor section connected

- Variable Volume/speed compressors and fans in the outdoor units modulate their Loading duration/speed, saving energy at part-load conditions.
- The system offers designers and occupants the ability to choose multiple individualized zones,.

VRF



VRF A/C Market Transition

Conventional Splits → **VRF A/C**

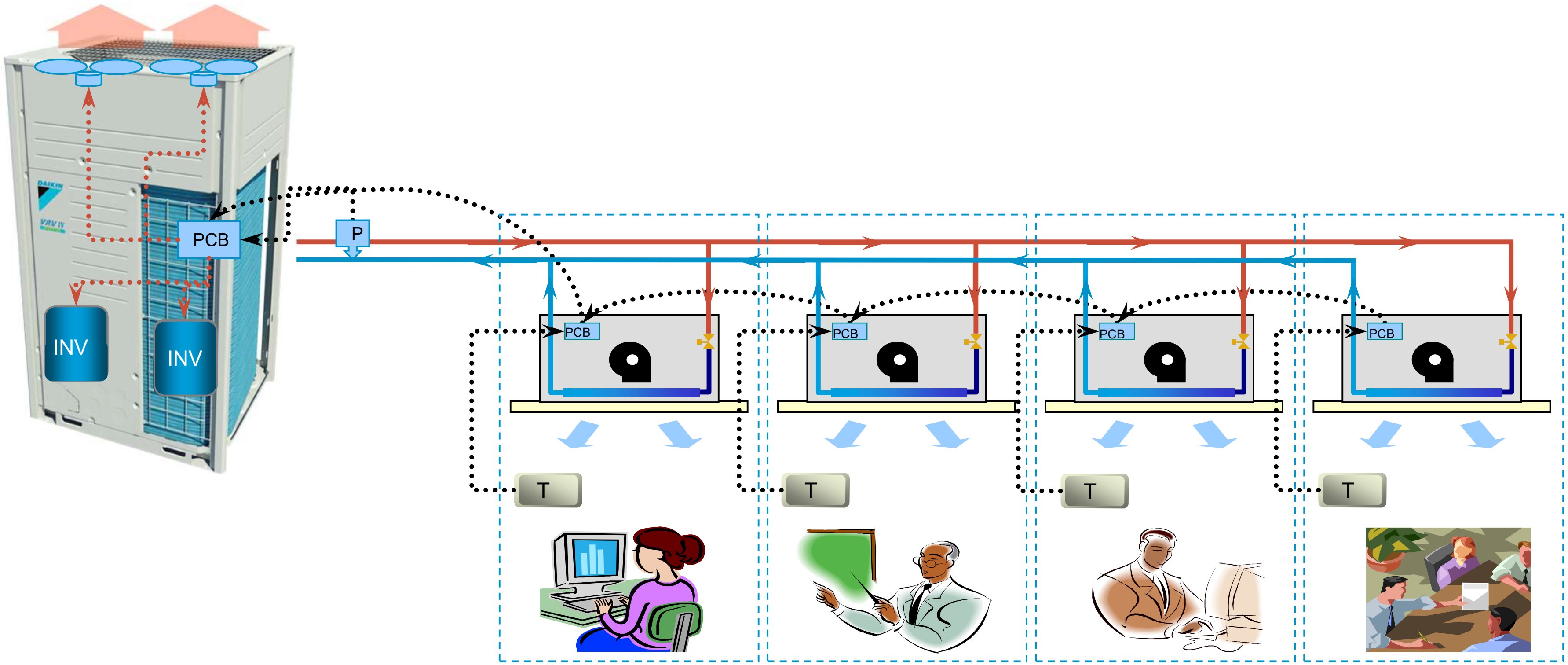
Benefits Of VRF A/C Systems

- Precise Temperature Control ± 0.5° C
- Precise Humidity Control
- Individual Room Comfort Control
- Superior Aesthetics & Prestige

Rapid Growth In Capacity Modulated System
– Single & Multi Head

Shift From Chillers/ Ducted Systems
– VRF (Multi Head)

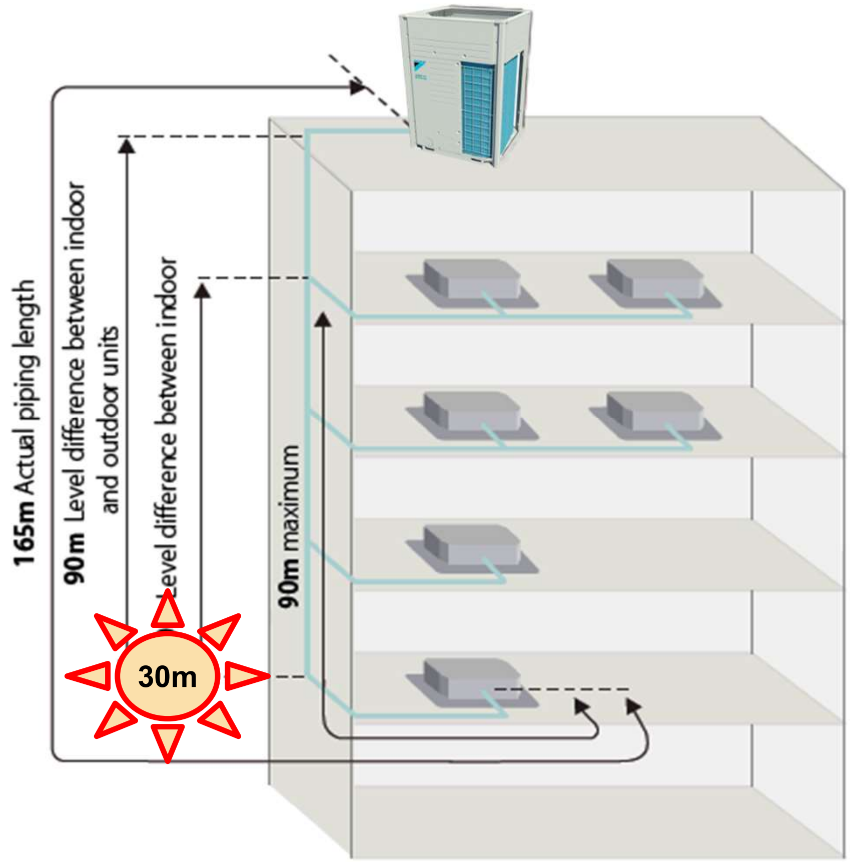
HOW DOES IT WORK? - VRV® Concept



Lengths - Heights

- Farthest indoor: 165m (190m equivalent)
- Height difference between outdoor and indoor: 90m
- Height difference between indoors: 30m
- Total piping length: 1.000m

Note: There are limitations depending on connectable type of indoors, piping diameters etc. Always consult technical literature.



8. SOUND AND VIBRATION

Sound and vibration in an air conditioning and ventilation system arise from mechanical and electrical equipment and from the flow of water through pipes and the flow of air through ducts and grills.
Installing flexible duct between equipment (air handler, fans) and duct connection.

Where fan noise will be a problem, sound attenuator should be used to meet the required sound level through attenuation.
Vibration isolators shall be mounted underneath the equipment and type strength of the vibration isolators to match the load requirement.

Allowable Sound Level as Per ES

Area	Low dBA	Average dBA	High dBA
Cinema theatres	-	35	40
Private executive type offices	35	40	45
General offices other private or semi private offices	40	45	50
Conference rooms	35	40	45
Air-Condition Classrooms	40	45	50
Hotel bedrooms	35	40	45
Hospital wards	35	40	45
Places of public resort e.g. shops	40	50	55
Circulation areas e.g. staircases, lobbies, car parks	50	55	60
Factory	70	72.5	75
Studio	25	27.5	30

REVIEW QUESTION

1. What is Air conditioning?
2. What are external cooling loads?
3. What are internal Cooling load?
4. Discuss how the cooling load is affected by orientation of a bulding and window area?
5. What is self contained air conditioning system? Name two types?
6. What is central air-conditioning system?
7. What is fan coil unit?
8. What is AHU?
9. What is a chiller?
10. What is Roof top unit?
11. What is VRF system
12. Compare and contrast Fan coil units and VRF systems.