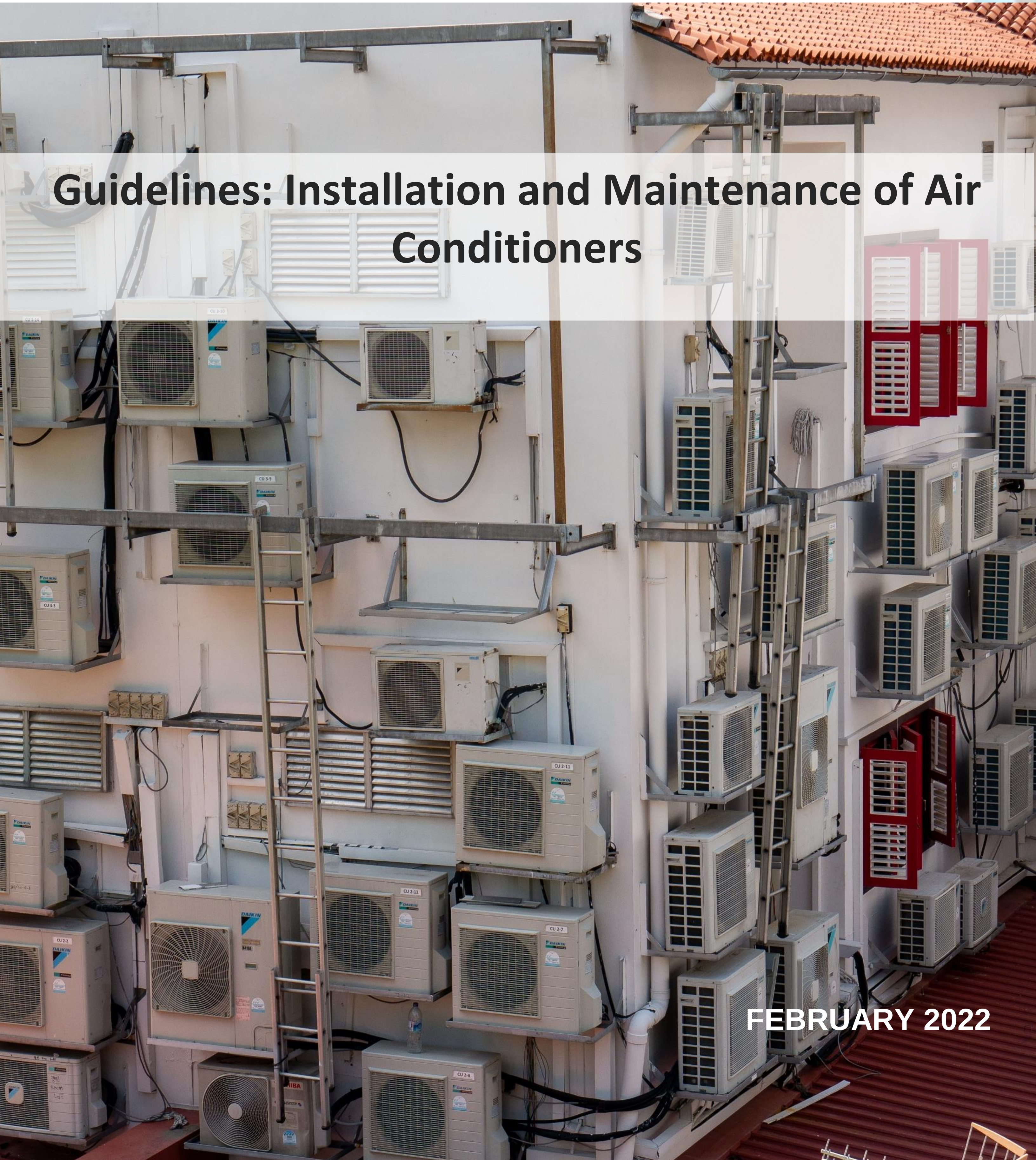
Energy Efficiency Management Office

Guidelines: Installation and Maintenance of Air Conditioners



FEBRUARY 2022

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ACRONYMS AND ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CO_2	Carbon dioxide
EER	Energy Efficiency Ratio
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefins
IEC	International Electrotechnical Commission
SEER	Seasonal Energy Efficiency Ratio
COP	Coefficient of Performance
ISO	International Standardisation Organization
KWc	Kilowatt Cooling
MEPS	Minimum Energy Performance Standards
SEER	Seasonal Energy Efficiency Ratio
TWh	Terawatt-hour
U4E	United for Efficiency
UNEP	United Nation Environment Programme
AC	Air conditioner
GWP	Global warming potential
UV	Ultra Violet
BTU	British Thermal Unit
EU	European Union
MS	Mauritius Standards
W	Watt
Wc	Watt cooling
R value	Resistance value
VRV	Variable Refrigerant volume

1. AIR CONDITIONING SYSTEM OVERVIEW

1.1 Definition, Operating Principles & Main Components

Air conditioner means a device capable of cooling or heating, or both, indoor air, using a vapour compression cycle driven by an electric compressor, including air conditioners that provide additional functionalities such as dehumidification, air purification, ventilation, etc.

An air-conditioning system distributes cooled air in an enclosed space. Air conditioning involves modifying the temperature and humidity of the air supply to make users more comfortable in a space, subject to heat gains and/or losses and depending on the product's use and climatic conditions.

The key components of an air conditioner consist of a compressor, a condenser, an evaporator. A space is cooled by eliminating heat gains, which are absorbed by the refrigerant circulating in the indoor evaporator under pressure from a compressor installed in the outdoor unit. The compressor "compresses" the refrigerant, which, owing to the changes in its state, can transfer cooling energy in hot weather and heating energy in cool weather in the case of reverse cycle air conditioning systems.

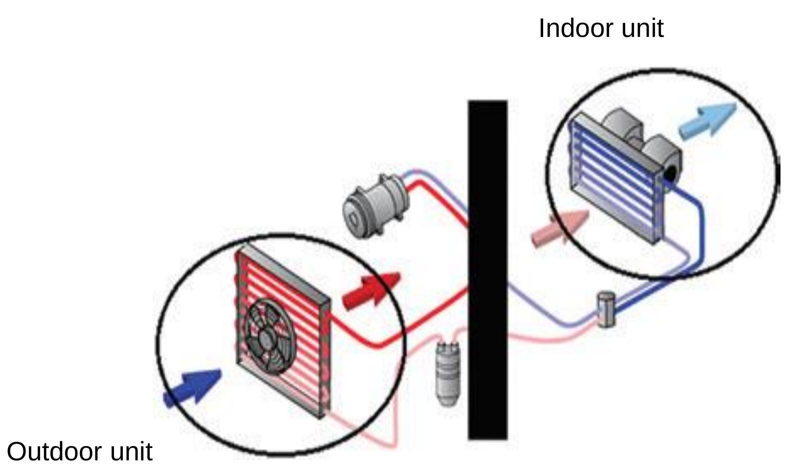
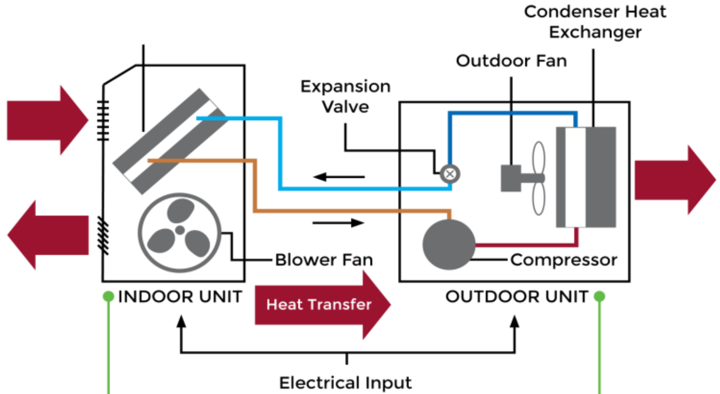


Figure 1: Illustration of the main components of an air conditioner

The main components of a split air conditioner, the most widely used type, include an indoor unit installed inside the room to be cooled and an outdoor unit installed outside the room in open space. In addition, a tubing connects the indoor and outdoor units carrying the refrigerant.

Basic air conditioning vapour compression cycle



Indoor Unit

The indoor unit produces the cooling effect inside the room. It is a box-type housing in which some parts of the air conditioner are enclosed: the evaporator coil, air filter, cooling fan, drain pipe, and louvers or fins.

- The **cooling fan or blower** sucks the hot and unclean air from the room, and supplies cool and clean air back by passing it over the cooling coil and air filter.
- The **air filter**, located just before the cooling coil, removes dirt particles from the room air and helps supply clean air to the room.

Outdoor Unit

The outdoor unit contains some parts of the split air conditioner: compressor, condenser[23], condenser cooling fan and expansion valve.

- The **compressor** compresses the refrigerant and increases its pressure before sending it to the condenser. During this process, heat is generated in the compressor and removed through heat exchangers to the outdoor ambient.
- The **condenser** removes the heat from the refrigerant. It is made of coiled copper or aluminium tubing, which has a high rate of conduction. It is covered typically with aluminium fins so the heat from the refrigerant can be removed at a faster rate.
- The **condenser cooling fan**, located in front of the compressor and the condenser coil, blows surrounding air from the open space over the compressor and the condenser with the aluminium fins, thus cooling them.
- The **expansion valve** is used to lower the temperature and pressure of the refrigerant.

Figure 2: Basic air conditioner vapour compression cycle

1.2 Different Types of Air Conditioner

Individual air conditioners systems can be configured in various ways:

- Combined indoor and outdoor units: Windows (monobloc) air conditioners
- Separated indoor and outdoor units: Split air conditioning systems
- Multiple indoor units separated from a single outdoor unit with multiple refrigerant circuits: Multi-split air conditioners

- Multiple indoor units separated from a single outdoor unit with one refrigerant piping: VRF/VRV systems

The scope of this guideline includes the most popular types of residential air conditioners. These are window type, non-inverter split type, inverter split type, multi-split type, portable AC and VRV/VRF heat pump air conditioners.

Moreover, this guideline will have main focus on cooling applications since heating applications from heat pumps have relatively low market shares for the residential sector.

1.2.1 Windows Air Conditioners

In window type air conditioners (also called monobloc or single packaged unit) all the components, i.e the compressor, condenser, expansion valve and cooling coil; are enclosed in a single housing. They are relatively easy to install.

Some units may be noisier than other types when operating. They are generally less efficient, due to size constraints, have fewer options to improve efficiency.

Figure 3: Window type AC unit (Front view)

Advantages of Window Air Conditioners

- Lower purchase price
- Easy to install

Disadvantages of Window Air Conditioners

- Lower efficiency
- Noisier operation

The sales growth of window units has drastically decreased over the past 15 years in the local context and these type of AC units are no more commercially being sold. Some old window units still running but will ultimately disappear. Hence no further consideration is given to window units in this guideline.

1.2.2 Split Air Conditioners

Split AC is the most common kind. This consists of two distinct units, an internal (indoor unit) and an external one (outdoor unit), connected by refrigerant piping and electric cables. The outdoor unit contains the compressor, and is often the noisier of the two.

Due to the blower being the only moving part in the indoor unit, this unit of AC is almost silent. These can be fit into walls, and with the latest designer looks, can add to the facade of the room as well.

The indoor units can be of different models such as wall mounted (fixed on wall), ceiling mounted (fixed on ceiling/floor), cassette (fixed within false ceiling, concealed (requires air grilles & ducts, generally installed in bulk head).

Table 1: Different models of AC IDUs

1	Wall Mounted Unit	  

2	Conceal Ducted Unit	 
3	Cassette type Unit	 
4	Ceiling Mounted Unit Floor Mounted Unit	  

The split AC dominate air conditioner sales. In addition, they are up to 30% more efficient given the hot side is separated from the cold side, without heat transmission between them (unlike windows air conditioners).

These systems may be larger in capacity and generally installed by trained technicians.

The split Air Conditioners can be of two types:

- Non-inverter type
- Inverter type

1.2.2.1 Non-Inverter Split Air Conditioners

They refer to systems with a fixed speed compressor where the unit turn on & off to maintain room temperature. Also known as the on-off or conventional air conditioner.

Advantages of Non-Inverter Split Air Conditioner

- Lower purchase price than inverter type air conditioners
- Lower control system than inverter type air conditioners. Highly skilled manpower not required
- Repair cost is lower inverter type

Disadvantages of Non-Inverter Split Air Conditioner

- Less efficient than inverter type air conditioners
- Compressor stop & start, hence compressor does not modulate as inverter type, wear & tear more
- Does not give accurate cooling temperature as inverter type

1.2.2.2 Inverter Split Air Conditioners

Split air conditioners using a compressor controlled with a variable speed drive (VSD) are also known as inverter units. The inverter technology (DC) is the latest evolution of technology concerning electro motors of the compressors. An inverter is used to control the speed of the compressor motor, so as to continuously regulate the temperature.

The DC inverter units have a variable frequency drive that comprises an adjustable electrical inverter to control the speed of the electromotor. The drive converts the incoming AC current to DC and then through a modulation in an electrical inverter produces current of desired frequency. A microcontroller can sample each ambient air temperature and adjust accordingly the speed of the compressor.

The inverter AC units have increased efficiency, extended life of parts and sharp fluctuations in the load are eliminated. This makes the inverter AC units quieter. The inverter AC units might be more expensive than constant speed AC units, but this is balanced by lower energy bills. The sales of inverter AC units have increased considerably on the local market due to its energy saving attributes, replacing rapidly the conventional AC units.

The difference between inverter and fix speed air conditioners is that the former can vary the speed of the compressor, delivering precise cooling as required.

Inverter units are designed to meet cooling conditions occurring rarely, operation at part load is more frequent, making inverter split air conditioner more efficient than non-inverter units.

Advantages of Inverter Split Air Conditioners

- More efficient than non-inverter split air conditioners
- Achieves desired temperature quicker and no temperature fluctuations
- Quiet operation as compressor sits in outdoor unit

Disadvantages of Inverter Split Air Conditioners

- Typically, higher purchase price than non-inverter split units
- Highly skilled manpower required due to advanced control system
- Repair cost higher than non-inverter type (for e.g, replacement of faulty electronic card)

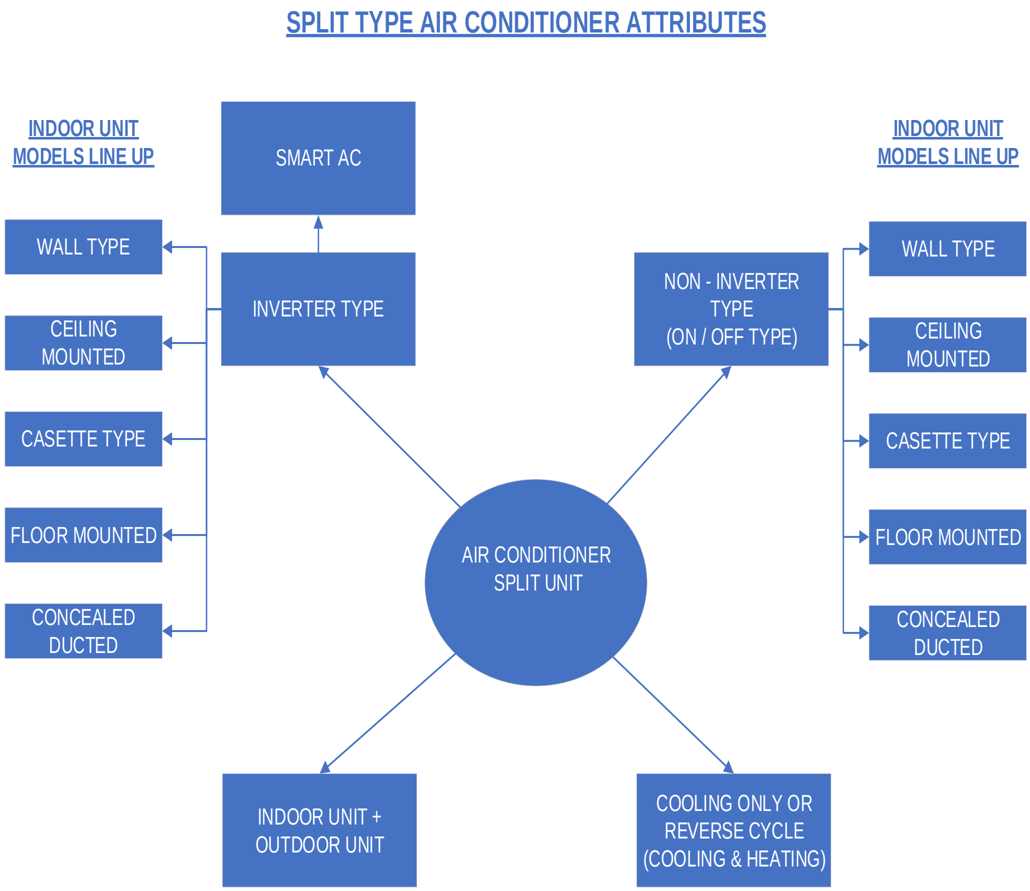


Figure 4: Split type AC attributes

1.2.3 Multi-Split Air Conditioners

Multi-split air conditioners contain numerous indoor units (typically up to four units) connected to a single outdoor unit. They are used to multiple rooms.

Advantages of Multi-Split Air Conditioners

- Multiple indoor units using one outdoor unit
- Can be installed in various rooms
- Separate controls for different rooms

Disadvantages of Multi-Split Air Conditioners

- No redundancy since all indoor units rely on one outdoor unit
- High purchase price

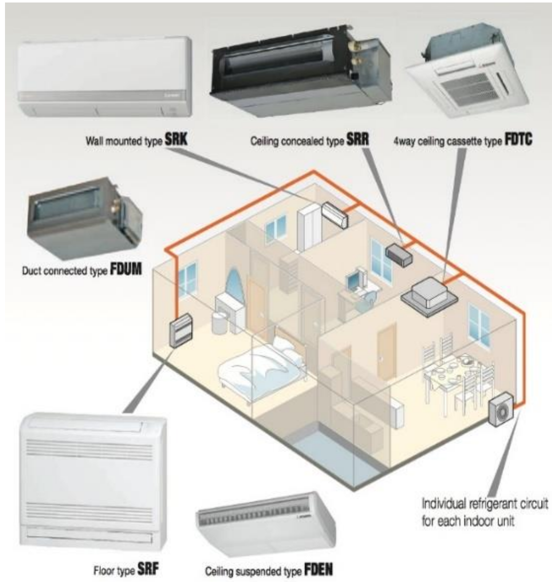


Figure 5: Multi split air conditioner

1.2.4 Portable Air Conditioners

A portable air conditioner is a self-contained unit, similar to a window air conditioner. It is typically designed with wheels to allow it to be moved. Water condensed from the portable air conditioner may be collected in a bucket for manual removal, drained through gravity hose, or evaporated and exhausted with the condenser process air.

Figure 6: Portable air conditioner

Advantages of portable air conditioners

- Lower purchase price
- Can be moved from room to room
- Easy to install

Disadvantages of portable air conditioners

- Typically, less efficient: lower efficiency at hot climate/better efficiency if outdoor air temperature is low
- Noisier operation
- Water need to be removed manually

1.2.5 VRV or VRF Heat Pump Air Conditioners

A VRF (Variable Refrigerant Flow) or VRV (Variable Refrigerant Volume) air conditioning system is a particular type of heat pump air conditioning system in which *one* outdoor unit can be connected to multiple indoor units. Each indoor unit is individually controllable by its user and a variety of indoor unit models can be mixed and matched to suit individual indoor requirement (wall mounted, cassette, ducted, ceiling, etc)

The outdoor unit can be made up of a number of modules to create the required capacity. The compressors can be operated at varying speeds, so the VRF units work at only the rate needed to meet the prevailing heating or cooling requirements, considerably enhancing the efficiency.

Advantages of VRF air conditioning system

- Energy efficiency
- Installation flexibility
- Heat & cool simultaneously
- Quiet operation
- State of the art smart technology controls

Disadvantages of VRF air conditioning system

- High purchase price
- Complex refrigerant piping installation make standard of initial installation a crucial factor on life expectancy. Highly skilled manpower resources required.
- Leak detection trouble shooting very difficult
- Being a centralised system, shut down of the outdoor unit for troubleshooting entail shutting down of all indoor units

1.3 AC Classification

Air conditioners are generally classified of several criteria: the most common of these are presented below.

AC CLASSIFICATION

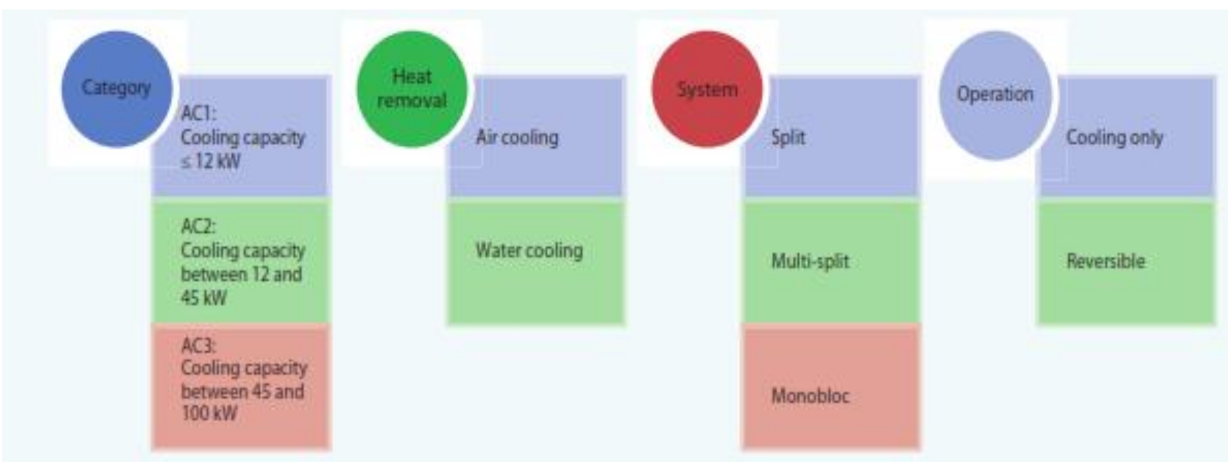
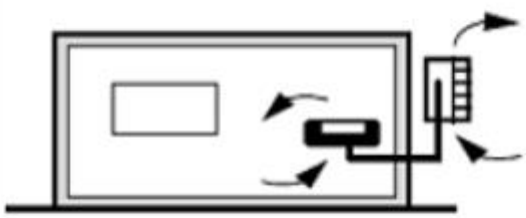
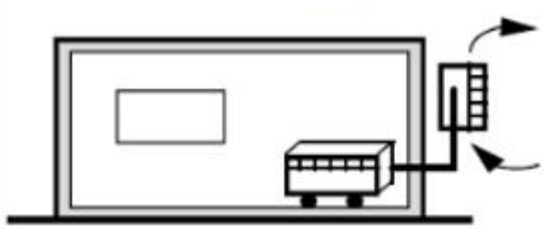
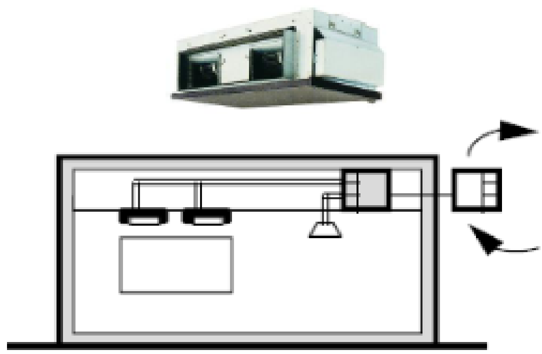
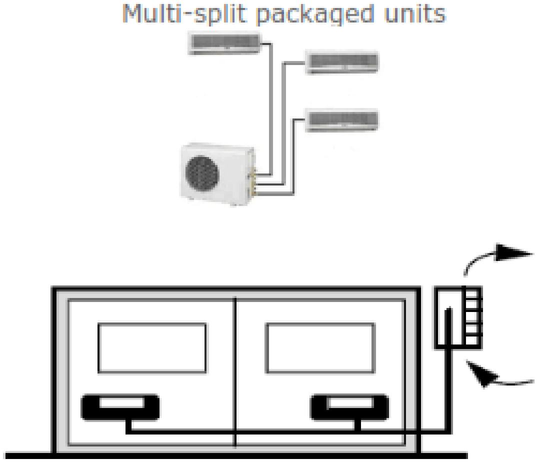
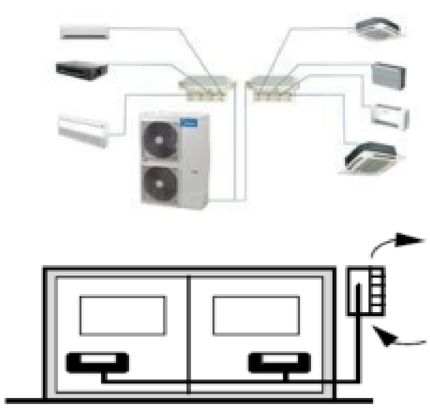


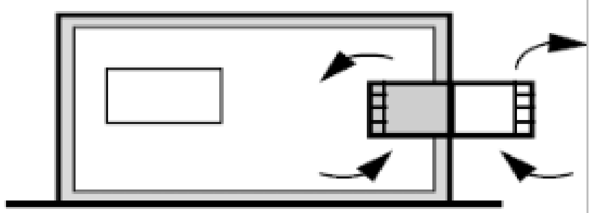
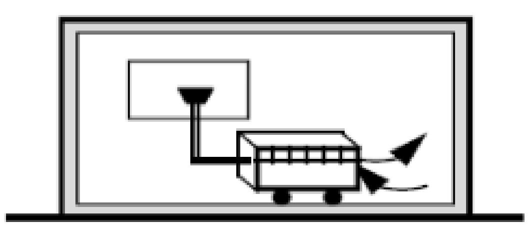
Figure 7: Air conditioner classification

1.4 Summary of Type of Air Conditioners

Table 2: Summary of Type of Air conditioners

Product group	Product category	Definition
Air conditioners - cooling only and reversible	Split (Non-ducted fixed split-packaged unit)  	A split-packaged unit is defined as a factory assembly of components of a refrigeration system fixed on two or more mountings to form a matched unit. This type of appliance comprises two packages (one indoor and one outdoor unit) connected only by the pipe that transfers the refrigerant. The indoor unit includes the evaporator (respectively condenser in heating mode) and a fan, while the outdoor unit has a fan, compressor and a condenser (respectively evaporator in heating mode). Fixed non-ducted indoor units can be mounted high on a wall, floor-mounted or as 'cassette', ceiling-suspended, built-in horizontal or built-in vertical.
	Mobile Split (Non-ducted split packaged unit with mobile indoor unit)  	Indoor unit(s) can be also be non-ducted and mobile. Mobile split units are often categorised at points of sales as mobile or portable air conditioners. Opposed to fixed split, the compressor is located in the indoor unit, while the outdoor unit only contains the condenser heat exchanger and fan. The outdoor unit for a mobile split can be either fixed or mobile.

Product group	Product category	Definition
	Ducted split packaged unit 	Indoor unit(s) for split can also be ducted. Ducted indoor units can deliver cool air to several rooms or to several spots within a single room.
	Multi-split packaged units 	Multi-split packaged units comprise several interior units (up to 4) connected to one exterior unit. These units are similar to split interior and exterior units. Indoor units can be ducted or non-ducted.
	Multi Variable Refrigerant Flow (VRF) units[1] 	This type of product is similar to multi-split packaged units, except instead of having one refrigerant connection between each indoor unit and the outdoor unit, the refrigerant is distributed in the building via a single connection to the outdoor unit. This product may allow to have heating and cooling in different zones of the building and heat recovery between zones, these options are not available for multi-split package air conditioners. These have been mostly non-residential products, but recently some manufacturers offer smaller systems ≤ 12 kW.

Product group	Product category	Definition
	Single-packaged unit, through the wall  	Single-packaged units, commonly known as 'window' or 'through-the-wall' air conditioners (respectively they are called "room air conditioners" and "package terminal air conditioners" in the USA), are strictly defined as a factory assembly of components of a refrigeration system fixed on a common mounting to form a single unit. This type of equipment comprises a single package, one side of which is in contact with the outside air heat release outside, while the other side provides direct cooling to the air inside. The two sides of the appliance are separated by a dividing wall, which is insulated to reduce heat transfer between the two sides. This type of air conditioners has relatively low sales in the EU but is more common in the USA.
	Single duct mobile air conditioner  	Single-packaged mobile units, commonly known as 'mobile' or 'portable' air conditioners comprise a single package, one side of which extracts indoor air to cool the condenser and releases it outdoor, while the other side provides direct cooling to the air indoor. The two sides of the appliance are separated by a dividing wall, which is insulated to reduce heat transfer between the two sides.

Source AC & comfort fans: review of Regulation 206/2012 & 626/2011 – Final report – EU, HAL – 2018

2. SIZING OF AIR CONDITIONERS

Air Conditioners are designed to accomplish three tasks:

- Reduce the air temperature
- Remove excess moisture
- Filter/Clean the air

2.1 Room Conditions & BTUs

To accomplish these tasks, the right air conditioner must be sized based on the conditions of the room. However, the sizing of an air conditioner is a very complex calculation as it involves various parameters and differs from region to region.

In Mauritius, the sizing of domestic AC is mostly based on the area of the room, and the region. The sizing of the air conditioners should depend on how much cooling capacity will be required to keep the occupant at a comfortable temperature.

This load will be partly dependent upon the home's square footage (square metre).

Also more accurate load determination will include: -

(a) building construction, orientation to the sun, "R" value of the insulation;

(b) number, size, and placement of rooms;

(c) number, size, and placement of windows and doors;

(d) types of windows and doors (thermal efficiency);

(e) number and arrangement of floors;

(f) the climate

Room temperature: The typical temperature of the room will help determine how powerful the air conditioner needs to be in order to keep the room cool. This vary through-out the year.

The temperature normally ranges from 20 °C to 26 °C (CEB recommends range 24 °C to 26 °C in order to save energy)

British Thermal Units or BTUs are used to measure thermal energy.

When choosing an air conditioner, the BTU/hr rating refers to the amount of heat that the unit can remove from the air over a certain period of time. An air conditioner with a higher BTU/hr rating will be able to remove more heat than an air conditioner with lower BTU/hr rating.

An air conditioner that is too large for a room will cool that room too quickly and then shut off without removing the humidity, giving the air a damp and uncomfortable feel.

So the first step, when sizing the air conditioner, is to measure the room or space that it will be cooling. This will provide the necessary information needed, in order to choose an appropriately-sized unit.

To do this, determine the square footage (square metre) of the room by multiplying the length by the width.

Air conditioners cooling capacity are also designated in Kilowatt cooling (KWc).

1 Watt cooling= 3.412 BTU/hr

1 Kilowatt cooling = 3412 BTU/hr

1 BTU/hr = 0.3 Watt cooling

1 BTU/hr/ft2 = 3.15 W/m^2

2.2 Cooling load calculation using online calculator of local supplier

The table below shows some cooling requirement rate in sizing the residential air conditioners capacity among different local AC suppliers and the CEB.

Table 3: AC sizing from local suppliers on line calculator

	CEB (Authority)	**King Bros (AC Supplier)**	**Dragon Electronics (AC supplier)**	**J Kalachand (AC Supplier)**
BTU/hr/ft^2	64	75	74-83	64-74
Wc/m^2 (SI Unit)	202	237	233-262	202-233

Except for the CEB which do not have an interactive web site, the values above are available through the on-line calculator from the local AC supplier websites which give the user a first estimate on the selection of air conditioner capacity based on the room areas by inputting the room dimensions and the location of the site (coastal or non-coastal region).

The cooling rates vary from supplier to supplier and even with the CEB.

2.3 Cooling load calculation using thumb rule approach

There is a general consensus among various actors of the air conditioning industry such as the consultants, contractors & the Energy Services Division of a thumb rule approach for a cooling rate of 60 BTU/hr/ft^2 in the domestic sector as a quick estimate to calculate the AC capacity based on the room dimensions on construction projects.

The table below shows the sizing of the AC based on the commonly built room dimensions in typical residential projects.

For e.g., for a standard house having a room size of 10 m^2 floor area, the quick cooling load estimate from the table will indicate the choice of an AC of capacity 9,000 BTU/hr.

Table 4: AC cooling capacity from room size

Room Dimensions Sqm (ft²)	AC cooling capacity - BTU/hr (kWc)
9.4 - 14 (100 - 150)	9,000 (2.6)
14.1 – 18.7 (151 - 200)	12,000 (3.5)
18.8 – 28 (201 - 300)	18,000 (5.2)
28 – 37.4 (301 - 400).	24,000 (7)
~46.7 (~500)	30,000 (8.7)
~56 (~600)	36,000 (10.5)
~65.4 (~700)	41,000 (12)

Note: Quick reference guide for domestic sector construction projects

(Based on 60 BTU/hr/ft^2 or 0.19 kWc/m^2). Conversion factor 1 m^2 = 10.7 ft^2

A trained AC technician chosen to install the new system should be able to perform these calculations. Having the wrong-size heating-cooling system can lead to multiple problems. Over-sizing your cooling system is not a good thing.

Determining the load by using rules of thumb may lead to an over-sized cooling system, resulting in an increased initial cost, increased monthly utility bills, increased maintenance, and shortened equipment life because the equipment cycles off and on too frequently.

An underpowered unit will struggle to cool a room effectively, running constantly and using excess energy. To avoid this, many people will simply buy the most powerful air conditioner that they can afford, but that will also have unwanted effects. Air conditioners are designed to remove both heat and humidity from a room.

A big cooling system cools down the temperature very quickly, but it does not run long enough to remove sufficient moisture or "humidity" from the air.

Many people then turn down the thermostat to make the air conditioner run longer, increasing the utility bill.

In some cases, the insufficient moisture removal resulting from over-sized cooling equipment can lead to mould growth and other types of moisture-related damage.

2.4 Detailed Cooling Load calculation

There are a few things that must be consider for the detailed Cooling load calculation.

The cooling load consists of two parts:

1. The temperature of the air, called the sensible load
2. Moisture or "humidity" in the air, called the latent load

In order to have a more accurate load calculation, the following adjustments are to be considered: -

- Heavy Sun Exposure to walls & roof
- No. of people occupying the space
- Lights, air infiltration
- Windows orientation & shades

The chart below represents more detailed parameters for the cooling load estimation for room air conditioner.

Table 5: Room AC Cooling load estimator

Room Air Conditioner Cooling Load Estimator						
Heat Source	(A)Floor area m2	(B) Mu ltiplying factor Wc/m2				Cooling Load (A) x (B) Watt (Wc)
Area of Windows		Exposed to sun			Fully shaded	
		No awnings No Curtains	No awnings or cuiains of	Awnings curtains		
South		120	95	65	60	
South East		380	260	130	60	
East		430	300	145	60	
North East		370	260	130	60	
North		270	190	100	60	
North West		370	260	130	60	
West		430	300	145	60	
South West		380	260	130	60	
Outside wall area less glass		Exposed to the sun	Brick,brick veneer.weather board fibro		35	
					40	
		Not exposed	Brick,brick veneer.weather board fibro		15	
					15	
Internal wall area		8				
Ceiling area		Uninsulated 50		Insulated 8		
Suspended floor area		Uncarpeted 12		Carpeted 6		
Door area		Closed when not in use		100		
People		Sitting or sleeping		120 W/person		
		Active		250 W/person		
Lights Appliances		Power / lights		20W/m2		
Sensible Cooing loat (Watt Wc)						
Required thermal coolng capacity = Sensible cooling load x 1.3						

Source AC supplier GREE Aust/NZ – website www.greenonline.com/calculator

Note: Heat generated by electrical equipment such as personal computers, laptops, server, printers have minimal incidence for rooms in residential premise but more relevant for office building projects.

3. AIR CONDITIONING SELECTION

Once the base BTU/hr (KWc) requirement is known, the selection of the air conditioner becomes a daunting task since the market is flooded with different types and different air conditioning brands having several features.

Figure 8: AC selection dilemma

The following factors that need to be considered when selecting residential air conditioners.

3.1 Efficiency & Cost

One of the most important things to remember when purchasing an AC system is that it's an investment for the family and home. So although the cheaper option is the more attractive option, remember, generally, it's the less expensive systems that will be costing more down the track, both through increased running costs and also increased maintenance costs.

Conversely, the higher quality systems tend to have higher efficiencies, which make them less expensive to operate and more likely to pay for themselves over time.

The current demand for energy efficient air conditioner has also seen a rise in in-house technologies that lead to further savings.

Energy Efficient Ratio (EER) and Star rating system on the labelling are now significant parameters that have to be considered for the usage of an AC. EER is the ratio of cooling capacity (in watts) to power consumption (in watts). The higher the star rating, better is the efficiency of the system.

The effectiveness of an air conditioning system can be appropriately judged by the amount of cooling per unit of power consumed. Higher the amount of heat removed per hour per unit of power consumed, higher is the efficiency of air conditioner. Also, higher the EER, better is the air conditioner.

Energy efficient air conditioners have been elaborated in more details as a separate chapter in this report.

3.2 Comfort & Practicality

When choosing an air conditioner it is important to know the different types and models of AC systems available on the market. The different type of the air conditioners has already been elaborated in Chapter 1 above. Out of these, the split type units represent the lion's share of the sales in the domestic sector. The latest trend in the split type air conditioner segment can basically be classified as:

- **Reverse Cycle:** An air conditioner with both heating and cooling capabilities.
- **Inverter:** An air conditioner that delivers a constant airflow and adjusts the intensity of the outdoor unit (compressor) to achieve the desired temperature set-point. Inverter systems are more energy efficient than the traditional fixed-speed air conditioning units.
- **Smart AC:** An air conditioner that connects to home network in order to control and monitor its output through an app on compatible tablet or mobile devices.

Once the appropriate system has been selected, some other important features are also to be considered such as the noise level and available electrical connection.

Noise level

Noise from air conditioners can be a source of disturbance to the occupant and also the neighborhood by disrupting their sleep and interfering with their normal daily activities (listening to the TV, talking to the phone, studying). Air conditioner noise can range from being a nuisance to actually damaging people's health and is a common cause of noise related complaints.

Noise by definition is unwanted or unpleasant sound. Due to the range of noise that can be heard by the human ear, a scale was developed called the decibel scale [dB(A)] which is used to represent how loud a particular noise. The higher the air conditioner capacity the higher is the decibel level.

The siting of the air conditioner is the most important factor in ensuring noise is not going to intrusive. Placing the unit close to the neighbour's house is likely to create excessive noise, as the noise is trapped and reflected between the walls and the eaves of the house. Placing the air conditioner on the rear or facing the street on placing on the roof reduces the noise reaching the neighbor. Barriers can be introduced to reduce the noise level.

Figure 9: AC Noise disturbance

For the split type air conditioner, the decibel level of both the indoor unit and the outdoor unit are specified in the technical literature. When comparing air conditioners, check the sound pressure level of the unit. The smaller the number of dB(A) on the label, the quieter the air conditioner. Comparing noise level on units help to choose a quieter unit.

Environment Protection Act (Mauritius)

Noise Exposure limits

Neighbourhood Noise

07.00 -18.00hrs : 60 dB(A)

18.00 - 21.00 hrs : 55 dB(A)

21.00 – 07.00 hrs : 50 dB(A)

+5 dB(A) adjustment possibility

dB(A) – Equivalent A-weighted sound pressure level

It may be found that the sound pressure level label of an air conditioner is 56 dB(A) or more and wonder how it could comply to with a legal limit of 55 dB(A).

This can be explained by the following comparison. A light bulb with a power rating of 60W has a certain intensity of light at the actual bulb, but with distance this intensity decreases, although the power of the globe remains 60W. Similarly, the noise level of a air conditioner with a sound pressure level of 56 dB(A) will decrease as the distance from the unit increases.

Noise can also affect our performance, learning and stress levels. The level of annoyance experienced from the noise depends on the level of noise, type of noise, how often it occurs, how long it goes, time of day or night and the individual's own tolerance.

Electrical safety connections

- Avoid using any kind of extension cords to power an air conditioner. These can cause fires and are unreliable.
- Get the proper power supply and required protecting device (RCDs, DP switch) to the AC unit. This will reduce fire risk and stress on the electrical system of the house.
- Do visual inspections to ensure that all the electrical cords are working properly and are not damaged by rodents.
- Once the AC unit is plugged for use ensure that there is sufficient access and lighting to power off the unit.
- Avoid putting the AC units where water could get into it. Also don't put plant or other things on top of the unit.
- Keep the Ac unit electrical wires from hot items. Hot surfaces can damage the units.
- Grounding of the AC unit is compulsory.
- Ensure a single length of electrical wires between Indoor Unit (IDU) & Outdoor Unit (ODU). Ensure no breaks on wires and hence no connections in PVC trunking or cable tray.
- Consult the Service manual of a typical AC unit about the safety aspects of electrical connections (refer to Annex 1).
- Typical electrical requirement for Split AC units.

Table 6: Typical electrical requirement for Split AC units

TYPICAL ELECTRICAL REQUIREMENT FOR SPLIT AC UNITS							
AC CAPACITY (BTU/HR)	LOAD IN kW INVERTER TYPE (EER 3.5)	LOAD IN Amps INVERTER TYPE	LOAD IN kW NON INVERTER TYPE (EER 2.5)	LOAD IN Amps NON INVERTER TYPE	CIRCUIT BREAKER RATING	RCD RATING	CABLE SIZE
9,000	0.8	3.3	1.1	4.6	2P 16A	2P 25A 30 mA	3C x 2.5mm²
12,000	1.0	4.4	1.4	6.1	2P 16A	2P 25A 30 mA	3C x 2.5mm²
18,000	1.5	6.6	2.1	9.2	2P 20A	2P 25A 30 mA	3C x 2.5mm²
24,000	2.0	8.7	2.8	12.2	2P 25A	2P 25A 30 mA	3C x 4.0mm²
36,000	3.0	13.1	4.2	18.3	2P 32A	2P 40A 30 Ma	3C x 4.0mm²

EER varies for different AC model

Anti-corrosion coating for the ODU

Corrosion attack on the ODU casing and condenser fins are common problems encountered in coastal region and also in wet region which result in high degree of degradation of the ODU to such extent that the life time of the equipment is shortened.

The standard manufacturer's specification does not allow for Ac units meant for tropicalized climate like ours. These anti corrosion coating are factory mounted from manufacturers are available on special order.

Some local suppliers import AC units which already has the anti-corrosion casing and the blue or gold or black condenser fins protection. Some local suppliers also have the facility to undertake in-situ special anti-corrosion treatment on the ODU of the AC units.

3.3 Taking Control of the AC System

With the leaps and bounds in technology in recent years, especially for the home, there are a wide range of new possibilities now available to the homeowner. One of these new possibilities is the opportunity to take control of the home products thanks to the introduction of smart devices.

When it comes to choosing an AC system, make sure to keep in mind the functions that matter most. If its total control over the AC system that is required, consider installing a smart air conditioning system, which gives the ability to control the entire AC system from anywhere in the world at the touch of the fingertips.

Simply install the required applications to the tablet or mobile device and have complete comfort and control.

This translates into energy savings whereby the air conditioner.

i) can be turned off or adjusted at the set temperature to reduce demand when the user is not at home, and into comfort when the user is at home.

ii) turn the air conditioner on or off, or adjust the temperature to improve the comfort level without getting up.

iii) give complete insight on technical nature such as watts, voltages, current, units consumed.

3.4 Reliability

Another key consideration when choosing an air conditioner system that will serve the home for decades is reliability. When it comes to picking a pricier model, it pays to stick with a reputable company with extensive experience and great after-sales service. Purchasing an air conditioner is a family investment.

Famous brands which have been in the market for decades offer the more reliable choice.

3.5 Summary

A checklist for selection of an air conditioner is as follows: -

(a) Capacity: Calculate required cooling capacity from room size (described in Chapter 2).

(b) Make a first selection of AC unit from available range (described in Chapter 1). Inverter split AC units are the most in demand nowadays due to its energy saving capacity. Ensure selection of unit is equal or a little more than the required capacity.

(c) Locate position of indoor and outdoor units such that horizontal & vertical distance between them is minimum.

(d) Ensure the AC unit has the best Energy rating. The higher the better.

(e) Check manufacturer's reputation & reliability for lifetime of the AC unit.

(f) Check local supplier's credentials for installation charges done by trained technicians, after sales service, servicing, commissioning sheet, etc.

(g) Check noise level of indoor & outdoor units to compare with other manufacturers.

(h) Check warranty available for AC unit in general and for compressor in particular (one year or multiple years).

(i) Check features associated with the AC unit on remote controller (timer, turbo boost, Wifi, smart, etc) and aesthetic look of indoor unit.

(j) Check monthly power consumption (from supplier)

(k) Check for anti-corrosion coating for coastal climate and rainy region.

(l) Check and ensure stabilised electrical supply is available. Or make provision for same (as advised by professionals).

(m) Check the refrigerant gas used. Mostly R410a available on the local market nowadays.

4. AIR CONDITIONING INSTALLATION

No matter what type of air conditioner that's chosen to be installed for residential application, there is one hurdle that needs to be faced, the installation.

Air conditioning installation is an important part of the process and in essence that help in deciding between which type of system could go in the living quarters. Here are some of the processes that are involved for the split type and window type air conditioner setup

For many consumers a split air conditioner offers the best of all worlds in the air conditioning department.

The term split means that half of the system is on the outside while the rest is on the inside. In this case the compressor unit and many of the loud running features are outside while the indoor unit rests comfortably inside - without taking up window space.

Installing a split air conditioner is a more advanced process.

What absolutely needs to be present, though, is a hole between the inside and outside of a home so that refrigeration lines can be run to the indoor unit. The first step in installing a split air conditioner is deciding where it's going to be mounted and cutting a hole for those lines.

4.1 The Three Sections of a Split Air Conditioner

There are obvious some pretty detailed steps to installing a split air conditioner with an outside condenser coil and indoor unit. To better understand the basics of the install it's easier to break them down in three areas:

- **Outside Condenser -** The condenser is placed outside so that the noise of it running doesn't bother people inside and so that there's more ventilation for the hard-working coils. The condenser is placed on a slab or fixed on bracket near the home.
- **Indoor Evaporator -** The indoor evaporator is the brains of the operation where the temperature is controlled and the cool air is delivered. The vent is the messenger so to speak, the condenser does all the hard work outside and the evaporator brings the good news inside.
- **The Connectors (Piping & Wiring) -** Of course lines are needed to connect the two devices with copper wire delivering refrigerant, wires carrying

electricity, and tubes dispensing the water that is formed in the cooling process outside.

4.2 Pre-installation

4.2.1 Use checklist for pre-Installation

The pre-installation check list ensures that there is a mutual agreement on the installation of both the Indoor unit (IDU) and the Outdoor unit (ODU).

Indoor unit:

(a) Obtain user approval on final best location after pros & cons of different options considered

(b) The restrictions on installation specified in the IDU installation drawings are met as per Installation manual

(c) IDU should be sited where both air inlet and air outlet have clear paths

(d) IDU is not in the path of direct sunlight.

(e) IDU is away from the source of heat or steam

(f) Cool air is circulated throughout the room without obstruction

(g) The IDU is away from the from electronic ignition type fluorescent lamps as this may shorten the remote controller range

(h) The IDU is at least 1m away from any television or radio set

(i) IDU is installed at recommended height of 2.1m

(j) Position of window or door in the room does not cause short circuiting of cooled air from the IDU to the outside/corridor, as this leads to wastage of energy.

(k) Position of bed or study table do not blow directly on the head of the occupant and wardrobe position does not represent an obstacle in the air flow distribution.

Outdoor unit:

(a) Obtain user approval on final best location after pros & cons of different options considered

(b) The restrictions on installation specified in the ODU installation drawings are met as per Installation manual.

(c) ODU should be sited where both air intake oo the condenser coil have required clearance and hot air outlet have no obstruction such as bushes, trees, etc.

(d) The ODU is not in the path of direct sunlight.

(e) The ODU noise level is not a source of disturbance for the neighbours.

(f) The ODU is installed in such location where it is easily accessible for servicing and intervention.

(g) The ODU has the shortest pipe runs to ensure better efficiency.

(h) Installation accessories (not provided by the manufacturer), where required, such as concrete slab, L-support brackets, additional refrigerant, condensate pipes, power sockets, sealing of hole, etc are brought to the knowledge of the user.

(i) Additional run of pipes are well protected and not exposed to UV rays of the sun

4.2.2 Energy saving measures before AC installation

The following energy saving measures are worth taken into consideration before installation of the split AC unit.

Planning ahead

Location of the IDU & ODU is very important as mentioned above. Excessive pipe runs between ODU & IDU should be avoided as drop off in performance can be experienced, resulting in more energy consumption. Also, always provide suitable service access for technicians to carry out effective system maintenance, and follow up on energy consumption, in accordance with the manufacturer’s recommendations.

Selection/sizing

As described in Chapter 2 & 3, correct sizing and selection of air-conditioning equipment is key to achieving optimum energy efficiency. Over-sizing in itself doesn’t render the system operationally inefficient. However, increased power consumption over the lifetime of the system can prove otherwise. Alternatively, under-sizing the system can result in excessive operation during normal system lifetime and can cause premature failure. Of course, where possible, select Energy A, A* or above rated equipment with the latest in DC inverter technology. It is also important to adhere to the manufacturers' recommended pipe sizes and maximum pipe lengths as system capacity will reduce significantly if these are exceeded.

Control/set point

The most energy-efficient air conditioning systems installed in any application can be rendered energy inefficient if not controlled in the correct manner. Most of today's control options can greatly increase the efficiency of an air-conditioning system. Control of operation times and set-point temperatures are the most basic and fundamental of control functions that will enhance system efficiency. Also consider options available on air conditioning systems, such as Energy Saving and Economy modes.

Refrigerant charge

Paying attention to refrigerant charge is important for any air-conditioning system. Undercharging will result in the starvation of refrigerant within the system, in turn reducing the ability of the refrigerant to absorb the required amount of energy to satisfy the heating or cooling demand of the conditioned space. Operation times will subsequently increase, increasing energy consumption and also creating higher risk of system failure. If a system is undercharged, always check for leaks within the pipe work and equipment and repair or replace as necessary before re-charging.

Insulation

Poorly insulated and/or damaged insulation on pipe work breaks the vapour seal allowing condensation to form on the pipe. This condensation can soak into the insulation destroying the thermal insulation properties. The resulting exposed pipes will decrease the system's efficiency. Many split system expansion devices are located in the outdoor unit and poorly insulated pipe work can affect the efficiency of the air conditioning system. Exposed pipes will act like a heat exchanger and absorb or reject energy before the refrigerant reaches the indoor or outdoor unit reducing the performance of the air conditioning system. Always ensure pipe work insulation is of the correct quality and standard as recommended by the manufacture and/or in line with good refrigeration installation practice.

Servicing and access

Too often, system maintenance is neglected – and even the most efficient air-conditioning systems will not fulfil their operating potential if not serviced regularly. Regular maintenance checks will ensure that the air-conditioning system operates as efficiently as possible. Energy consumption can increase substantially as a result of replacing poorly maintained or dirty components. Simple routine maintenance such as checking and cleaning fans, filters, coils/heat exchangers, etc will maintain system efficiency. Frequently, poor planning with regards to system location makes it impossible for service engineers to gain safe and suitable access to units on routine maintenance visits. If the filter or coils cannot be inspected or cleaned, the system's efficiency will be dramatically reduced as the airflow across the coils becomes restricted. Over time this will result in costly repairs to the condenser as the compressor will inevitably fail.

Reference should always be made to the manufacturer's recommendations to location and service space requirements as detailed within installation and maintenance manuals.

Air distribution

Good air distribution is key to an effective and efficient air-conditioning system. Consider the distribution of air into the conditioned space. Avoid 'dead zones' and draughts as they may lead to the occupants using the controls erratically. Always consider the usage of the space and the furnishing within the space to avoid any possible 'short circuiting' of airflow. Short circuiting lead to wastage of energy.

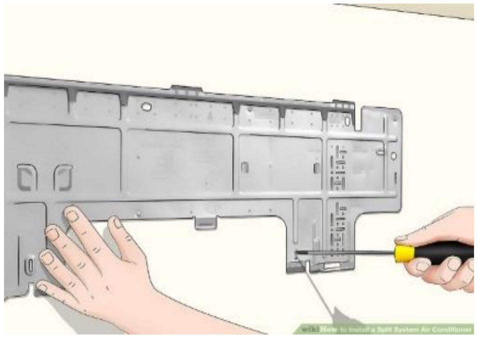
Usage & the people factor

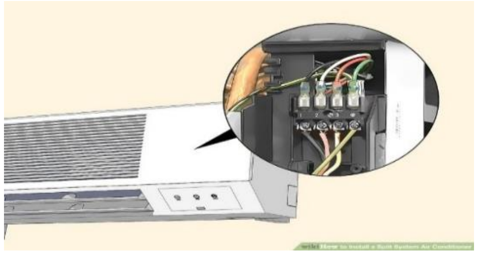
Understanding how and when to use the airconditioner is also a pre-requisite for energy efficiency. Basic functions such as fan speed and louvre angle can be adjusted to improve efficiency. Use external shading to reduce the amount of light/ heat entering a space, and louvres can be retrofitted to buildings to provide shade during summer whilst allowing lower winter sun to penetrate the area. Blinds can also be angled to reduce solar heat gains whilst reflecting light onto walls and ceilings to reduce demand for electric lighting. While these are all things that can be done to boost efficiency, all this work can be undone by the 'human factor' – i.e if occupants leave doors and windows open. The answer is not usually to issue a set of rules, but to encourage staff involvement by demonstrating how they can be more in control of their own environment. Explain how thermostats operate and give guidance on recommended operating temperatures and on how to set heating or cooling units correctly. This is more a people issue than a technical one, but vital to the overall performance and efficiency of a system.

4.3 Installation Guidelines

Table 7: Typical Split AC Installation Guide

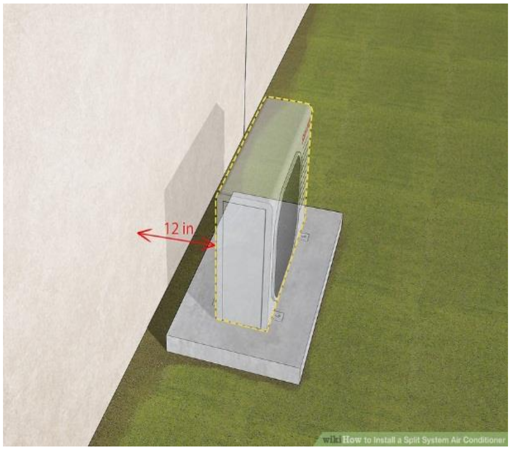
Part 1 - Setting up the Indoor Unit

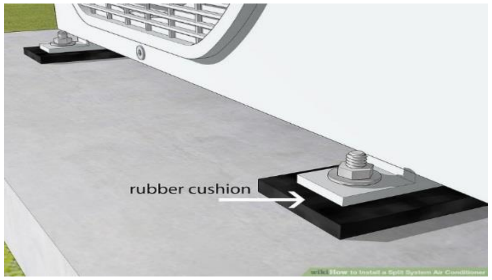
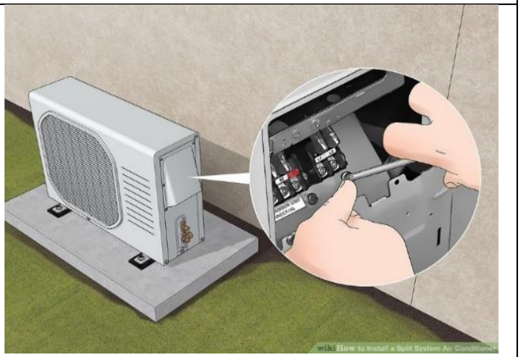
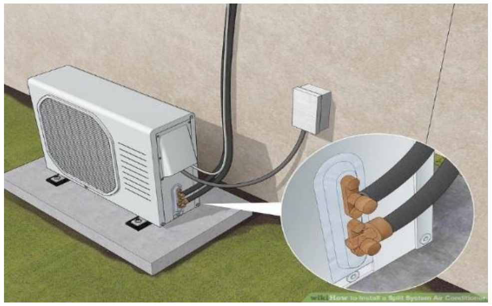
1	• Select an unobstructed location on your interior wall to mount the indoor unit. • Choose a spot away from direct sunlight and heat sources for the best results. • Choose a location with studs to ensure the wall is strong enough to hold the weight of the unit. • Mount the unit 7 feet (2.1 m) off the floor and ensure there's at least 6–12 inches (15–30 cm) of open space on every side of the unit to allow for proper airflow. • Install the unit at least 3.3 feet (1.0 m) away from antennas and power or connecting lines that are used for television, radio, home security systems, intercoms, or telephones. The electrical noise from these sources could cause operational problems for the air conditioner. • Avoid locations where gas may leak or where oil mist or sulfur exists	
2	• Secure the mounting plate to the interior wall. • Hold the mounting plate against the wall where the indoor unit is to be installed. • Use a level to make sure it is both horizontally and vertically level. • Use a pencil to mark the locations of the screw holes, remove the plate, then drill a hole into the wall where each screw will go. • Position the plate so it matches up with the holes, insert plastic anchors into the holes, and secure the plate to the wall with tapping screws	

3	• Drill a 3 in (7.6 cm) hole through the wall to feed the pipes outside. • Make a mark in the center of the hole in the mounting plate. • Use a keyhole saw or a drill with a hole-cutting attachment to create a circular 3 in (7.6 cm) opening through the wall that slopes slightly downward toward the ground to ensure adequate drainage. • Make sure there are no pipes or wires behind the wall before drilling or cutting the hole.	
4	• Check the electrical connections on the indoor unit. • Lift the A/C unit’s front panel and remove the cover. • Make sure the cable wires are connected to the screw terminals and that the wiring matches the diagram that came with the unit.	
5	• Run the pipes and cables through the hole in the wall, then connect them to the unit. • Secure the included copper pipes of the unit and additional copper pipe run, power cable, and drain pipe together with electrical tape. Place the drain pipe on the bottom to ensure a free flow of water. • Ensure the additional copper pipe runs and interconnecting wires are as specified in the instruction manual. • Run the pipes and cable through the hole in the wall, then secure them to the designated spots on the indoor unit as directed by the instruction manual. • Minimize how much the pipes and cable bend to ensure that the unit performs well. • Make sure that the drainage pipe allows water to drain in an appropriate place. See the instruction manual included with the kit for more information.	

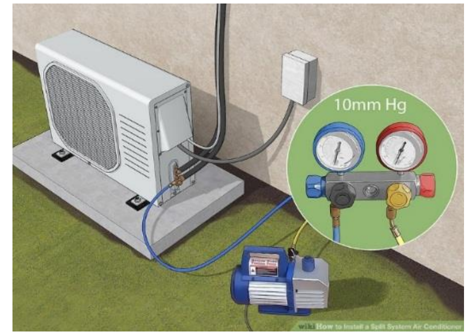
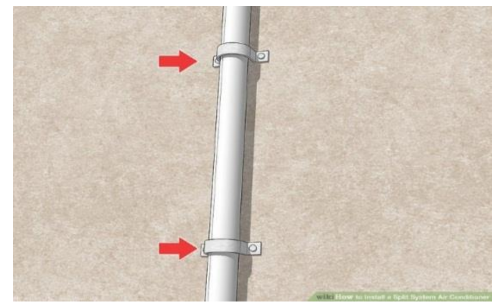
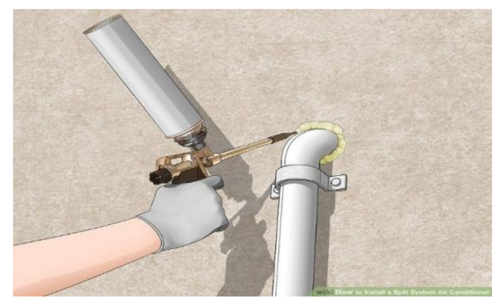
6	• Secure the indoor unit to the mounting plate. • To attach the air conditioner to the wall, simply align the female connections on the back of the unit with the male connections on the mounting plate. • Press firmly to secure the unit in place. • Make sure the unit tilts backward 2-3 degrees so that water can flow out of the drain pipe. • Refer to typical manufacturer’s instruction manual for installation detail	

***Part 2* - Installing the Outdoor Condenser (on Ground level)**

1	Position the outdoor unit away from any heavily trafficked, dusty, or hot areas. Find the hole drilled through the mounting plate for the interior unit and position the exterior unit within 50 feet (15 m) depending on unit capacity or as specified in the instruction manual, so the piping and cable can easily be attached. Choose a location with at least 12 inches (30 cm) of space surrounding its perimeter to ensure proper functioning. If possible, select a shady location that's sheltered from the wind in addition to dust and traffic to keep your unit functioning at its best. Make sure that no antenna of a radio or television is within 10 feet (3.0 m) of the outdoor condenser. Note: Outdoor unit is also commonly installed on wall using galvanised L-support brackets or installed on roof.	
2	• Lay a concrete pad on the ground. • Don't place the outdoor unit directly on the ground, as it's heavy and can shift around on dirt or rocks. It's necessary to install the condenser on a concrete pad. • Position the pad where identified to install the unit and use a level to make sure it's flat and even. • Situate the concrete pad so that it's high enough to keep the unit out of any water that may puddle on the ground due to rain.	

3	• Secure the outdoor unit on top of the concrete pad. • Lay a rubber cushion on top of the pad to minimize vibration, • Set the outdoor condenser unit on top of the pad. • Secure the unit to the concrete with anchor bolt.	
4	• Check the electrical wiring in the outdoor unit. • Remove the cover on the condenser. Refer to the unit's wiring diagram in the instruction manual and make sure the wires are connected as the diagram suggests. • Make any adjustments as necessary. • Fasten the cables with a cable clamp and replace the cover.	
5	• Connect the piping and cable to the outdoor unit. • Use flare nuts to secure the 2 copper pipes from the indoor unit to the outdoor unit as per the instruction manual. • Connect the power cable that runs from the indoor unit to the outdoor unit as well. • Finally, connect the power supply to a designated outlet. • Refer to typical manufacturer's instruction manual for installation detail	

<u>Part 3</u> - Completing the Project

1	• Bleed the air and humidity from the refrigerant circuit. • Remove the caps from the 2-way and 3-way valves and from the service port and connect a vacuum pump hose to the service port. • Turn the vacuum on until it reaches an absolute vacuum of 10mm Hg. Close the low pressure knob and then turn off the vacuum. • Test all of the valves and joints for leaks, then disconnect the vacuum. Replace the service port and caps. • Note: When vacuumising, low pressure valve in open position & high pressure valve in closed position. Before running the AC high pressure valve in open position.	
2	• Affix the piping (or trunking/cable tray) to the wall with clamps. • To ensure the pipes and cables don't move around or become disconnected. • Attach them to the exterior wall of your home using the clamps that came with the kit. • Follow the directions in the manual to ensure the clamps are spaced adequately.	
3	• Seal up the hole in the wall using expanding polyurethane foam. • Spray expanding polyurethane foam into the hole you drilled to feed the cable and piping through the wall. • Make sure the hole is completely sealed to prevent hot air or insects from getting through. • Let the foam dry as per the instructions on the label before turning on your air conditioning.	

4	• Turn on the unit, commissioning and enjoy the cool air! • All that's left to do is to start the air conditioner, which can be done from the indoor unit. It should only take a minute or 2 for cool air to start blowing into the home. • Commissioning procedures (Refer to Annex 2 Check list) .	

Typical Split Air Conditioner Installation as per Manufacturer's Instruction Manual (Refer Annex 1)

Energy Efficiency Management Office

4.4 Post Installation Checklist

The post-installation check list ensures the user to check the final installation of both the Indoor unit (IDU) and the Outdoor unit (ODU).

(a) IDU & ODU are installed on solid bases.

(b) Check the refrigerant lines are properly installed with appropriate bending radius and thermally insulated. Ensure insulation not exposed to UV rays of the sun.

(c) Condensate pipe is properly installed.

(d) The AC unit is earthed.

(e) Batteries are inserted in the remote-control.

(f) The hole in the wall for refrigerant pipes is properly sealed.

(g) Installation manual recommendation has been followed on restrictions.

5. AIR CONDITIONING SERVICING & MAINTENANCE

An effective air conditioning system is an important feature within a property as it promote a comfortable stay at home and also create a conducive working environment. Many property owners invest in quality and expensive systems but don't ensure that the AC units are regularly serviced.

Aircon systems parts are susceptible to regular wear and tear, depending on the hours of operation. This wear and tear cause the units to lose some of their efficiency every year. A poorly maintained aircon unit consumes more energy in order to function normally. Regular air conditioning helps the AC unit to run at almost optimum efficiency and serve the property for an extended period.

5.1 Importance of regular AC maintenance and servicing.

Improves efficiency & save electricity

AC servicing helps to improve its efficiency so that it can work the way it is supposes to and also help to save on electricity bills as it will not be using extra energy to work. An efficiently running AC unit consumes less power than a poorly maintained air conditioning unit. This means that by failing to have the AC unit inspected and serviced regularly, this end up in incurring high energy bills

Prolong lifespan

AC servicing is vital as it helps to prolong the lifespan of the unit. This is because it is well taken care meaning that any defects are taken care of on time to ensure that it runs the way it is supposed to without any problem. Failure in some parts of your unit compromises the entire unit and this reduces the lifespan of the unit. Investing the small amount needed to schedule regularly servicing helps saves on long-term costs.

Reduces Emergency Repairs

Poorly maintained ac units are bound to experience numerous and unexpected breakdowns. This is due to the fact that minor damages that you may not easily notice tend to grow into major problems which may require costly repairs. However, by having your unit regularly inspected, minor issues are able to detected early enough and fixed. If there are any parts that have suffered wear and are damaged, they can be repaired or replaced.

Improves the air quality

Air conditioners help purify the air we breathe in through filters. These filters trap dust and dirt particles. It is, therefore, essential to ensure that these filters are regularly cleaned or replaced. Failure to clean and replace these filters causes the trapped pollutants and allergens to find their way back into the air. It is important to make sure that the occupant is breathing clean and healthy air at all times. Most people like to switch on the aircon at night hence it is important to ensure the unit is serviced so that only quality air circulate in the house which is fee from germs and other types of bacteria. This will definitely reduce the trips made to the doctor which and help save money and time.

Prevent water leakage

When the air conditioner is filled up with dirt and fungus, it will definitely not function in the proper way. This usually leads to water leakage which can cause material damaged. Servicing the unit corrects this problem on time to ensure the air con is used without this problem.

Hence, there are clearly considerable benefits of having the air conditioning unit regularly serviced and maintained. Not only are there financial gains but also one can enjoy an efficiently working air conditioner.

Air conditioner should be serviced regularly especially before the start of the warmer weather. A technician will come out to inspect and service the air conditioner. This will keep things in running order and helps spot potential trouble.

The technician will give the unit an overall inspection, looking for any signs of trouble. They will test the voltage, inspect the overall condition of the unit, check the refrigerant, and examine the drainage lines.

Figure 10: Air conditioner inspection

They will inspect the blower motor and test the thermostat to ensure proper operation. A motor that is drawing too many amps may be about ready to fail completely. A thermostat that doesn't engage the unit when it's supposed to could need adjustment or replacing.

The air filter will need to be checked every month. The technician will check it as part of the servicing. They should also clean various parts like the compressor, condenser, evaporator coils, and drainage line.

Figure 11: AC indoor unit servicing

Finally, they should test refrigerant levels and observe the air conditioner function through a complete cycle. If any problems are still present, they should report and recommend repairs.

5.2 Basic Maintenance & Servicing of AC Unit

- Turn off the power to the unit by switching off the DP switch.
- Switch off the circuit breaker at the electrical panel.
- Follow the steps as detailed below.

Table 8: Basic maintenance & servicing steps Split type AC (Indoor & Outdoor units)

1	**Step 1: Clean filter**. • The simplest and most effective way to keep the air conditioner running smoothly is cleaning the filter regularly (on monthly or quarterly basis). • By regularly cleaning the filter, a lot of the burden on the system is reduced. A dirty or clogged filter makes the air conditioner work much harder than does a clean filter. • Cleaning the filters regularly is easy on the budget and easy on the system as well. This will lower the utility bill and will extend the life of the air conditioner.	
2	**Step 2: Keep coils clean.** • The air conditioner coils and fins on the outside of the unit need to be kept clean and clear of obstructions. Leaves and other debris sometimes accumulate around the unit. If obstructions are present, the unit must work harder to function than it should. The unit can be cleaned with a regular garden hose and a broom. Splashing of water on electrical components is to be avoided. • Pressure washer is to be avoided, as the strong spray could cause harm to the system. A little bit of housekeeping in this regard goes far toward keeping the air conditioner working optimally.	

3	**Step 3: Keep surrounding shrubbery trimmed.** • If shrubbery around the unit have been planted to hide it from view, be sure adequate space is maintained around the unit so that it function without obstruction. • A quick trim will do the trick.	
4	**Step 4: Adjust the thermostat.** • The thermostat settings on the remote control is to be checked regularly as the season varies. This will lessen the amount of time the unit has to work each day and will lengthen its life cycle. • An additional benefit will be a lower utility bill each month. Pre-programming the thermostat to match the schedule so that the room can be pre-cool is also possible.	
5	**Step 5: Check the seal.** • Ensure all doors & windows are properly sealed to help keep the home/room cool. The less cool air that escapes from the room, the less the unit will have to work. • A trained HVAC technician can detect most problems before they become major ones. A typical tune-up will include various tests to ensure that the unit's internal parts are functioning correctly, as well as a filter check, and a refrigerant charge if needed. • The technician will likely also clear the drain, and clean the unit thoroughly inside and outside.	

Table 9: General Servicing Split type AC (Indoor & Outdoor units)

1.	**Clean the evaporator coils.** • Open the cover and use the soft paint brush to dust off the coil. • Next, spray the coil with coil cleaner, letting it drip into the drain pan. • Afterwards, clean the drain pan with soap and hot water. • Make sure the drain flows freely. If it does, skip the next step.	
2	**Clean the evaporator drain.** • This is usually a 1-inch PVC pipe coming off the evaporator enclosure. Follow it to where it drains out. • Attach the wet/dry vacuum to this end, sealing it with duct tape or with a rag. • Remove the vacuum's filter to avoid damaging it and turn the vacuum on for 2-3 minutes to clear out any blockage.	
3	**Clean the filter**. • This should be done on a monthly or quarterly basis.	
4	• Turn the power back on and let it go through a full cycle. If it's not cooling like it used to, diagnose the cause and inform of the repairs.	

5	**Clean the condenser.** • If it's at ground level, it is more likely to have debris than at the roof. • Remove the grate over the fan and vacuum any debris found inside. • With a garden hose, spray the fins from the inside out. (Never use a pressure washer. The fins are very thin and can damage easily.) • All rusty parts are to be treated with anti-corrosion products and final coat of paint to match condenser.	
6	**Inspect the fins.** • They are very thin and bend easily. If damaged spots are noticed, like where the fins are flattened, straighten them gently with the butter knife or fin tool. • Be careful not to damage the tubing within the fins.	
7	**Good housekeeping** • Rake any ground-level debris away from the condenser and prune any branches or bushes away at least two feet.	

A maintenance checklist is provided at Annex 3.

5.3 Good Servicing practice of HCFC/HFC-based Air Conditioners during repairs

In domestic air-conditioning appliances, HFCs are the most commonly used replacement for HCFC refrigerant. Step-by-step procedures for good servicing practices for both HCFC and HFC-based appliances

5.3.1 HFC/HCFC Servicing Steps

1) Recover the HCFC or HFC into a cylinder using a recovery machine for split air-conditioners.

2) Flush and clean the refrigeration system with nitrogen.

3) Do the necessary repair work on the appliance, as required. The system should stay open for as little time as possible. In case required for HCFC/HFC-based appliances, change the filter drier.

4) Flush using oxygen-free dry nitrogen to ensure that nitrogen flows freely.

5) Leak test with dry nitrogen or an electronic leak detector. Release nitrogen into atmosphere (charge a small quantity of refrigerant and remaining nitrogen into the system, while using electronic leak detector).

6) Evacuate to lowest pressure, check if vacuum holds.

7) Charge HCFC/HFC or HFC blend.

8) Run unit and check its performance.

These steps are elaborated in detail in the table below.

Table 10: Good servicing practice during repairs

1	**Step 1: Recovery of HCFC/HFC Refrigerant** Both HCFCs and HFCs are greenhouse gases, and HCFC have ODP as well. It is recommended to recover the pure or azeotropic refrigerant in a cylinder rather than venting it out in the atmosphere. To recover the HCFC or HFC, the following tools are needed: • A good recovery machine (preferably an oil-less compressor) and • A recovery cylinder	
2	**Step 2: Cleaning and Flushing** • Cleaning and flushing are important steps. Synthetic and hygroscopic oils must not be exposed to ambient conditions for extended periods of time. The HFC and POE combination is very sensitive to contamination, therefore, proper cleaning and flushing of system is required. Once the old filter is removed, the system needs to be properly flushed and cleaned of micro particles. • The following good practices are advised for cleaning and flushing the system: • Always use dry nitrogen at about 5-10 bar (70-140 psig). The nitrogen cylinder must be fitted with a two-stage regulator. It must have a proper regulator. • ODS ref gas, should not be used. Use ODS-free substances when chemical cleaning is required. There should be no traces of liquid chemical after the cleaning is done. Technicians must be aware that exposure to any of the chemicals by inhalation, eye and skin contact or ingestion is toxic to humans. • Technicians must wear personal protective equipment (PPE) while handling chemicals. • Atmospheric air contains moisture, which is detrimental to the RAC system. Use of air should be totally avoided, especially with HFCs or HCFCs.	
3	**Step 3: Repair the System** • Carry out all necessary repairs.	

<table>
<tr><td>4</td><td>Step 5: Pressure Testing and Leak Detection
Pressure testing to check for leakage in the circuit should be done after repairs using oxygen free dry nitrogen (OFDN).
The test pressure can be 1.5 times the working pressure. In case of air conditioners, it may be about 20 bars. Test pressure varies depending on the refrigerant.
For instance, R-410 around 43 bars for test pressure.
The given pressure is to be monitored over a period of time (may be 15 to 20 minutes) in order to check for a fall in pressure.
Use electronic leak detector and look for leakage if any.</td><td></td></tr>
<tr><td>6</td><td>Step 6: Evacuation – HCFC/HFC
Evacuation is very important to remove non-condensable gases and moisture from HCFC/HFC refrigerants.
HFC systems need deeper vacuum than HCFCs (500 microns or lower) because of hygroscopic nature of polyol ester oil.
A two-stage vacuum pump, capable of pulling vacuum between 20 to 50 microns at blank off is required. A micron gauge capable of reading between 5 to 5000 microns is required to make accurate measurement of the vacuum.</td><td></td></tr>
<tr><td>6a</td><td>Evacuation – 1st step
First make proper connection to the vacuum pump (or the manifold) connecting an appropriate hose to the access valve. Then switch on the vacuum pump and open the valves. Run the pump and evacuate till the gauge shows the lowest vacuum at which it holds steady. This level should be around 500 microns or preferably lower.
Next, close the valve to isolate the vacuum pump from the manifold and observe the rise in pressure (vacuum holding). The pressure should not rise beyond 1,500 microns (the lower the better) in 5 to 10 minutes. This is an indication that most of the moisture is expelled. Of course, lower readings like 500 microns or so are even better and welcome.
In case the pressure increase is greater, the system should be evacuated once again and the vacuum holding repeated.</td><td></td></tr>
</table>

6b	**Evacuation – 2nd step** • After the vacuum gauge shows the vacuum, close the valve and remove the micron gauge. • Then attach the charging cylinder with valve in close position. • Again run the vacuum pump for two minutes with side valve in open position to remove the non-gases from the charging hose. By doing this there will be no need to purge the refrigerant from the charging hose.	
	Recommended Evacuation – R-410A • With R-410A, technicians need to follow good practices, including deep vacuum. The following is the methodology for performing a vacuum for R-410A air conditioners: • Step 1: Evacuate the system to 1,000 microns from both service valves. To measure the vacuum, a vacuum gauge must be used at all times—do not use a system manifold gauge. • Step 2: Break the vacuum with oxygen free dry nitrogen to 14 psig (1 bar approx). • Step 3: Evacuate to 500 microns. Step 4: Repeat Step 2. Step 5: Evacuate to the lowest pressure that pump will achieve (200 microns for a minimum of 1 hr).	
7a	**Step 7a: Charging by weight** • Following charging method should be followed: • Charge always in a well-evacuated system. • Charging should be done slowly and gradually, so that no liquid goes into the compressor. • Charging should be done by weighing accurate mass of charge; this is essential for good appliance performance. • In case excess refrigerant is charged by mistake, the excess refrigerant charge should not be vented out. It is better to release the full refrigerant and recharge the recommended weight after evacuation. • Charge the exact same weight of refrigerant in the system as recommended by the appliance manufacturer instead of charging by feel (To ensure good cooling performance and low energy consumption	

7b	**Step 7b: Avoid Overcharging!** • Undercharging an air-conditioner results in a relatively low condensing pressure. But when a technician charges by feel, once the refrigerant is charged, the condensing pressure rises until a given liquid level is obtained in the condenser/receiver. • While the condenser/receiver is being filled, the pressure remains constant. • Once the condenser/receiver is full, refrigerant backs up into the condenser, the useable condenser area is reduced and the condensing pressure rises further. • The caution is “Avoid Overcharging.	
8	**Step 8: Checking Proper Operation** • As a final step, the air-conditioner should be switched on and the following parameters verified to ensure that it is operating correctly: • Grill temperature—the return air temperature and grill temperature difference must be between 10°C to 15°C, depending upon wet bulb temperature; compressor current and extraneous vibrations. • If there are vibrations, remove them with anti-vibration pads.	

Source: Good servicing practices-Phasing out of HCFC in the RAC servicing sector – UNEP: 2015

5.3.2 Leakage

Why does leakage occur?

1. Refrigerant leaks are caused by material failure. The material failure is normally attributable to one or more of the following factors:

2. Vibration – Vibration is a significant factor in material failure and is responsible for “work hardening” of copper, misalignment of seals, loosening of securing bolts to flanges, etc.

3. Frictional wear – There are many cases of frictional wear causing material failure, and they vary from poorly-fixed pipe work to malfunctioning shaft seals.

4. Incorrect material selection – In a number of cases, the use of inappropriate materials leads to leaks. For example, certain types of flexible hoses are known to leak, while other materials cannot hold up to vibration, transient pressure and/or temperature changes.

5. Poor quality control – Unless the materials used in the refrigeration system are of a high and consistent standard, changes in vibration, pressure and temperature will cause failure.

6. Poor connections – Poorly made connections, such as brazed joints, flare connections, or valves without caps, can allow refrigerant to escape.

7. Corrosion – Exposure to a variety of chemicals or harsh weather can result in a variety of different types of corrosion, which decay the construction material and result in pitting on pipes.

8. Accidental damage – Accidental mechanical impacts to refrigerant-containing parts can happen under many circumstances, therefore it is important to ensure that all parts of the system are protected against external impacts.

9. Air conditioning systems are designed to operate correctly with a fixed charge of refrigerant. If it has been determined that a system has insufficient refrigerant, the system must be checked for leaks, then repaired and recharged.

Different Methods – Leak detection

- Leak Detection by Oil Stains

A trained service technician can identify a leaking system by observing the presence of oil stains on the outside of the equipment. If refrigerant leaks out, lubricant oil leaks out as well, but it does not evaporate rapidly and remains on the outside of the equipment and pipes, indicating the leak area.

- Leak detection with Electronic Leak Detector

Electronic refrigerant detectors contain an element sensitive to a particular chemical component in a refrigerant. The device may be battery or AC-powered and often has a pump to suck in the gas and air mixture. Often, an audible "ticking" signal, and/or flashing indicator lamp increases in frequency and intensity as the sensor finds higher concentrations of refrigerant, which in turn leads to the source of the leak.

Figure 12: Electronic leak detector

Many refrigerant detection devices also have varying sensitivity ranges that can be adjusted. Many modern refrigerant detectors have selector switches for switching between refrigerant types, e.g., HCFCs, HFCs, or HCs.

When using electronic refrigerant detectors in a workshop, always ensure good ventilation since sometimes it gives false signals due to other refrigerants being present in the surrounding area.

5.4 Do's & Don'ts in Air Conditioning Servicing

5.4.1 Common Practices that are damaging to Air-conditioning Systems

- Flushing with air / refrigerant
- Use of petrol for cleaning
- Leak testing using air/refrigerant
- Self-evacuation using system compressor or a used compressor as vacuum pump
- Improper assessment of vacuum achieved
- Charging by feel
- Contamination/Cross contamination of refrigerants

5.4.2 Area of focus

- Good tools
- Tube cutting, Deburring
- Flare fitting
- Swaging
- Bending
- Brazing
- Cleaning & Flushing
- Leak Testing
- Evacuation
- Measurement & Holding of vacuum
- Charging of refrigerant
- Cross contamination

5.4.3 Good Tools

Using proper tools and equipment leads to accuracy, reliability, responsiveness and credibility - the essential elements of quality service. In order for a refrigeration and air-conditioning system to be properly evacuated and dried, a technician needs to use the correct vacuum pump.

Tools like flaring tools and torque wrenches are required for more recently developed refrigerants, and these need to be of good quality. In order to properly handle and service these new refrigerants, facilities need to be upgraded in terms of tools and equipment.

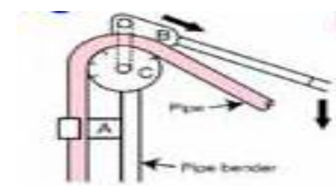
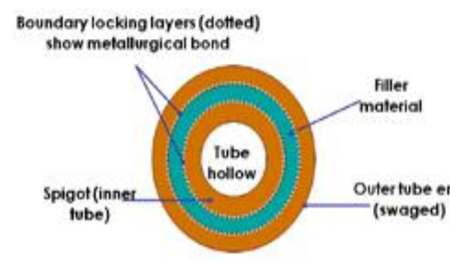
Many cheap tools and equipment are available on the open market, but they are not always accurate and their quality is uncertain. It is essential to have the right tools for the right job.

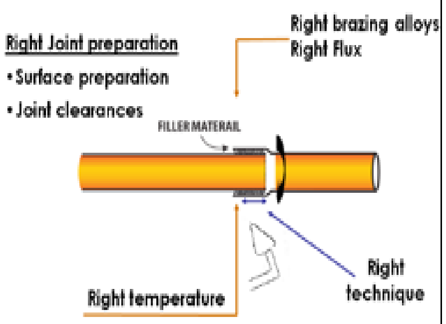
In order to have a good set of tools and equipment, technicians must understand the importance and benefits derived from each of them.

Since HCFC refrigerants are being phased-out, many alternatives are being commercialised. The level of accuracy required by these new alternatives is relatively high, making it that much more important to understand the use of each tool and equipment.

Table 11: Good practices in AC Maintenance

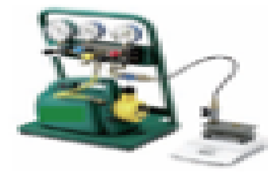
1.	**Tube Cutting and Deburring** • Tube cutting, a basic technical operation, is a good place to start with good practices. In the same way that if the base of a building is strong, you can construct a multi-storey building, proper tube cutting is an essential first step for a strong RAC system. • The technician must cut the tube by slowly rotating the wheel, adding pressure on every two rounds to cut the tube perfectly. After cutting, the pipe should be deburred from the inside and outside.	
2	**Flare Fitting** • As new refrigerants enter the market and technicians need to work on increasingly high pressures, they need to be able to prepare the right kind of flare fittings to tolerate these pressures. • A suitable flaring tool needs to be used so that the integrity of the copper is not compromised when it is flared.	 

3	**Swaging** • After the tube is properly cut and cleaned, it is ready to be swaged. • Many technicians use the hammer and swaging tool. After insertion, they try to give the tool a soft blow to enhance the gap of the swage. • This method results in a lot of play in both the pipes, which ultimately leads to poor brazing. • The new tool available on the market. It is like a flaring tool, but the technician changes the flaring cone with the swaging bit, which comes in a set of different sizes. • Remember to rotate the handle twice to loosen it, and then rotate and tighten again. • Repeat the process until the desired swaging is reached.	 
4	**Bending** • Often, when a tube is small, technicians bend it by hand. • The problem with this practice is that it is impossible to see any wrinkles on the inside of the tube with the naked eye, and if there is a wrinkle, it will restrict the flow of refrigerant. • Always use a pulley type tube bender so the tube will be correctly bent. • In some countries there are still a few technicians who use a spring-type bender but they should be encouraged to change to the pulley type bender for greater accuracy.	 
5	**Essentials of Brazing: The key aspects of brazing:** • In brazing, the base metals to be joined, copper (Cu) andiron (Fe) are never melted, but are heated to a temperature below their melting point (above 650°C but below the Cu melting point, 1,083°C). The filler rod, made of a special alloy, melts at these temperatures when it contacts the heated metals. • The brazing rod should melt on contact with the heated Cu tubes and should never be heated directly by the torch flame and melted onto the joint. This can happen only if the Cu tubes have been heated to the appropriate temperatures.	

	• The filler rod that has melted on contacting the heated base metals (Cu tubes) flows into the clearance between the overlapping Cu tubes by capillary action. This capillary action will take place only when the clearances are maintained within certain limits. • The figure shows a cross-section of the inner and outer tubes being brazed, along with the molten filler material. The melted filler rod, now liquid, coats the surface of the Cu tubes and penetrates superficially into their surface. • This process forms a strong metallurgical bond between the outer surface of one tube and the inner surface of the other tube where this overlap is formed. The boundary-locking layers in the diagram show the metallurgical bond.	
5a	**Good Brazed Joints: Prerequisites** (a) The first thing to be done before starting to braze is to ensure that the joints are correctly prepared. This involves a thorough cleaning of the surfaces to be joined, using emery or wire brush to leave a clean and bright surface. This will ensure removal of all dirt, grease, oil and other impurities that might be present on the surfaces and can prevent proper coating of the surfaces. The second thing is to ensure that the clearances between the two tubes to be joined are maintained correctly. The ideal clearance would be between 0.05 mm to 0.200 mm. If the tubes are the same diameter, this can be achieved using good swaging tools. (b) The next important aspect is the brazing temperature, which is a result of the right combination of fuel, torch and flame. The best results can be had using oxy- acetylene (c) It is also essential to use the right brazing filler rods. For Cu to Cu brazing, filler rods consisting of 7.5% phosphorus and the rest Cu (known as Phos Cu) can be used without a flux, as phosphorus itself acts as a good flux. Brazing rods with 2% silver (Ag) can also be used, preferably with a flux, as Ag lowers the melting temperature. For brazing copper to a different metal (Cu to Fe), filler rods containing phosphorus must be strictly avoided. For Cu to Fe brazing,rods containing at least 35% Ag must be used with a flux, the balance composition of the rods being Cadmium and Zinc (Cd and Zn).	

	(d) Finally, brazing operation with a torch must be done in a way that ensures that the base metals (the tubes) are heated in a manner that facilitates the flow of the molten filler rod into the clearances.	
7	**Cleaning and Flushing:** (a) Compressed air should never be used for flushing, particularly when a hermetic compressor is used to generate the compressed air. This is because the compressed air contains moisture and other gases and the lubricant from the compressor will contaminate the system. Instead, use only dry nitrogen. It is inert and will also absorb some of the moisture in the system. (b) Oxygen in the air can react with the compressor oil, while moisture in the air can be absorbed by the compressor oil. This is particularly critical for compressors running on HFCs.and POE lubricants. (c) Whenever chemical cleaning is needed to clean contaminated systems and use ODS-free alternatives, technicians must be aware of the toxic effects of these chemicals on human health (technicians should read the Material Safety Data Sheet on each chemical before use). These effects can occur after inhalation, eye or skin contact, or ingestion. Technicians must wear personal protective equipment (PPE) while handling these chemicals. Any chemical poured inside the RAC system for cleaning must be vaporised out of the system. (d) Though not at all recommended, petrol is sometimes used as a cleaning agent. This is not a good idea since commercial petrol contains all sorts of impurities that will contaminate the system.	
8	**Leak Testing** (a) Leak testing should always be done using dry nitrogen because it is inert. Dry nitrogen also absorbs moisture inside the system. Compressed air or oxygen should never be used for this purpose. (b) The same reasons that prohibit using air for flushing, mentioned earlier slide, hold for leak testing.	

	(c) The advantage of dry nitrogen is that it absorbs a good bit of the moisture present in the system and reduces the moisture removal load of the vacuum pump during the next step of evacuation. (d) When using an electronic leak detector, a small quantity of the refrigerant is introduced as a tracer gas and mixed with nitrogen, since the electronic leak detector never senses Nitrogen.	
9	**Equipment for Evacuation** (a) Using the appliance's compressor for evacuation ('self-vacuuming') is a common practice in the field. It is a bad practice, as not only does not evacuate all the moisture and other gases out of the system, but it also damages the compressor. (b) Reciprocating refrigeration compressors cannot produce the vacuum necessary to evacuate all the moisture. Further, using the appliance compressor as a vacuum pump can deposit moisture in the discharge chamber and valves, resulting in compressor deterioration. It can also pump out lubricant oil, which can lead to compressor failure. (c) The same reasons hold for separate reciprocating compressors being used as vacuum pumps. The vacuum created will be just as inadequate to boil out all the moisture in the system. (d) Moisture is present in the system as tiny droplets of condensed liquid, usually water. It can be removed only by boiling, which can be done either by heating or by creating a deep vacuum. On site, the most practical way to remove moisture is create a vacuum in the system deep enough to boil off the water. Water boils at 25°C at a vacuum of about 1" Hg or 25,000 microns. To ensure complete and rapid boiling off, a vacuum of at least 500 microns has to be reached. (e) Reciprocating refrigeration compressors generate vacuum of about 76,000 microns. Single stage rotary vacuum pumps are normally used for vacuum levels of about 76,000 microns. It is therefore essential to use a two-stage rotary vacuum pump to reach levels of 100 to 200 microns at a fairly good speed of pumping, particularly for refrigerants like HFCs and HCs. This will ensure that most of the water in the system will have boiled off.	

10a	**Equipment for Evacuation (Two stage)** (a) The reasons for using two-stage rotary vacuum pumps have been outlined previously. Evacuation is necessary for all HFC refrigerants, which, along with their lubricating oils, are highly hygroscopic. Moisture, if present, leads to other problems like sludge formation and capillary choking. (b) The two-stage rotary vacuum pumps are able to pull vacuum to about 100 microns because of their construction (a rotary multi-vane pump) and the excellent sealing done by the vacuum pump oil, which serves as both lubricant and sealant. (c) Reciprocating refrigeration compressors cannot produce such deep levels of vacuum because of the clearance volume in the pumping chamber or cylinder, and also because the sealing is not as good as in rotary vacuum pumps.	 
11	**Charging** (a) The performance of capillary-fitted air-conditioning systems, both in terms of cooling as well as energy consumption, is optimum at a particular charge weight, which is normally defined by the appliance manufacturer on the nameplate. (b) It has been shown that energy consumption (kWh/day) increases sharply if the charge is lower or higher than the optimum weight. (c) The most sensitive appliances are those fitted with HCs, where the charge weight is less than 50% of the equivalent HCFC-22 system. (d) Thus, after carrying out any air-conditioning system repair or servicing, it is best to recharge the system with the amount of refrigerant specified by the manufacturer.	
12	**Contamination and Cross-Contamination** • Contaminants: If sufficient care is not taken during servicing, refrigerant systems can be contaminated by moisture, non-condensable air (particularly if evacuation is not done thoroughly), chemical residues, dirt or dust. • Cross-Contamination: In addition to the above sources of contamination, there is also the risk of cross-contamination, which is the introduction or contaminants into an AC system from another system or equipment used during servicing.	

	• This can happen when the same refrigerants recovery cylinders are used for refilling different refrigerants. • This will seriously affect appliance performance	
13	**Likely Sites for Refrigerant Cross-Contamination** 1. The most common sites for substantial refrigerant residues are the evacuation & charging (E&C) units and the recovery and recycling (R&R) machine condensers. In both of these cases, where an E&C unit or a R&R machine is used for more than one refrigerant, there is the potential for cross contamination. In order to avoid this, the following action Is recommended: (a) Empty out the residual refrigerant completely before using a different refrigerant and evacuate the E&C unit or R&R machine, preferably to 1,000 microns, before reuse. This ensures removal of almost all traces of residual refrigerant. (b) It is better however, if separate machines are used for separate refrigerants. 2. Other potential sources of contamination are recovery cylinders. It is absolutely essential to use a separate cylinder for each and every type of refrigerant. 3. When retrofitting old systems with substitute refrigerants, it is necessary to remove all traces of old refrigerant oil through deep evacuation and changing of refrigeration oil is recommended.	
14	**How to Avoid Cross-Contamination** • Perform a deep vacuum up to 1,000 microns or less before switching to a new refrigerant. • And if possible, use separate E&C and recovery machines for each type of refrigerant. • Make sure that separate recovery cylinders are used for each refrigerant.	

Source: Good servicing practices-Phasing out of HCFC in the RAC servicing sector – UNEP: 2015

6. ENERGY EFFICIENT AIR CONDITIONING UNITS

The demand for air conditioners is increasing rapidly across the world, especially with hot climates.

The sales of air conditioners are growing significantly in emerging economies such as Brazil, India and Mexico as the standard of living improves. The same trend is being witnessed in Mauritius with the growing number of residential projects.

The global air conditioner stock is expected to increase from 660 million units in 2015 to more than 1.5 billion units by 2030, significantly increasing CO2 emissions from this sector. Additionally, the peak power demand from air conditioners can threaten the stability of electrical grids.

In 2015, room air conditioners accounted for approximately 20 per cent of the residential electricity demand in 150 developing and emerging countries.

Air conditioning makes up a significant portion of household energy demand in particular in regions with hot climates where periods of high use correlate with peak power demand in hot summer days, since many AC units operate at the same time and therefore increasing the electricity demand.

They are, thus, key driver of growing GHG emissions. This is because air conditioner refrigerants have a significant climate impact, and their electricity consumption increases GHG emissions from fossil fuel power.

Meeting the growing electricity demand from air conditioners is a national & global challenge to policy makers. However, it also presents a unique opportunity for energy savings and GHG reductions through well designed regulations to transform the markets and find cost effective, energy saving measures to respond to consumer demand.

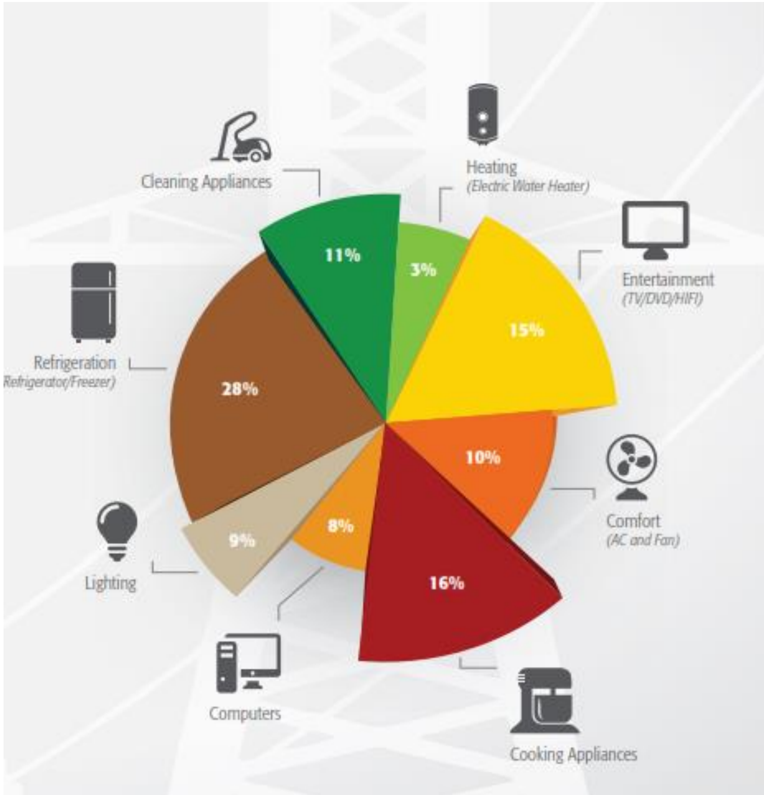


Figure 13: Residential Energy Use

Source CEB Guide

This chapter focus on the transition to energy efficient air conditioners for the household market.

6.1 Global & local market development of energy efficient air conditioners

- Air conditioning stock – AC demand on the rise & expected to accelerate in next decade; AC stock estimated to reach 1.5 billion units in 2030.
- Air conditioning sales & growth – Global annual AC sales over 60M units in 2014 and expected to reach 300M in 2030
- The air conditioner markets worldwide are growing at an average pace of 10% per year.

The market for split air conditioners is growing the fastest, representing 88% of worldwide room air conditioner sales. The market for window air conditioners is declining or disappearing in some countries. Window air conditioners are still very popular in the US, where they accounted for more than 90% of room air conditioner sales in 2014. (Source U4E 2017)

From the survey carried out during this assignment, installation of the window units the last five years has not been recorded by any local AC suppliers.

Inverter split air conditioners are widely available in markets such as EU, Japan, China, India & other developing economies.

From the survey carried out during this assignment the sales volume of inverter split units is increasing every year among the AC suppliers

Benefits of transitioning to high efficiency air conditioners

The benefits of transitioning to high efficiency AC and low GWP developed for 150 developing countries and emerging countries are as follows:

Annual Energy Savings (electricity consumption):

An estimated 620 TWh/year of electricity can be saved in 2030 if the best currently available technology for air conditioning is adopted.

Lower Emissions:

Improving room air conditioning efficiently (~30% more efficient than current technology) in parallel with low GWP refrigerants in these products could avoid up to 480 megatonnes of CO_2 in 2030.

Financial Savings:

Up to $56 billion ($ 17 billion only for India) can be saved cumulatively for consumers through 2030 by improving air conditioner energy efficiency policies. (Source U4E 2017)

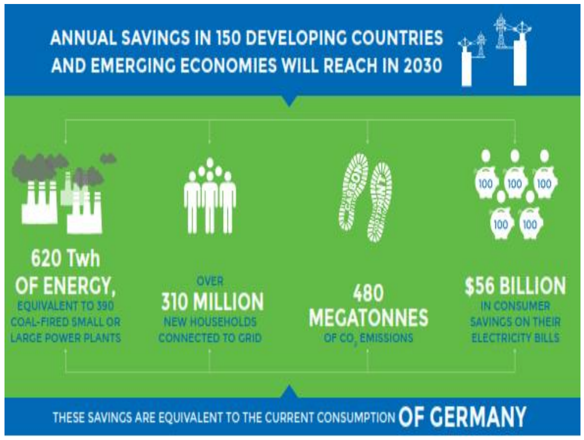


Figure 14: Benefits of transitioning the High Efficiency AC

6.2 Efficiency gains from High Efficiency air conditioners

There are multiple options to improve energy efficiency of air conditioners. These include the use of more efficient technologies and components such as inverter/variable speed compressors, fans, heat exchangers, expansion devices and refrigerant fluids.

If applied altogether, these improvement options could save between 60-72% of energy compared to a base case model (defined as a non-inverter split AC unit. In general, higher costs and size constraints are some of the barriers to include more efficient components in air conditioners.

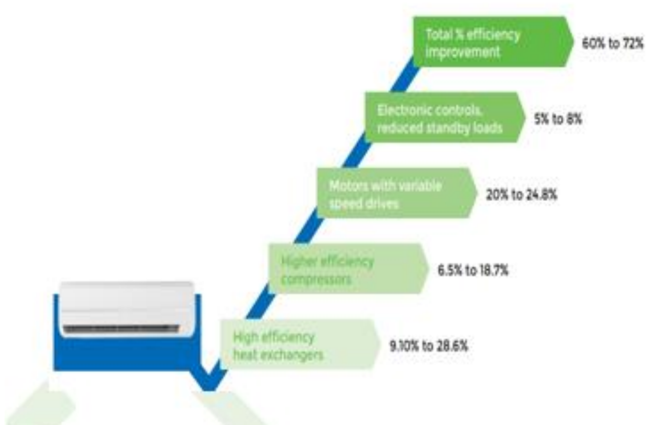


Figure 15: Efficiency gains for High Efficiency AC

6.3 Solar air conditioning

Solar air conditioning refers to any air conditioning (cooling) system that uses solar power. This can be done through solar thermal energy conversion and photovoltaic conversion (sunlight into electricity).

The solar air conditioner with photovoltaic conversion can be off grid type which uses DC batteries or the hybrid air conditioner which have dual purpose DC power & AC power through the inverter.

Figure 16: Solar AC off grid type

Figure 17: Hybrid Solar AC using DC & AC power

Figure 18: Solar AC with solar collectors

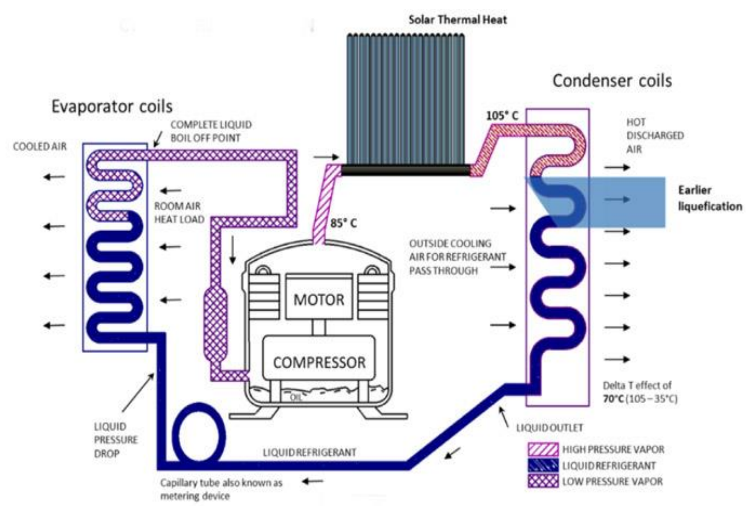


Figure 19: Solar Ac with solar collectors

The solar air conditioner which has the solar thermal energy conversion uses solar plate collectors mostly the evacuated tubes.

Solar air conditioning has not yet been gathering momentum in the local market since the few prototypes installed on a pilot basis has not reaped the required success.

Moreover, from the survey carried out during this assignment, not a single local supplier (among 17 suppliers interviewed) have installed a solar air conditioner the last five years. Hence not much first-hand information is currently available on the type of solar air conditioners which best suit our climatic conditions & which can become the future in the energy efficient AC units.

6.4 Performance Metrics, Energy Efficiency Ratio (EER) & Seasonal EER (SEER)

The ISO 5151 has been adopted by most countries as a reference test standard for measuring air conditioners' cooling capacity and efficiency. However, not all economies are aligned with ISO 5151, and some differences remain between test methods. North American (and some South American countries) follow standards set by ASHRAE.

The EER and SEER are the two main types of metrics in use internationally to rate energy efficiency of air conditioners.

The energy efficiency of an air conditioner is generally expressed by its coefficient of performance, also called Energy Efficiency Ratio (EER).

The EER is the ratio of the cooling capacity and the power consumed when measured at full load (i.e., at the maximum deliverable cooling capacity of the air conditioner). This EER has been the basic parameter used to indicate the energy performance of air conditioners in Minimum Energy Performance Standards (MEPS) and energy efficiency labelling regulations.

Given that air conditioners typically operate at full load for only a small number of hours in the cooling season, EER is often not the best representation of air conditioner performance especially for variable speed systems since it does not take into account performance at part-load. Many countries (China, EU, India, Japan, Republic of Korea, US) have transitioned to the Seasonal Energy Efficiency Ratio (SEER) as a metric to rate performance and capture part-load performance.

The SEER represents the expected overall performance of an air conditioner for a typical year's weather in a given location. Instead of being evaluated at a single operating condition, the SEER is calculated with the same indoor temperature, but over a range of outside temperatures over the course of the cooling season.

6.5 Mauritius Standard for Energy Efficiency & Labelling of AC (MS 200:2013)

An EER metric can be a first step in countries where MEPS are implemented for the first time, while an SEER (considered a more complicated metric) could be adopted in countries where standards are already in place and a metric that considers seasonal performance would achieve higher energy savings.

6.5.1 Labelling Evolution

Product labelling is one of the most direct and effective means of delivering information about energy efficiency to consumers.

When implemented well, labelling is one of the most cost-effective energy-efficient policy measures.

The EU Energy labeling is long known & appreciated tool for consumers, advising them on the energy efficiency and other functional performance qualities of models which are to be considered for their purchase.

The purpose of Energy Labels is to rank all models of certain type of products within certain energy class range, typically from A to G or A+++ to D and show the ranking at the points of sale.

The old labelling classified energy class range from A to G.

Figure 20: E.g Old label Energy class A to G

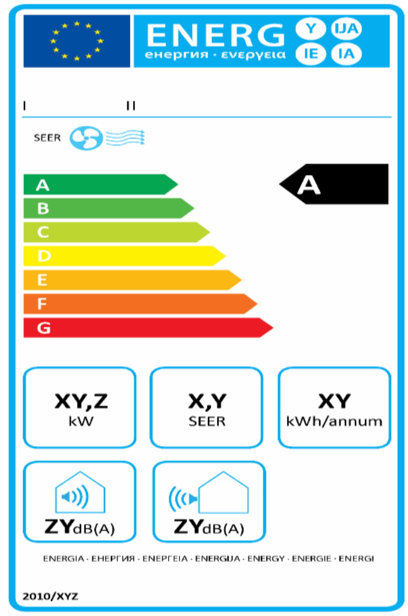


Figure 21: EU Old label with Energy Class A to G

The new Eco Design label measures are another set of the EU legislation that regulates the energy consumption and functional performance aspects of products, through setting of the minimum requirements for the placing on the market. They are based on the Seasonal Energy Efficiency indicators (SEER) and SCOP (heating function) which considers the efficiency of the part load condition.

In practice (at the point of sale) these type of products are displayed showing the full range of energy classes (A+++ to D) but at the same time the eco design legislation prohibits the market entry of some models below a certain minimum energy class.

6.5.2 Labelling Regulations

The EU Regulations establishes requirements for the labelling and the provision of supplementary product information for electric mains-operated air conditioners with a rated capacity of ≤ 12 KW output power for cooling or heating.

6.5.3 Labelling details

The new energy label refers to all Eco Design air conditioning units and is required for giving useful information of energy consumption and energy classification.

A comparison has been done between the Eco Design label as ratified by the EU to explain the information portrayed on the Eco Design label for an Air conditioner currently available on the local market.

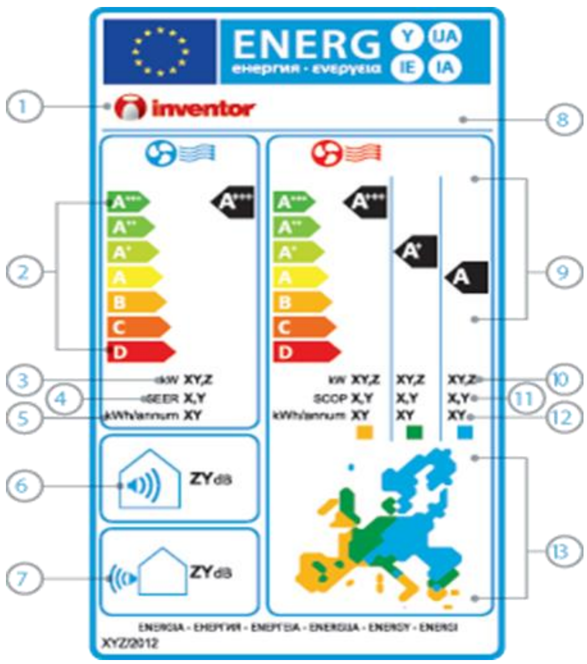


Figure 22: EU Eco design label with Energy Class range A+++ to D (Reversible type AC)

Figure 23: E.g Eco Design label for a local supplier (Reversible – 3 climate zone)

1. Brand name – [**XXX**]

2. Energy classification in cooling mode, A+++ the most efficient **[A++**]

3. Design load cooling (KW) [**4.6**]

4. SEER: Seasonal Efficiency Ratio (for cooling mode), is the cooling season energy efficiency performance, expressed as the ratio between the reference seasonal cooling demand in KWh/a and the seasonal electricity consumption for cooling for cooling KWh/a [**6.1**]

5. Annual power consumption in cooling mode. [**264**]

6. Sound power level (dB) indoor unit. [**58**]

7. Sound power level (dB) outdoor unit.[**63**]

8. Indoor's & Outdoor's units model name. [**XXX**]

9. Energy classification in heating mode. [**A+++, A+, B**]

10. Design load heating (KW). [**3.3, 3.3, 5.0**]

11. SCOP: Seasonal Coefficient of Performance (for heating mode) is the heating season efficiency performance, expressed as the ratio between the reference seasonal heating energy demand in KWh/a and the seasonal electricity consumption for heating which may vary according to the climate profile chosen in KWh/a. [**5.1, 4.0, 3.3**]

12. Annual power consumption in heating mode. [**906, 1155, 3182**]

13. European map divided into 3 climate zones.

Below is an Eco Design label for a reversible type Air conditioner (make XXX).

Figure 24: E.g Eco Design label for a local supplier (Reversible – 1 climate zone)

The energy label for air conditioners referred to the **Energy Efficiency Ratio** (EER, cooling function) and **Coefficient Of Performance** (COP, heating function) to express the energy efficiency of all air conditioners. These indicators are measured at full load operation only.

For some cooling only units, EER and COP is still applied.

Figure 25: E.g Eco Design label for a local supplier (Cooling only)

The energy efficiency classes are dependent on the type of air conditioner and the related SEER/SCOP.

The Energy efficiency classes as defined by EU Regulation 626/2011 Table 21 is tabulated below. Also, EU Regulation 626/2012 Table 21 which shows the minimum efficiency requirements and Table 23 which shows the requirements for maximum sound power level for air conditioners are reproduced below.

Table 12: Energy Efficiency Classes for AC

Energy Efficiency Class	SEER	SCOP
A+++	SEER ≥ 8.50	SCOP ≥ 5.10
A++	6.10 ≤ SEER < 8.50	4.60 ≤ SCOP < 5.10
A+	5.60 ≤ SEER < 6.10	4.00 ≤ SCOP < 4.60
A	5.10 ≤ SEER < 5.60	3.40 ≤ SCOP < 4.00
B	4.60 ≤ SEER < 5.10	3.10 ≤ SCOP < 3.40
C	4.10 ≤ SEER < 4.60	2.80 ≤ SCOP < 3.10
D	3.60 ≤ SEER < 4.10	2.50 ≤ SCOP < 2.80
E	3.10 ≤ SEER < 3.60	2.20 ≤ SCOP < 2.50
F	2.60 ≤ SEER < 3.10	1.90 ≤ SCOP < 2.20
G	SEER < 2.60	SCOP < 1.90

Source: EU Regulation 626/2011 (Table 27)

Table 13: Minimum Efficiency Requirements

	Air conditioners, except Double and single duct Air conditioners SEER	SCOP (heating Season average)
If GWP of refrigerant > 150 for < 6 kW	4.60	3.80
If GWP of refrigerant ≤ 150 for < 6 kW	4.14	3.42
If GWP of refrigerant > 150 for 6-12 kW	4.30	3.80
If GWP of refrigerant ≤ 150 for 6-12 kW	3.87	3.42

Source : EU Regulation 626/2012 (Table 21) Minimum efficiency requirements

Table 14: Requirements for maximum sound power level

Rated capacity ≤ 6 kW		6 < Rated capacity ≤12 kW	
Indoor sound power level in dB (A)	Outdoor sound power level in dB(A)	Indoor sound power level in dB (A)	Outdoor sound power level in dB(A)
60	65	65	70

Source: EU Regulation 626/2011 (Table 23)

7. AIR CONDITIONER REFRIGERANTS

Refrigerants used in air conditioners have changed over the years as they have become controlled substances under the Montreal Protocol due to damage they cause to the ozone layer and the climate system. HCFCs, the last-generation refrigerants commonly used in air conditioners, are scheduled to be totally phased out in developed countries by 2030 and in developing countries by 2040.

Non-ozone depleting HFCs are commercially available alternatives to HCFCs. While they do not deplete the ozone layer, HFCs are potent GHGs, hundreds to thousands of times more powerful in trapping heat in the atmosphere than CO2. Since the HCFC phase-out was agreed, annual HFC consumption has increased at a rate of 10 – 15 per cent per year, raising alarm to their potential contribution to rising global temperatures.

Avoiding production and use of HFCs by using technologically feasible low-GWP substitutes could avoid as much as 0.5 °C warming by the end of the century.

In order to reduce production and consumption of these powerful greenhouse gases, the parties to the Montreal Protocol unanimously adopted the Kigali Amendment in October 2016, agreeing to add HFCs to the list of controlled substances and approving a timeline for their gradual reduction by 80 – 85 per cent by the late 2040s.

7.1 Environmental Impact of Refrigerants

7.1.1 Importance of Ozone

Life on Earth has been safeguarded against harmful ultraviolet radiation due to the protective ozone layer in the atmosphere.

While the sun’s rays help sustain life on Earth, they also contain harmful ultraviolet (UV) rays.

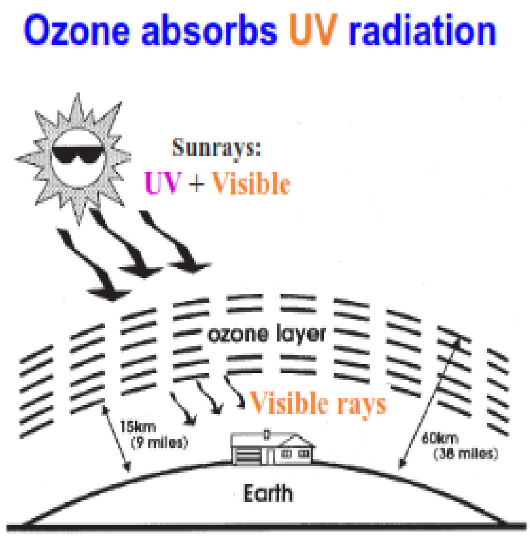


Figure 26: Importance of Ozone

Located in the Stratosphere, the ozone layer efficiently screens out almost all the Sun's harmful UV rays, absorbing them and preventing them from causing damage on the Earth's surface.

7.1.2 Ozone formation

Ozone is a tri-atomic molecule of Oxygen which join together to form the ozone molecule (O_3). Through natural atmospheric processes, ozone molecules are created and destroyed continuously.

In the Stratosphere zone (the layer found between 11 – 36 km above earth's surface, that contains the ozone layer), UV rays from the sun react with the existing oxygen molecules (O_2) and break them down into oxygen atoms. In the reaction that follows, three oxygen atoms join together to form ozone molecules. Thus oxygen is continually converted into ozone.

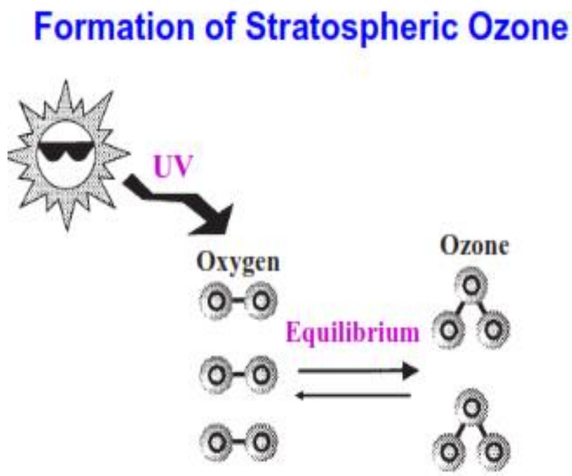


Figure 27: Stratospheric Ozone Formation

The reverse reaction also take place where some ozone molecules decomposed into three oxygen atoms, which join together in twos to become oxygen molecules. In this way, a continuous equilibrium is maintained between ozone and oxygen in the stratosphere.

7.1.3 Ozone Depletion

Ozone is not a stable gas and is particularly vulnerable to destruction by natural compounds containing hydrogen, nitrogen and chlorine. A chain reaction is triggered when the HCFC molecules come close to the ozone layer. The HCFC molecule decomposes and releases a Chlorine radical when it comes into contact with the sun's rays. This chlorine radical reacts with an oxygen atom from an ozone molecule, yielding an oxygen and a chloromono-oxide molecule. The chloromono-oxide molecule is unstable and breaks again, releasing a free chlorine radical. This chlorine radical now starts a similar reaction with another ozone molecule. These repetitive cycles deplete the ozone layer.

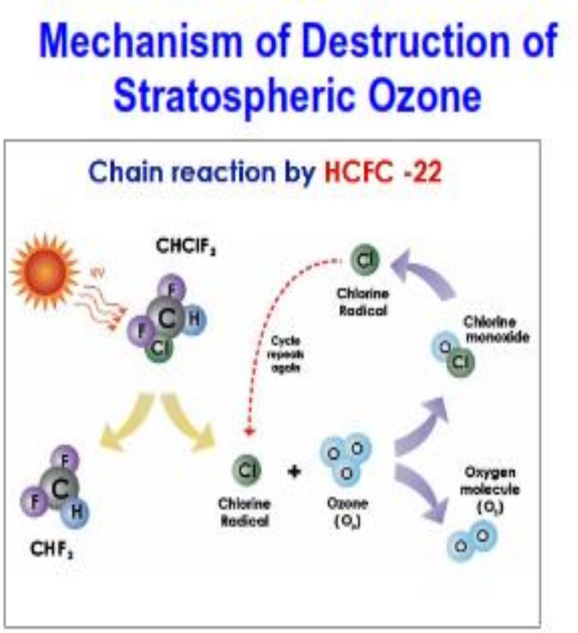


Figure 28: Stratospheric Ozone destruction

The presence of chlorine atoms in ODSs is the cause of ozone depletion. Reactions by manmade, ozone depleting chemicals upset the natural ozone balance in the stratosphere, raising serious concerns.

7.1.4 Consequences of Damaging the Ozone layer

Ultra Violet radiation (UV) is classified in three ranges: UV-A, UV-B, UV-C. Of these, UV-A is the least energetic and harmful.

The component of UV-C in the solar spectrum itself is small, and that reaching the earth is practically nil. UV-B, however is energetic enough to cause biological interactions. With the loss of the natural ozone shield, the Earth's living organisms are exposed to the harmful effects of UV-B radiation.

Among other effects, UV-B radiation can increase in the probability of skin cancer among human beings. It can also induce eye injury, damaging the cornea and lens of the eye, which can lead to cataracts. UV radiation can also suppress the human immune system, making it prone to a number of infectious diseases. Fish and other ocean animals are affected by this radiation, since it adversely influences aquatic life, leading to decreased reproductive capacity and impaired development. Materials are also harmed by increased UV radiation, which has adverse effects on synthetic polymers, naturally occurring biopolymers and other materials of commercial interest. Material used in buildings, paints, packaging and countless other substances can be degraded by UV-B rays, which accelerate photodegradation rates. Typical damage ranges from discoloration to loss of mechanical integrity. Increased UV-B radiation may also cause decreased crop yields and damage to forests, as well as increased cancer rates in humans.

7.1.5 Global Warming – Greenhouse effect

Another important environmental impact of refrigerants relates to the phenomenon of Global Warming.

The Greenhouse Effect is:

The solar radiation interacts with Earth's surface in several ways. Out of the total solar radiation, nearly 20% is reflected from the Earth's atmosphere, 20% is dispersed into the atmosphere and 9% is reflected from earth's surface or dust. The remaining, nearly 51%, penetrates the atmosphere and reaches earth's surface.

Most of the solar radiation reaching the earth's surface are reradiated to the atmosphere.

As the reradiated radiation leaves the earth, it once again interacts with the atmosphere. Some of this manages to escape (about 17%), but the majority of radiation is returned back to the earth's surface by the presence of greenhouse gases. This reflected energy further warms the surface of the earth, leading to what is called the Green House effect.

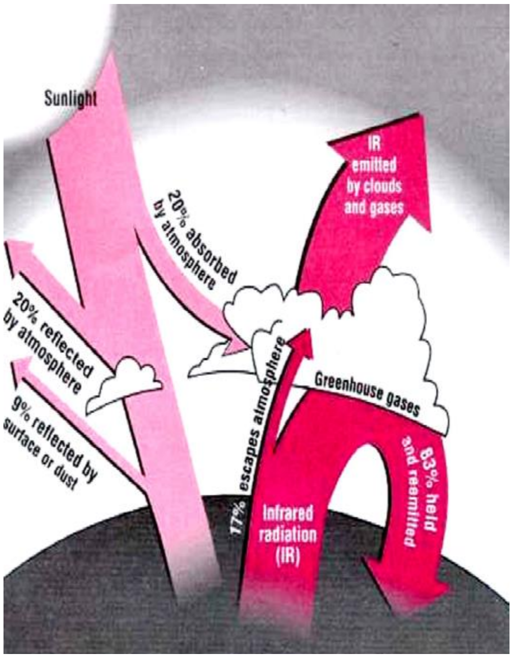


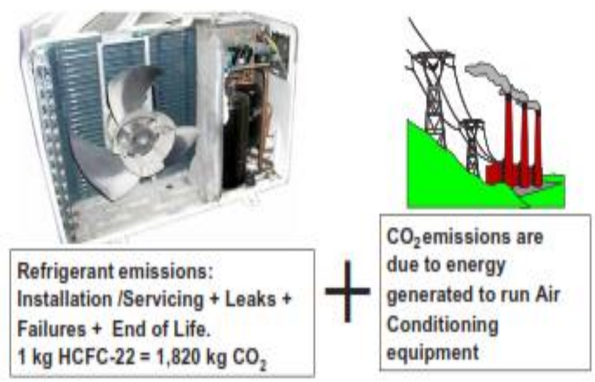
Figure 29: Greenhouse effect

Nature made the greenhouse effect which is necessary to sustain life on earth. Absence of greenhouse effect would have rendered the earth temperatures so low that human life would not have existed.

However, some of the greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Sulphur hexafluorides (SF_6), Halocarbons (HFCs), Perfluorocarbons (PFCs) & Nitrogen Trifluoride (NF_3) essentially emitted through human activities, cause an increase in the level of greenhouse effect and thus, high global warming and this is harmful to mankind and the living beings on earth.

7.1.6 How ACs contribute to Global Warming

- Refrigerant emissions over the working life of AC (Direct emissions)
- Consumption of electricity over the entire working life of AC
- Electricity use contributes almost 90% of the CO_2 emissions. Emissions can be around 1 kg of CO_2 per kWh



1 kg R410A = 2,068 kg CO_2; 1 kg R134a = 1,430 kg CO_2

1 kg R404A = 3,922 kg CO_2

Figure 30: How ACs contribute to Global warming

Air Conditioners contribute to global warming in two ways, called the direct and indirect contribution. Direct contribution is due to the direct emission of refrigerant used in air conditioners. Refrigerant emits during installation and servicing, due to leakage, failure and at the end of life of ACs. As HCFCs and HFCs are having high global warming potential (e.g GWP of HCFC-22 is 1820) small emission to environment contributes high global warming.

Indirect contribution is the energy-related contribution that is represented by the emissions of Greenhouse gases (mainly CO_2) that arise from the production of electricity. Over the entire life cycle of air conditioning equipment, considerable amount of electricity is consumed. In most countries, electricity generation is by fossil fuel.

Various experiments and calculations have shown that the indirect contribution of ACs to the greenhouse effect is significantly higher than the direct contribution associated with the emission of HCFCs.

7.2 Commonly used refrigerant

Commonly used refrigerant in air conditioning sector are shown below.

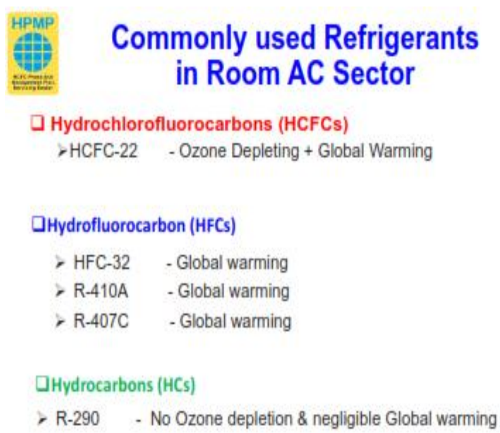


Figure 31: Commonly used refrigerant in room AC system

The refrigerants used are divided into three categories – HCFC, HFCs and HCs.

HCFCs, including HCFC-22 are ozone depleting substances which are being phased out under the HPMP of Montreal Protocol, in accelerated phase-out schedule. These are also having high global warming potential.

The next category refrigerants are HFCs and blend of HFCs. At present, HFC-32 and blends like R410A, R404A and R407C are commercially available and used as refrigerant in room air conditioning sector. These chemicals are not having ozone depleting potential, but they are having high global warming potential. The Montreal Protocole has been amended to phase down HFCs as these chemicals have high GWP values.

The 3rd category refrigerant, HCs, like R-290 and R-600a are commercially available refrigerant which are not having ozone depleting potential and having negligible global warming potential compared to the other two categories of refrigerants.

7.3 Handling of HCFC & HFC gas

Handling Precautions

The following points need to be considered for the safe handling of HFCs

(a) HFCs are heavier than air, so they displace air.

(b) HFCs have no smell.

(c) Since they are heavier than air, HFCs collect in lower positions like the bottom of an appliance or the basement of a building.

(d) HFCs can be toxic; a person may suffocate if a high concentration of HFC is inhaled.

Storage of Cylinder / Can

HFC cylinders should be stored in dry, well-ventilated areas, away from direct sunlight. Make sure there are no sources of direct heat near the storage. No flame or torch must be ignited near the cylinder. The best practice is to work in a well-ventilated area.

Cylinder Valve

The cylinder and cylinder valves should not be modified, as they are specifically designed for HFC use. It is advised never to refill disposable cylinders, as they are not designed for refilling.

Safety: Decomposition

HFCs decompose on heating and form hydrofluoric acid. It is therefore advised that appliances should not be heated by flame, electrical heating elements, or smoke. The work area must be well ventilated. If the cylinder becomes cold or some frost forms on the outside of the cylinder while charging, do not heat it with a flame, just put the cylinder in hot water (40°C) and then charge the refrigerant. In case of any decomposition, ventilate the work area and make sure no one smokes.

Safety: Do not overfill cylinder

It is important for not overfilling a cylinder. A refillable or recovery cylinder should not be refilled more than 75% of volume and at a temperature of 21°C, as the temperature is directly proportional to the space covered by the refrigerant.

When the cylinder is refilled to 85% of its volume and exposed to direct sunlight, and if the temperature reaches 54°C, the cylinder can explode. This is because if atmospheric temperature increases, the refrigerant volume also increases. This can lead to explosion.

Safely: POE Oils

Polyolester oils (POE), Polyalpha olefin oils (PAO) and Polyalkyl glycol oils (PAG) are used with HFCs. The oils cause ski problems. Technicians should wear gloves when handling the oil or oil-filled components. Technicians must take special precautions when handling burnt-out systems, as burnt-out compressors form undesirable gases, specifically acids. The best option is to wear personal protective equipment (PPE) while handling burnt out systems and when working with mineral oils.

Safe Disposal of Refrigerants

In determining the proper management of waste refrigerants, the recovery, recycling and reclamation of refrigerant gases is normally considered wherever these facilities are available in other countries. The recovery process in refrigerant gas cylinders is followed in our local context.

Once a decision has been taken to discard a recovered refrigerant (i.e. where there is no further certain use for it by the end-user or by the contractor), it is considered a hazardous waste and must therefore be managed in accordance with the relevant waste legislation.

Waste refrigerant gases must be brought to an appropriately authorised waste facility when taken from an end-user site by the licensed contractor in safe transportation. The storage of waste refrigerant gases is not permitted on any site.

7.4 HCFC Phase out management plan

Article 5 Developing countries POMP

Montreal Protocol successfully phasing out the production and consumption of ODSs. All 197 countries of the world are working together to phase out ODSs.

In Kigali, Montreal Protocol made amendment to phase down the use of HFcs in 2016 called Kigali amendment. It is a dedicated effort to reduce GHG emission through phase down of HFCs and improve energy efficiency.

The HCFC Phase-Out Schedule – Article 5 (Developing) countries is shown below.

Table 15: HCFC phase out schedule

Schedule	Year
Baseline	Average of 2009 and 2010
Freeze	2013
90% (reduction of 10%)	2015
65% (reduction of 35%)	2020
32.5% (reduction of 67.5%)	2025
Annual average of 2.5%	2030 to 2040
0% (reduction of 100 %)	2040

7.5 Alternative to HCFC gas

Refrigerant options

Manufacturers are considering alternatives to transition to climate-friendly refrigerants in room air conditioners (i.e. substances with zero ozone depleting potential and low GWP).

These alternatives, including propane (R-290), HFC-32 (R-32), and HFC/hydrofluoro olefins (HFO) blends; pose a lower climate burden.

They display different characteristics affecting their environmental performance, energy efficiency, safety and cost. The table illustrates the properties of various refrigerant classes such as GWP, ODP and alternative refrigerant.

Table 16: Basic refrigerants information & alternatives

Refrigerant	Chemical name or mixture composition (in % by mass)	ODP†	GWP‡		Comparable refrigerant *
			(100)	(20)	
HCFC-22	Chlorodifluoromethane	0.05	1780	5310	-
HFC-32	Difluoromethane	0	704	2530	R-410A
HCFC-123	2,2-dichloro-1,1,1-trifluoroethane	0.03	79	292	-
HFC-134a	1,1,1,2-tetrafluoroethane	0	1360	3810	CFC-12
HFC-152a	1,1-difluoroethane	0	148	545	CFC-12, HFC-134a
HC-290	Propane	0	5	18	HCFC-22
R-404A	125/143a/134a (44,0/52,0/4,0)	0	4200	6600	HCFC-22
R-407C	32/125/134a (23,0/25,0/52,0)	0	1700	4100	HCFC-22
R-410A	32/125 (50,0/50,0)	0	2100	4400	-
R-444A	32/152a/1234ze(E) (12,0/5,0/83,0)	0	90	330	CFC-12, HFC-134a
R-444B	32/152a/1234ze(E) (41,5/10/48,5)	0	310	1100	HCFC-22
R-445A	744/134a/1234ze(E) (6,0/9,0/85,0)	0	120	350	CFC-12, HFC-134a
R-446A	32/1234ze(E)/600 (68,0/29,0/3,0)	0	480	1700	R410A
R-447A	32/125/1234ze(E) (68,0/3,5/28,5)	0	600	1900	R410A
R-451A	1234yf/134a (89,8/10,2)	0	140	390	CFC-12, HFC-134a
R-451B	1234yf/134a (88,8/11,2)	0	150	430	CFC-12, HFC-134a
R-454A	32/R1234yf (35,0/65,0)	0	250	890	HCFC-22
R-454B	32/R1234yf (68,9/31,1)	0	490	1740	R410A
HC-600a	Iso-butane	0	4	15	CFC-12, HFC-134a
R-717	Ammonia	0	0	0	HCFC-22
R-744	Carbon dioxide	0	1	1	-
HFC-1234yf	2,3,3,3-tetrafluoro-1-propene	0	< 1	1	CFC-12, HFC-134a
HFC-1234ze(E)	Trans-1,3,3,3-tetrafluoro-1-propene	0	< 1	4	CFC-12, HFC-134a
HC-1270	Propene	0	2	7	HCFC-22

† ODP are regulatory values and ‡ GWP are scientific values (UNEP, 2014)[1]
* "Comparable refrigerant" means in terms of operating pressures and volumetric refrigerating capacity

Source: Safe use of HCFC alternatives in RAC – UNEP 2015

7.6 Energy Efficient Refrigerant gas R32 & R290

A particular attention is being given in this section to the energy efficient refrigerant gas R32 & R290 (propane).

7.6.1 Refrigerant gas R32

R32 refrigerant is also known as difluoromethane and belongs to the HFC family of refrigerant. It is chlorine free and ozone-safe fluorocarbon and it is a component of R410A. This gas is poised to replace the other gaseous such as R410A as the preferred gas due to its lower GWP. Its chemical formula is CH_2F_2.

R32 has a GWP about one third that of R410A and it has excellent properties as a refrigerant. Therefore, the technology has been developed to use it by itself as an alternative refrigerant to replace R410A especially in the air conditioning sector. R32 delivers superior performance in both cooling/heating capacity and energy efficiency, compared to R410A, volumetric capacity of R32 is about 15% higher and its COP is about 6% higher. Hence it can contribute to reduce equipment's indirect impact on CO_2 emission.

Table 17: Theoretical characteristics of R32 compared with other ref gas

			R32	R410A	HCFC-22
Evaporator Pressure		MPa	0.81	0.80	0.50
Condenser Pressure		MPa	3.14	3.07	1.94
Glide in evaporator		°C	-	0.11	-
Discharge Temperature		°C	106	83	88
Cooling	COP *1		2.75	2.57	2.90
	Capacity	kJ / m³	4812	4150	3010
Heating	COP *1		3.75	3.57	3.90
	Capacity	kJ / m³	6562	5764	4049

Source: Daikin R32 Instructions for use and handling

R32 is flammable, but its flammability is extremely low compared with that of hydrocarbon refrigerants such as propane. Therefore, R32 is positioned as a slightly flammable refrigerant.

Table 18: Flammability properties of R32 compared with other ref gas

Flammability properties and Flammability classification by the applicable laws, regulations and standards

		R32	R410A	HCFC-22	Ammonia	Propane
Flammability range (in Air)	Lower flammability limit (LFL) vol.%	13.6	non	non	15	2.2
	Upper flammability limit (UFL) vol.%	28.4			28	9.5
Minimum ignition energy (MIE)	mJ	30 ~ 100	-	-	Not fixed	0.25
Maximum burning velocity (BV)	cm/s	6.7	-	-	7.2	38.7
Heat of combustion (HOC)	kJ/kg	9,400	-	-	18,600	45,700
ASHRAE standard 34		Class 2L (Slightly flammable)	Class 1 (Non-flammable)	Class 1 (Non-flammable)	Class 2L (Slightly flammable)	Class 3 (Highly flammable)
ISO international standard 817		Class 2L (Slightly flammable)	Class 1 (Non-flammable)	Class 1 (Non-flammable)	Class 2L (Slightly flammable)	Class 3 (Highly flammable)
GHS (Globally Harmonized System of Classification and Labelling of Chemicals)	MPa	Category 1 (Extremely flammable gas)	Not Classified	Not Classified	Category 1 (Extremely flammable gas)	Category 1 (Extremely flammable gas)

Source: Daikin R32 Instructions for use and handling

7.6.2 Handling Precautions of R32

Laws & Regulations

R32 is a high-pressure liquefied gas and is classified as slightly flammable refrigerant. To handle the refrigerant R32 safely, local laws & regulations have to be observed.

Handling of containers

R32 is a high-pressure gas and kept in high-pressure containers. Although these containers are of safe design, they may crack when handled roughly and this can cause accidents. Be very careful not to drop, hit or roll the containers or to let them fall over.

Storage

Like all other high-pressure gases, store R32 in a cool, dark and well-ventilated place. If R32 gas is leaked it tends to sink to a lower level and remain there since R32 is heavier than air. If R32 gas accumulates to high concentrations in some area, symptons of oxygen deficiency may occur to the person who gets into the area, accidental combustion of the gas may result. All containers for high-pressure gases including R32 have a safety device fitted. If the storage temperature or pressure rises above certain level, the safety device is actioned so that the gas escapes.

Precautions about decomposed gas

Keep R32 away from heat or open flame. If R32 is combusted or thermally decomposed as a result of exposure to flame or heat source, hazardous will be generated.

Health Precautions

Like other liquefied high-pressure gases, R32 should be prevented from coming into direct contact with the skin or eyes and from being inhaled.

Emergency treatment methods are as follows.

- If gas is inhaled
  - Move the person to airy place to rest in a relaxed position
  - Keep the person warm with a blanket
  - If breathing is weak loosen the clothing artificial respiration can be given
- If liquefied gas gets into the eye
  - Wash the eyes out with water for 15 minutes or more. Try to avoid rubbing the eyes and blinking.
  - When needed seek medical assistance immediately.
  - To prevent such accidents, always wear protective goggles when handling R32.
- If liquefied gas comes into direct contact with the skin
  - When liquid R32 evaporates, its temperature drops dramatically.
  - Direct contact with the skin in this state may cause frostbite.
  - If a large quantity of evaporating liquid R32 comes into direct contact with the skin, it will cause frostbite, so seek medical assistance immediately.

7.6.3 Refrigerant gas R290

The hydrocarbon propane C_3H_8 is a naturally occurring gas found in the depth of earth. Propane can be separated from other petrochemicals and refined for commercial use. As a Liquefied Petroleum Gas (LPG), propane can be converted to liquid under low pressures.

In general, the thermodynamic properties of propane help to reduce pressure losses and improve heat transfer. These favourable properties like high latent heat, high liquid specific heat, etc, makes it an energy efficient refrigerant.

It can be seen from the table below, R290 exhibits the most desirable properties as compared to common refrigerants.

Table 19: Comparison of various thermo-physical properties of selected refrigerants

Refrigerant	Critical temperature (°C)	Liquid viscosity (Pa s x10^6)	Vapour viscosity (Pa s x10^6)	Liquid specific heat (kJ/kg K)	Liquid thermal conductivity (W/m K)	Latent heat (kJ/kg)
R22	96.1	216	11.4	1.17	0.095	205
R407C	86.0	211	11.3	1.42	0.096	210
R410A	71.4	161	12.2	1.52	0.103	221
R290	96.7	126	7.4	2.49	0.106	375

Advantages of R290

- Zero ozone depletion potential
- Very low global warming potential compared to common refrigerants
- Excellent thermodynamic properties leading to high energy efficiency
- Good compatibility with system components
- Low charges allowing smaller heat exchangers and piping dimension

Safety aspect of R290

The safety aspect of propane like its high flammability, being odourless & hence not detected by smell and being heavier than air therefore it accumulates at ground level in case of leakage represent key challenges for its introduction in the local market.

Therefore, the use and handling of R290 requires adequate safety measures such as fire and explosion provision, safe storage requirement, emergency procedures, personnel protection, etc

The survey conducted for this assignment has not registered any local suppliers importing AC units which are using these refrigerant gases.

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ANNEX 1: SPLIT AC MANUFACTURER'S SERVICE MANUAL

Split Air Conditioner

Wall Mounted Type

Service Manual

MUP 09-HI

MUP-12HI

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Energy Efficiency Management Office

SAFETY PRECAUTIONS

The following safety precautions must be taken when using your air conditioner.

1. Warning: Prior to repair, disconnect the power cord.

2. Use proper parts: use only exact replacement parts. (Also, we recommend replacing parts rather than repairing them.)

3. Use the proper tools: use the proper tools and test equipment, and know how to use them. Using defective tools or test equipment may cause problems later-intermittent contact, for example.

4. Power cord: prior to repair, check the power cord and replace it if necessary.

5. Avoid using an extension cord, and avoid tapping into a power cord. This practice may result in malfunction or fire.

6. After completing repairs and reassembly, check the insulation resistance.
Procedure: prior to applying power, measure the resistance between the power cord and the ground terminal. The resistance must be greater than 30 megohms.

7. Make sure that the grounds are adequate.

8. Make sure that the installation conditions are satisfactory. Relocate the unit if necessary.

9. Keep children away from the unit while it is being repaired.

10. Be sure to clean the unit and its surrounding area.

INSTALLATION

Selecting area for installation

Select an area for installation that is suitable to the customer's needs.

1 Location of indoor unit

- Keep the air inlet and outlet at a far distance from the blockage.
- Keep the height distance between the indoor and outdoor unit at most 5m.
- Mount on the wall solid enough to bear the weight of the unit and not cause any shake.
- Avoid direct sunshine.
- A place easy for condensate drain and easy for connecting with the outdoor unit.
- Keep a far distance away from the fluorescent lamp, it may influence the operation of remote controller.
- Keep at least 1m away from the TV radio and other home appliances.

2 Location of outdoor unit

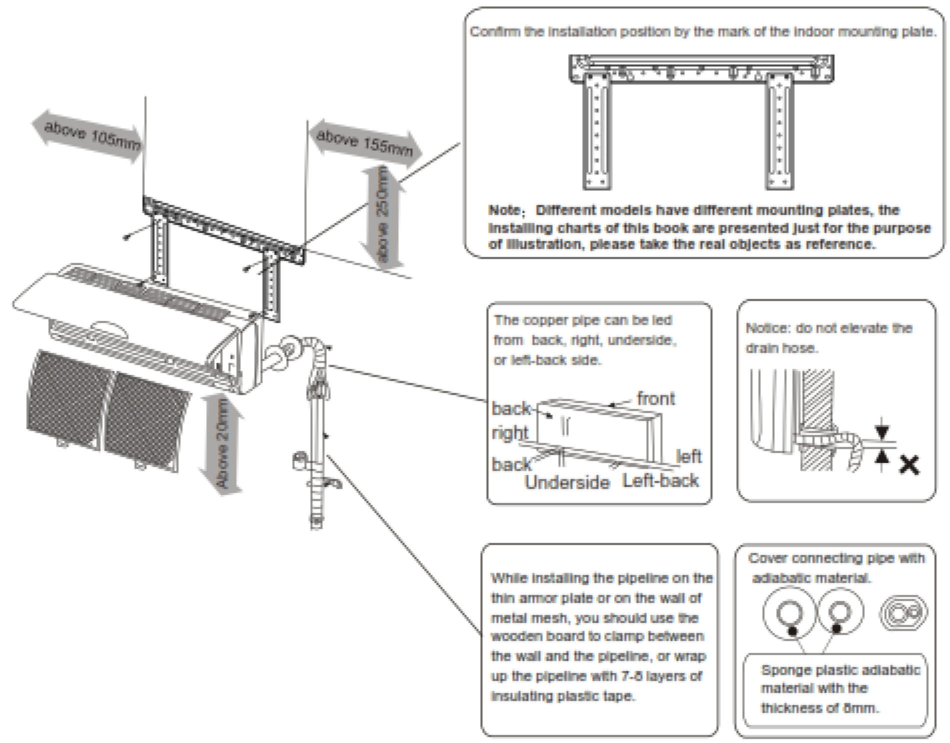
- A place solid enough to bear the weight of the unit and not cause any shake.
- Good ventilation, less dust, far from direct rain and sunshine.
- A place where the air discharged out of the outdoor unit or the operation noise will not annoy your neighbours.
- No blockage near the outdoor unit.
- **Avoid places close to inflammable gas leakage.**

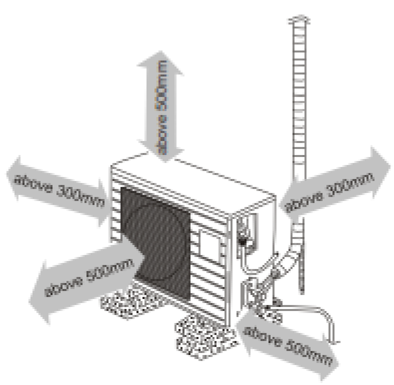
Caution:

It is harmful to the air conditioner if it is used in the following environments: greasy areas (including area near machines). Salty area such as coastal areas, areas where sulfuric gas is present such as hot spring areas. Contact your dealer for advice.

INSTALLATION

Installation diagram of indoor unit and outdoor unit





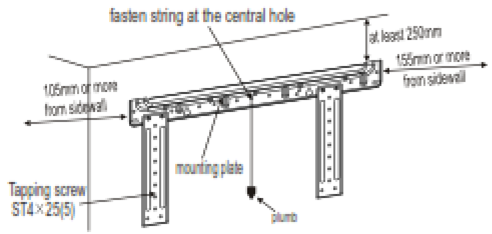
INSTALLATION

1 Securing the mounting plate and drill on the wall

Note: Different models have different mounting plates, the installing charts of this book are presented just for the purpose of illustration, please take the real objects as reference.

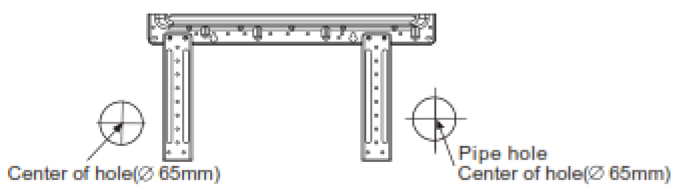
- **Secure the mounting plate**

The mounting plate should be attached to the structural part of wall (post etc).



NOTICE:
- The holes at solid arrow position must be secured to avoid the shake of mounting plate.
- When the expansion bolts are used, two holes (11×20 or 11×26) that the distance between them is 450mm should be adopted.

- **Drill on the wall**



Operation:

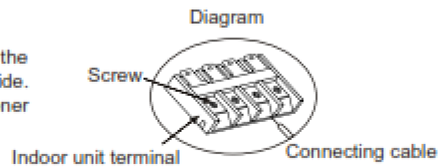
1.Confirm the position of the wall hole according to the chart (If it need to orientat a hole on the left side of the mounting plate, please refer to the method of orientating the right wall hole in the above chart).

2.Use the aiguille to drill a hole with a diameter of 65mm .

INSTALLATION

2 Wiring

- Open the front grille;
- Remove the screw from electrical box cover, pull the electrical box cover away from the unit and set aside.
- Remove the screw from fastener, pull the fastener away from the unit and set aside.
- Connect the cable.
- Replace the fastener and electrical box cover.



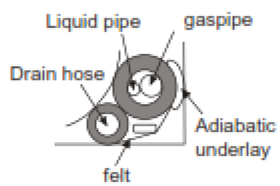
NOTE:

The appliance shall be installed in accordance with national wiring regulations.
The appliance must not be installed in the laundry.
The appliance must be installed 2.3m above the floor.
The appliance must be positioned so that the plug is accessible.
For some models whose cooling capacity are above 4600W (17000BTU/h), an all-pole disconnection device which has at least 3mm separation distance in all pole and a residual current device(RCD)with the rating of above 10mA shall be incorporated in the fixed wiring according to the national rule.

3 Installation of the drain hose

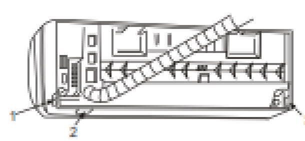
■ NOTE:

- The drain hose must be arranged beneath the copper pipe.
- The drain hose must not be hunched or twisted.
- While wrapping up the drain hose, do not pull it.
- The drain hose through the room must be wrapped up by the thermal insulation materials.
- The copper pipe and the drain hose must be wrapped up by felt strip. Adiabatic pad should be used at where the pipe contacts the wall.



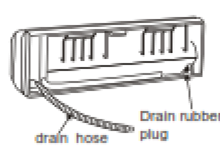
■ ROUTE OF PIPE

- If pipe comes out of the right side of the indoor unit, cut part "1" of the unit;
- If pipe comes out of the lower-right side of the indoor unit, cut part "2" of the unit;
- If pipe comes out of the left side of the indoor unit, cut part "3" of the unit.



■ REFIT OF DRAIN HOSE

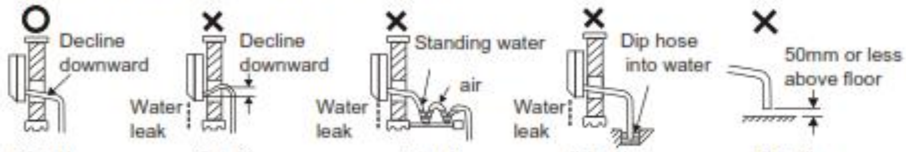
- If pipe comes out of the left side of the indoor unit, the drain hose must be refitted, otherwise water leakage may occur.
- Refit methods: Interchange the position of drain hose and drain rubber plug.
- Clearance is not allowed after refit, it would lead to water leakage.



INSTALLATION

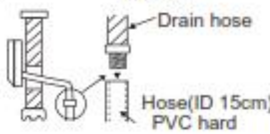
■ Arrangement of the drain hose

- To drain the condensate water easily, the drain hose should be declined downwards.
  The following 5 arrangement methods are incorrect.



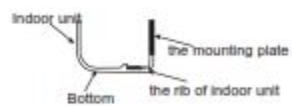
(Fig. 1) (Fig. 2) (Fig. 3) (Fig. 4) (Fig. 5)

- If you find the drain hose not long enough to connect with the indoor unit, you can extend it with the hoses in the accessory box.
- The drain hose through the room must be wrapped up with the special adiabatic material.



4 Installation of the indoor unit

Let pipe go through the wall hole and attach the indoor unit to the mounting plate.(Press the rib of indoor unit inside the hook of the mounting plate.)



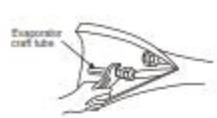
5 Pipe Connection

- The number of bent position of the pipe in the indoor unit should not exceed 10.
- The number of bent position of the pipe in the indoor unit and the outdoor unit should not exceed 15.
- The radius of bent position should be more than 10cm.
- Please break the evaporator craft tube with pincers before connecting. After exhausting the inside air, use the wrench to twist down the nut of connecting tube of the evaporator.
- Put some seal oil to cover the joint and the flare.
- Align the centre of joint in line with that of flare and tighten the nut of connecting pipe with wrench.

Attention:

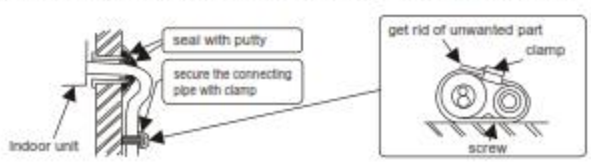
Do not exhaust the inside air just by loosing the nut since there is the air of certain pressure inside the tube of indoor unit. Please do not make extra effort for fear of damaging the flare.

DIAMETER OF PIPE	TORQUE(N • m)
6.35mm (1/4")	13.7---17.6
9.52mm (3/8")	34.3---41.2
12.7mm (1/2")	49.0---56.4
15.88mm (5/8")	73.0---78.0



6 Wall sealing and Pipe fastening

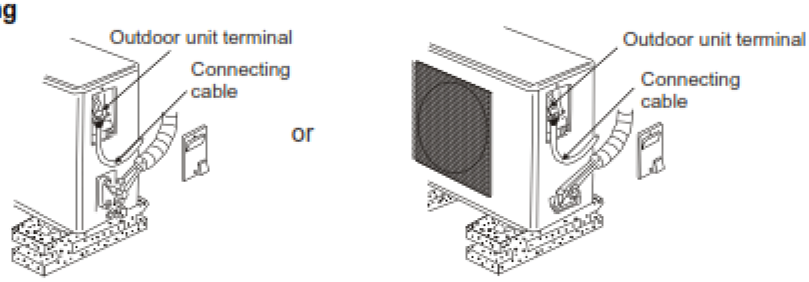
- Use putty to seal the wall hole.
- Use clamp (pipe fastener) to secure the pipe at specified position.



INSTALLATION

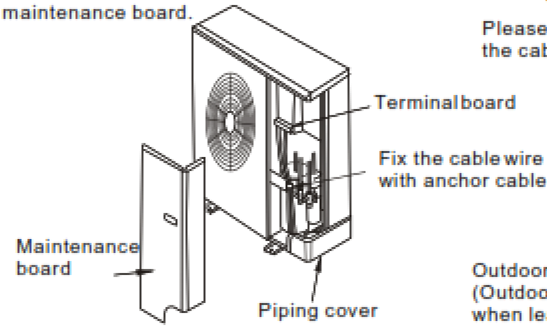
Installation diagram of indoor unit and outdoor unit

1 Wiring



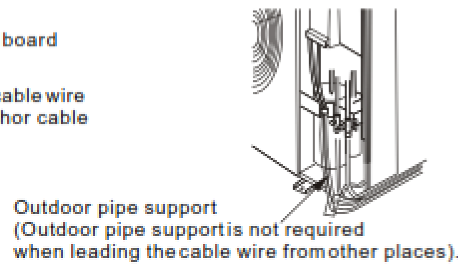
Wiring For Above 6000W Model (Above 21000BTU/h Model)

1 Remove the self-tapping screws (2 pcs) on the maintenance board and take out the maintenance board.



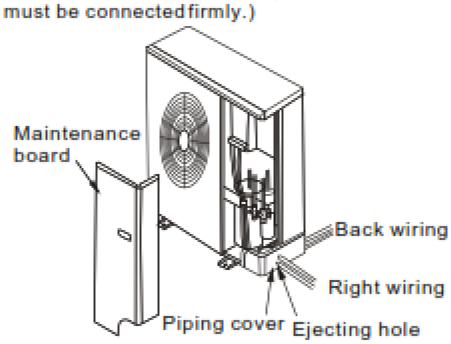
The cable wire can be led from the back hole of the piping hole or ejecting hole.

Please utilize outdoor pipe support when the cable wire is led from the backside.



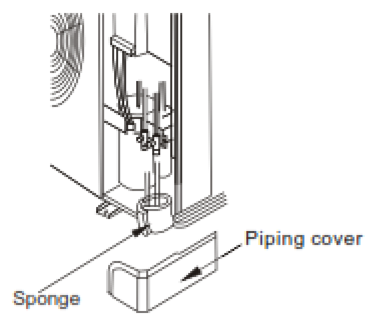
2 Loosen the self-tapping screws (2 pcs) on the fixing clip to loosen the fixing clip.

3 Loosen the fixing screw of the wire terminal board, pass the power wire and signal wire through the fixing clip. Then firmly fix the power wire and signal wire on the terminal board with the fixing screw. (Earth wire must be connected firmly.)



4 Tighten the self-tapping screw on the fixing clip.

5 Install the maintenance board. After the pipes and cable wire are installed, please seal the sponge block as per drawing indication.



INSTALLATION

Notice:

- If the signal wire has to be bought separately, choose electric wire above 0.75mm^2.
- If the interconnection cord for power supply has to be replaced, please see the following table for reference.

MODEL	SPECS (Interconnection cord)
≤2700W(10000BTU/h)	≥1.0mm^2
3000W(11000BTU/h)-4000W(15000BTU/h)	≥1.5mm^2
4500W(18000BTU/h) -8000W(28000BTU/h)	≥2.5mm^2

WARNING:

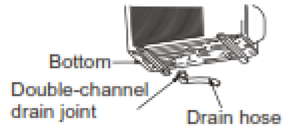
- **Please take the electric circuit diagram attached to the indoor/outdoor units as major reference while installing.**
- **The power wire and signal wire between the indoor/outdoor units must be connected one by one as per corresponding number on the wiring terminal board.**
- **The connecting cables must be clipped together.**
- **Special cable must be used to connect indoor unit and outdoor unit. It should be ensured that the terminals are not influenced by external force. Poor connection may cause fire.**
- **The electric box cover must be mounted and secured in position, otherwise fire or electrical shock may occur because of dust or moisture.**
- **The temperature of refrigerant circuit will be high, please keep the interconnection cable away from the copper tube.**
- **All the models shall be connected with the mains which has system impedance limitations. While installing the unit, please see the following table for impedance information or consult with the supply authority.**

R410A series	3500W (12000BTU/h)	≤0.219Ω
	5100W (18000BTU/h)	≤0.186Ω
	6800W (18000BTU/h)	≤0.124Ω

INSTALLATION

2 Installation of the drain joint(only for heat pump type)

- Insert the outdoor double-channel drain joint in one of the bottom holes of the suitable size then connect drain hose and joint together.

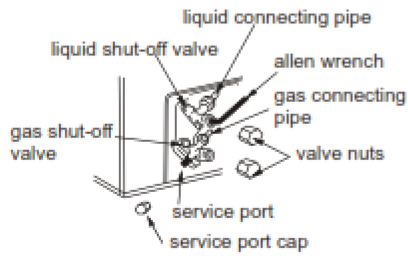


3 Joint of the connecting pipe

- Put some seal oil to cover the joint and the flare.
- Align the centre of joint in line with that of flare and tighten the nut of connecting pipe with wrench. (Adjust the torque by the same method of connecting pipe for indoor unit.)

4 Air exhausting

- Screw down the cap of both gas shut-off valve and liquid shut-off valve as well as the nut of service port.
- Use Allen wrench to turn the valve cork of liquid side at 90° counter-clockwise, and close it after 10 seconds. Use soapy water to check the gas leakage especially at all joint. If there is no gas leakage, please turn the valve cork of liquid side at 90° counter-clockwise again.
- Press the cork of service port at gas shut-off valve, 10 seconds later, when you see foggy gas discharged, that means inner air is exhausted out.
- Use Allen wrench to turn the valve cork of both liquid shut-off valve and gas shut-off valve counter-clockwise until they are completely open and then replace the valve caps and tighten them.

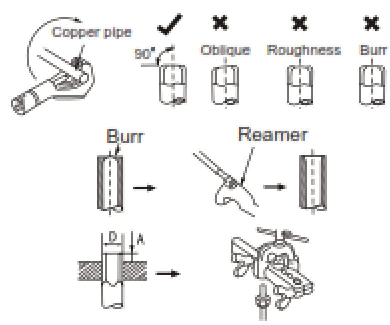


5 Process of flared tube

- Use the pipe cutter to cut off the broken part of flare.
- Remove burrs at the cut of the flare.
- Insert a nut into the connecting pipe and do flaring with specified flaring tools, reamers for example.

Remove burrs at the cut of the flare.

Outer diameter	A(mm)
6.35mm (1/4")	2.0--2.5
9.52mm (3/8")	3.0--3.5
12.7mm (1/2")	3.5--4.0
15.88mm(5/8")	4.0--4.5



- Check the quality of flaring technique.

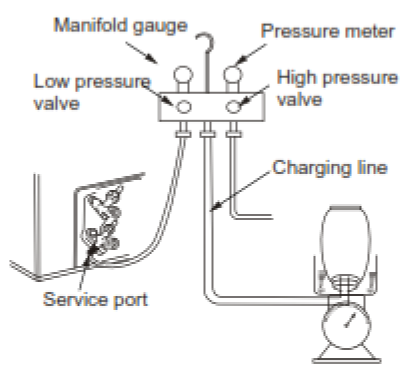
INSTALLATION

6 Adding refrigerant

- If the connecting pipe is longer than 7 metres, add refrigerant as needed. (Cool only type) added amount A=(Lm-7m)×15g/m ; (Heat pump type)added amount A= (Lm-7m) ×50g/m. (A: amount of added refrigerant, L: the length of connecting pipe)

The length of connecting pipe (m)	7	8	9	10
(Cool only type)added amount (g)	0	15	30	45
(Heat pump type)added amount (g)	0	50	100	150

- Exhaust the air as the above-mentioned method.
- Screw the gas shut-off valve to close, connect charging hose(low pressure) to the service valve and then open gas shut-off valve again.
- Set the unit to cool operation mode.
- Connect the refrigerant bottle to the charging hose and then convert it.
- Fill in liquid refrigerant as the above table.
- Stop operation of the air conditioner.
- Disconnect the manifold gauge after turning off the shut-off valve, and then open gas shut-off valve again.
- Tighten nuts and caps of each valve.



7 Relocation of the air conditioner.

- Refer to this procedure when the unit is relocated.

1. Carry out the pump down procedure.
2. Remove the power cord.
3. Disconnect the assembly cable from the indoor and outdoor units.
4. Remove the flare nut connecting the indoor unit and the pipe.
   At this time, cover the pipe of the indoor unit and the other pipe using a cap or vinyl plug to avoid foreign material entering.
5. Disconnect the pipe connected to the outdoor unit.
6. Make sure you do not bend the connection pipes in the middle and store together with the cables.
7. Move the indoor and outdoor units to a new location.
8. Remove the mounting plate for the indoor unit and move it to a new location.

INSTALLATION

8 Operation test

- Before test operation, wiring safety inspection must be carried out carefully again.

1. Emergency switch operation: Every press of emergency switch, the air conditioner runs as in the following order:

   Cool only type: Cool → Shut off

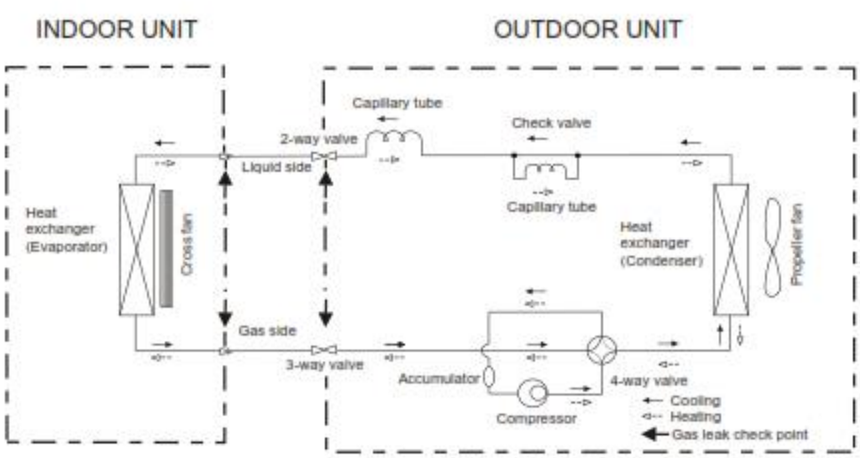
   Heat pump type: Cool → Heat → Shut off

2. Remote controller operation: If the indoor unit sounds like Di, Di when pressing I/O button, that indicates the air conditioner is under the operation of remote controller. After that, press every button to test their functions.

3. Check switch operation: Open the front grille and press the check button. Switch on the power source and then the operation test is activated. If the indicator lamps light up at first and then go out in succession or the LED window of the indoor unit illuminates at first and then goes out, the system is under normal operation. If one of the indicator lamps is flashing at all times, or failure codes are displayed on the LED window of the indoor unit, the system has something wrong and please check malfunction immediately.

BLOCK DIAGRAM

Refrigerant Cycle Block Diagram



TROUBLE SHOOTING

Items to be checked first

1. Is the voltage of the power correct?
   The input voltage shall be rating voltage ±10%.
   The air conditioner may not operate properly if the voltage is out of this range.
2. Is the link cable connecting the indoor unit and the outdoor unit linked properly?
   Please refer to the "wiring diagram"
   Check the terminals if the indoor unit and outdoor unit are properly linked by the same number of cables.
3. When a problem occurs due to the contents illustrated in the table below, it is symptom not related to the malfunction of the air conditioner.

Operation of air conditioner	Explanation
In COOL operation mode, the compressor does not operate at a room temperature higher than the setting temperature that the indoor fan should operate. In a HEAT operation mode, the compressor does not operate at a room temperature lower than the setting temperature that indoor fan should operate.	It happens after a delay of 3 minutes when the compressor is reoperated. The same phenomenon occurs when a power is on. As a phenomenon that the compressor is reoperated after a delay of 3 minutes, the indoor fan is adjusted automatically with reference to a temperature of the air blow.
Fan speed setting is not allowed in AUTO or DRY mode.	The speed of the indoor fan is set to low in DRY mode. Fan speed of 3 steps is selected automatically in AUTO mode.
Compressor stops operation intermittently in DRY mode.	Compressor operation is automatically controlled in DRY mode depending on the room temperature and humidity.
Compressor of the outdoor unit is operating although it is turned off in HEAT mode.	When the unit is turned off while de-ice is activated, the compressor continues operation for up to 10 minutes(maximum) until the deice is completed.
Timer indicator lamp lights up and the air conditioner does not operate.	Timer is being activated and the unit is in ready mode. The unit operates normally if the timer operation is cancelled.
The compressor and indoor fan stop intermittently in HEAT mode.	The compressor and indoor fan stop intermittently if room temperature exceeds a setting temperature in order to protect the compressor from overheated air in HEAT mode.
Indoor fan and outdoor fan stop intermittently in HEAT mode.	The compressor operates in a reverse cycle to remove exterior ice in HEAT mode, and indoor fan and outdoor fan do not operate intermittently for within 20% of the total heat operation.
The compressor stops intermittently in COOL mode or DRY mode, and fan speed of the indoor unit decreases.	The compressor stops intermittently or the fan speed of the indoor unit decreases to prevent inside/outside air frozen depending on the inside/outside air temperature.

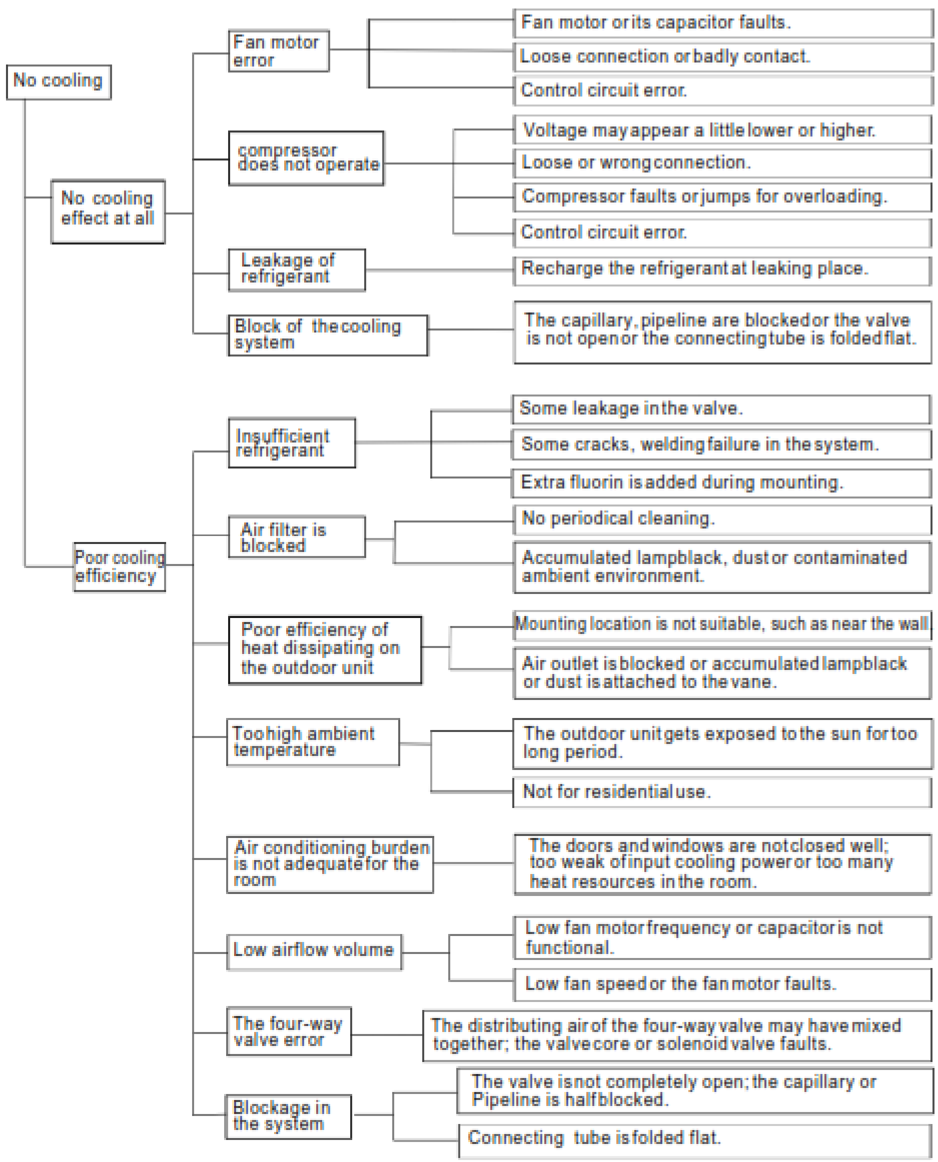
SELF DIAGNOSIS FUNCTION

Our company provides the end-users with thoughtful services by installing various diagnostic systems to indicate the following irregular performances.

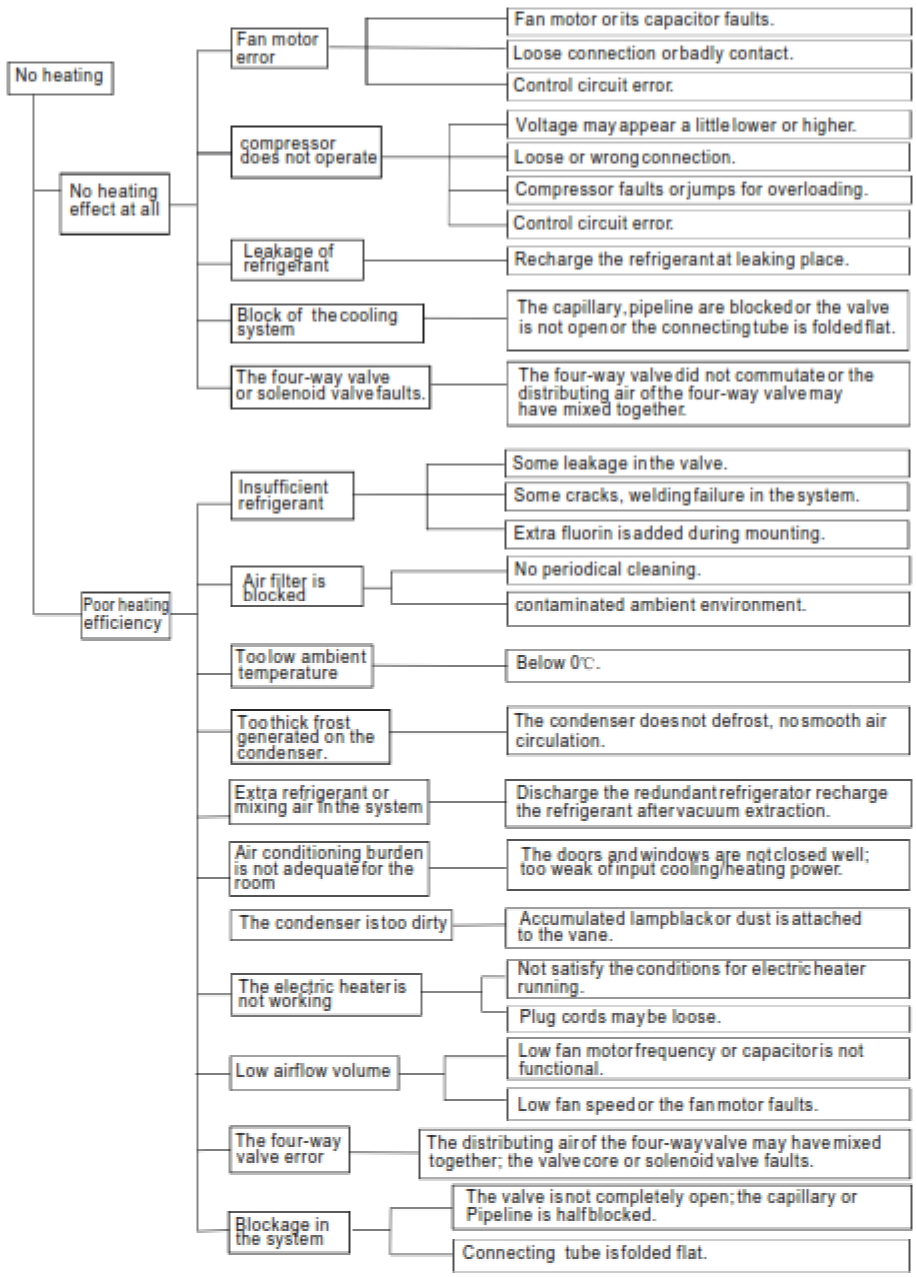
Check code	Diagnosis of malfunction
FAULT F6	PG motor faults
FAULT F7	Indoor TEMP sensor faults
FAULT F8	Indoor coil pipe TEMP sensor faults
FAULT F9	Outdoor coil pipe TEMP sensor faults

RUN indicator lamp	SLEEP indicator lamp	TIMER indicator lamp	Diagnosis of malfunction
☆	☆	☆	Indoor coil pipe TEMP sensor faults
☆	☆	●	Indoor TEMP sensor faults
☆	☆	○	Outdoor coil pipe TEMP sensor faults
☆	●	☆	PG motor faults
Remark: ● lamp ON	○ lamp OFF	☆ lamp FLASH	

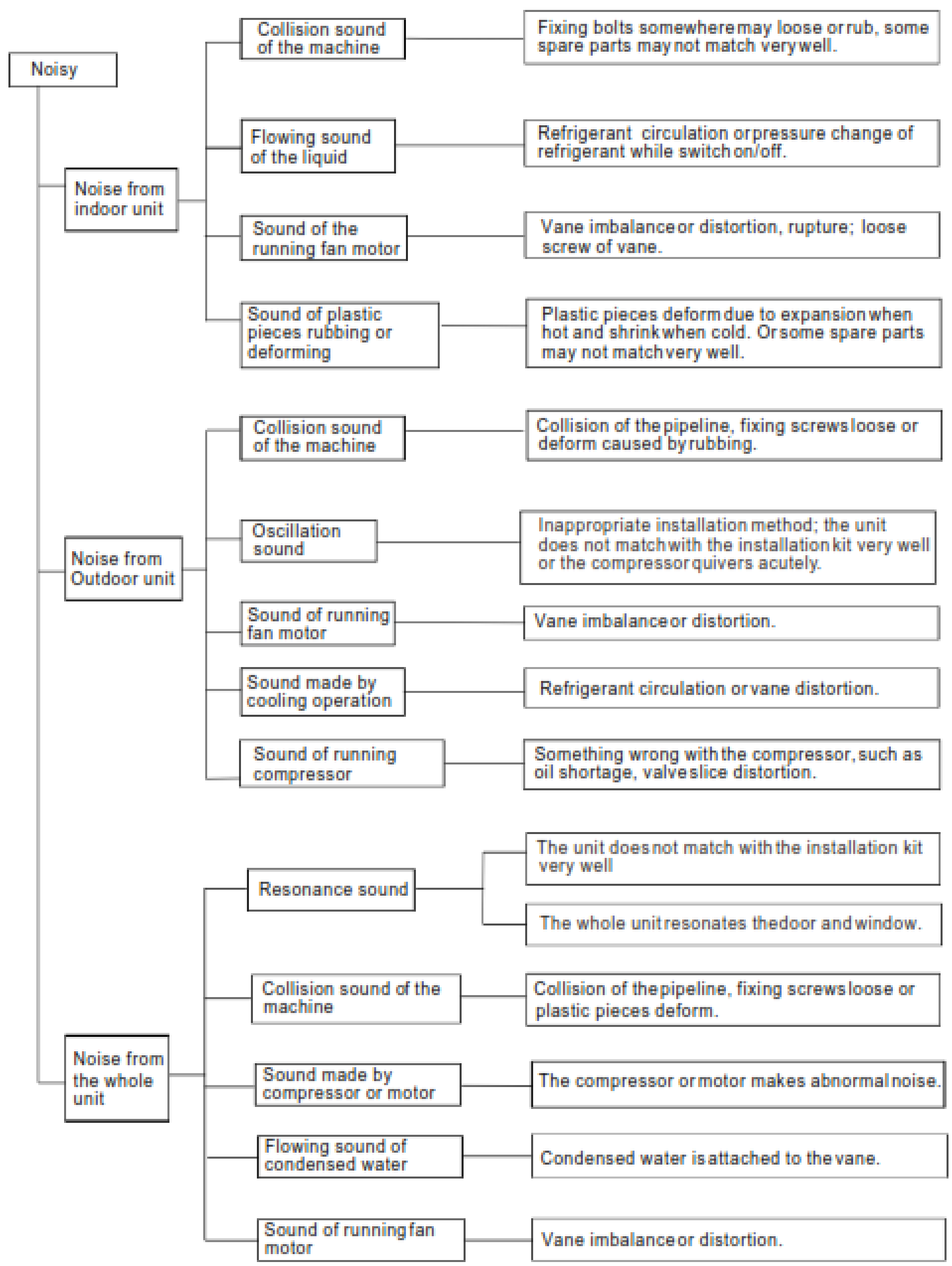
FAULT DIAGNOSIS BY SYMPTOM



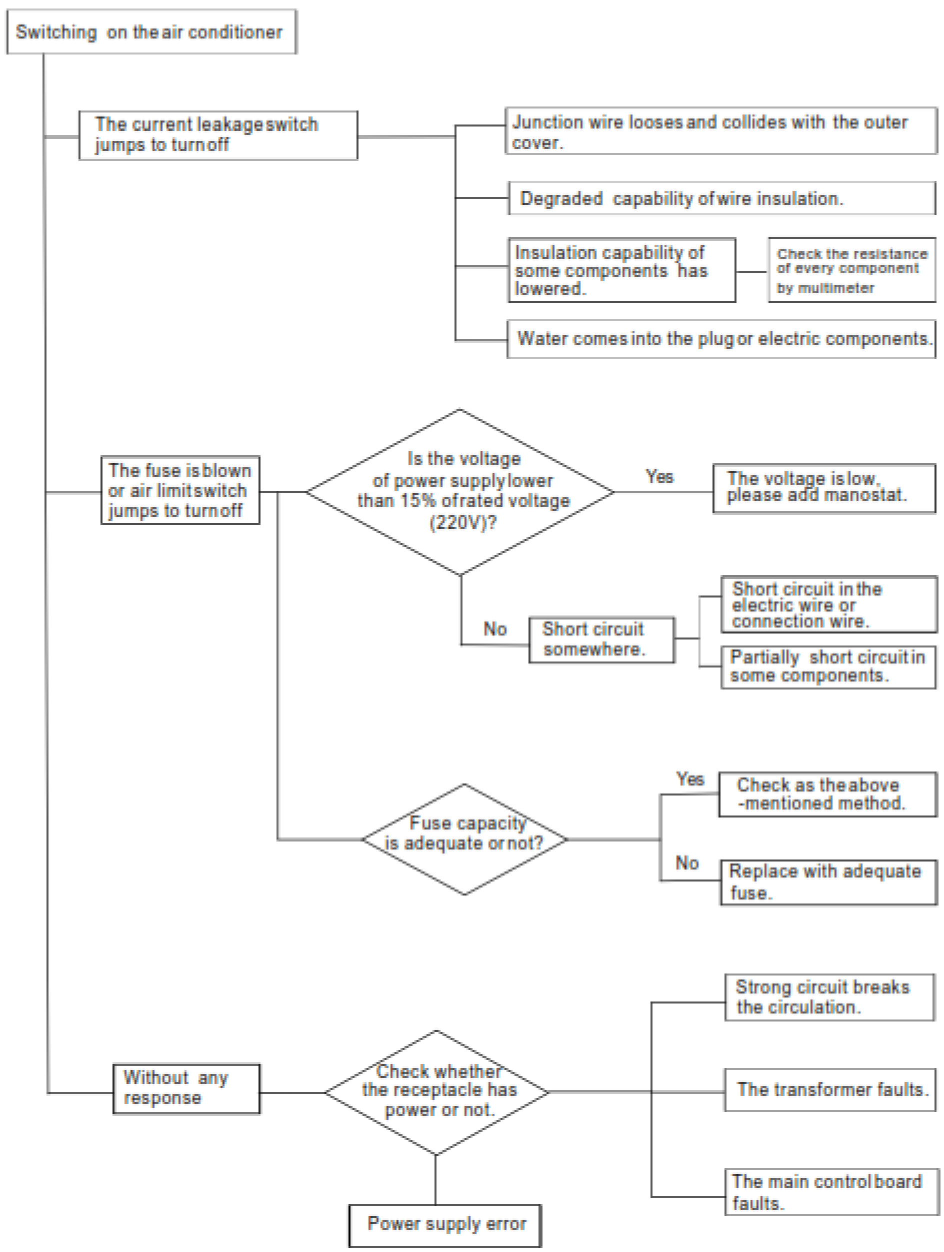
FAULT DIAGNOSIS BY SYMPTOM



FAULT DIAGNOSIS BY SYMPTOM



FAULT DIAGNOSIS BY SYMPTOM



CONTROL SPECIFICATION

1 ABBREVIATION

ST: Setting Temperature
PT: Indoor coil Pipe Temperature
RT: Room Temperature
OT: Outdoor coil pipe temperature
OFAN: Outdoor fan
IFAN: Indoor fan
COMP: Compressor

2 OPERATION OF MAIN BOARD

COOL MODE

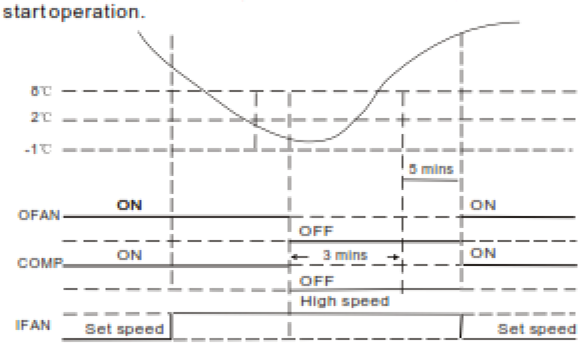
- The ST at cool mode is adjustable within 16℃-31℃.
- When RT≥ST, both the compressor and the outdoor fan start;
  When RT<ST-1℃, the compressor stops and 18 seconds later, the outdoor fan will stop.
  But the indoor fan keeps running at predetermined speed.
- Once turning on the unit while set at cool mode, the indoor fan immediately runs at predetermined speed; if all the conditions meet with the requirement of compressor operation, both the outdoor fan and compressor start running. If not, either the outdoor fan or compressor could start.
- The four-way valve keeps being off all the time at cool mode.

Condensate dew prevention

If the horizontal air flow louver is set at low angle on COOL mode, after a while, it will auto swing to its maximum angel for system protection. 3 minutes later, the horizontal air flow louver will resume to its original position.

Anti-ice function

- When PT=2℃, the compressor does not stop and indoor fan runs at high speed.
- When PT≤-1℃ for 1 minute, the compressor and outdoor fan stop and indoor fan runs at high speed.
- When PT≥8℃ for 5 minutes, anti-ice protection deactivates, both the compressor and the outdoor fan start operation.



CONTROL SPECIFICATION

HEAT MODE

- If the airconditioner is off and then turned on while set at COOL, HEAT or DRY mode, it will take approximately 3 minutes for the compressor to start.
- The ST at heat mode is adjustable within 16℃-31℃.
- When RT≥ST, the compressor stops; when RT<ST-1℃, the compressor starts.
- Once turning on the unit while set at heat mode, if all the conditions meet with the requirement of compressor operation, the four-way valve gets charged and 8 seconds later, the compressor and outdoor fan start running.

Strong-wing prevention :

- A.PT<27, the indoor fan stops running, the swing louver cannot be controlled by the remote controller.
  B.34>PT≥27, the indoor fan runs at low speed, the sweep louver erects.
  C.PT≥34, the indoor fan and the swing louver can be controlled normally.

Heat overload protection:

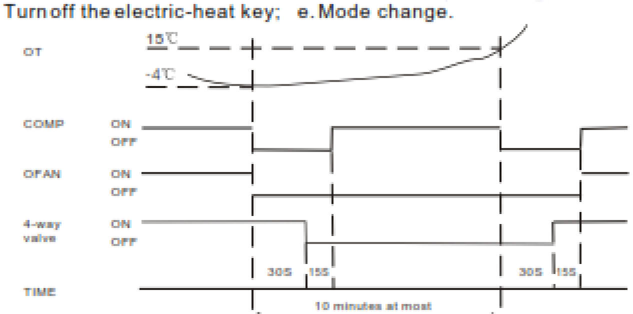
- For 7000BTU/h Model, when PT≥47℃, the outdoor fan stops; when PT≤42℃, the outdoor fan starts; when PT≥60℃, the compressor stops.
- For 9000BTU/h Model, when PT≥50℃, the outdoor fan stops; when PT≤47℃, the outdoor fan starts; when PT≥63℃, the compressor stops.
- For ≥9000BTU/h Model, when PT≥55℃, the outdoor fan stops; when Pt≤50℃, the outdoor fan starts; when PT≥63℃, the compressor stops.

Deice control:

- Conditions for activating deice:
  a. The working hours of compressor accumulates to be 40 minutes.
  b. When OT≤-4℃ for 1 minute.
- Conditions for terminating deice:
  a. When OT≥15℃ for 1 minute.
  b. Over 10 minutes of deicing operation.

Electric-heat control:

- Conditions for initiating electric-heat function:
  a. RT≤23℃; b. RT+3℃≤ST; c. The indoor fan runs;
  d. Turn on the electric-heat key; e. PT<50℃
- Conditions for terminating electric-heat function:
  a. PT≥50℃; b. RT≥26℃; c. The indoor fan stops running;
  d. Turn off the electric-heat key; e. Mode change.
- Conditions for terminating electric-heat function:
  a. PT≥50℃; b. RT≥26℃; c. The indoor fan stops running;
  d. Turn off the electric-heat key; e. Mode change.



CONTROL SPECIFICATION

DRY MODE

- In this mode, the air conditioner automatically sets the room temperature and this temperature is incontrollable by remote controller. The initial ST =RT-2℃.
- Control during dry mode:
  a. When RT<15℃, dry mode is not available; when RT≥15℃, the compressor intermittently runs under the influence of TS and RT.

  b. When RT≥23℃, if RT≥ST, the compressor runs intermittently as this:
  Run for 8 minutes → Stop for 3 minutes

  If RT<ST, the compressor runs intermittently as this:
  Stop for 4 minutes → Run for 1 minute

  c. When RT<23℃, if RT≥ST, the compressor runs intermittently as this:
  Run for 2 minutes → Stop for 3 minutes

  If RT<ST, the compressor runs intermittently as this:
  Stop for 4 minutes → Run for 1 minute

  d. In this mode, the indoor fan keeps running at low speed with the same pace as the compressor, and this speed can not be controlled by remote controller.

AUTO MODE

- In this mode, the air conditioner can automatically adjust the room temperature to decide the most suitable temperature. At the start of operation, the unit will automatically select the operation mode according to the room temperature. The following table shows the conditions which are set at start up.

Room Temperature (RT)	Cool only type		Heat pump type	
	Mode	Initial Setting Temperature	Mode	Initial Setting Temperature
RT≥26℃	Cool	24℃	Cool	24℃
26℃>RT≥25℃		RT-2		RT-2
25℃>RT≥23℃	Dry	RT-2	Dry	RT-2
RT<23℃		21℃	Heat	26℃

- Auto mode entering
  a. Once some operation mode is determined, it can not be changed even if the RT has altered.
  b. You can change the operation mode by remote controller.
- If restart within 2 hours, the unit will resume the same operation mode as before.
  If restart after 2 hours, the unit will select the operation mode according to the initial room temperature.
- At auto mode the ST can only be set + or - 2 ℃ of the RT.

CONTROL SPECIFICATION

■ FAN MODE

In this mode, the outdoor unit does not operate. The indoor fan alone operates.

Press UP & DOWN SWING button or LEFT & RIGHT SWING button to change air flow direction.

Press FAN SPEED button to change the fan speed of indoor unit.

■ LIGHT-WAVE MODE (only applied to light-wave series)

Every press of LIGHT-WAVE button, the air conditioner will cycle in the order of enter/quit light-wave mode. Once entering the light-wave mode, the light-wave icon will light up on display panel of the indoor unit and the air conditioner will judge whether to connect the light-wave tube by ambient temperature.

■ TURBO function (only applied to turbo series)

This function will make the air conditioner heat or cool quickly and during this period, the noise of the air conditioner will increase. Turbo function can be only started up in heat or cool mode(turbo heating or turbo cooling) otherwise, it can not be started up. When the air conditioner is in cool or heat mode, press turbo button to initiate turbo function, the remote controller displays "TURBO" and the icon of fan speed is "≝" ,meanwhile the air conditioner cannot be controlled by the remote controller. Press turbo button again or start up sleep mode or transit modes to exit turbo function. After exiting turbo function the fan runs at low speed.

■ FRESH AIR function (only applied to fresh air series)

When the air conditioner is on, press fresh air button to initiate or stop fresh air function. While this function is initiated the remote controller displays " FRESH AIR" ,meanwhile the fan starts to run, the letter " FRESH AIR" extinguishes and the fan stops if fresh air function stops.

■ CLEAN function (only applied to clean series)

When the air conditioner is on, press CLEAN/PLASMA button for 3 seconds to initiate or stop clean function. While this function is initiated the remote controller displays "CLEAN" and it will extinguish if clean function stops. Please note that after clean function starts up, the evaporator will only clean automatically on the condition that the air conditioner is turned off normally.Moreover, after the evaporator is checked dirty by the system, the LED of indoor unit will display "CLEAN" to remind you of starting up the clean function.

■ AIR QUALITY CHECKING function (only applied to air quality checking series)

When the air conditioner is on, air quality checking function starts up automatically, at the same time the air quality indicator light on the indoor unit will flash once, which shows that the air conditioner starts up air quality checking function. After the air quality checking function is initiated, if the air quality is good the indicator light extinguishes; if the air quality is bad the indicator light will flash 5 times then lighten. Air quality is showed through the lighteness of the indicator light, the lighter the indicator the worse the air quality. When the indicator light is lighten, fresh air function is supposed to be started up. After the air is renewed, the system will stop or continue fresh air function according to the air quality. You can also stop fresh air function as you like. When the air conditioner is turned off, the indicator light will flash once to show the air quality checking function is in gear. And every time starting up inoizer, aux-heat, light-wave, plasma,clean and turbo function the indicator light will flash once.

CONTROL SPECIFICATION

■ SLEEP mode

Normal sleep

When the air conditioner is in cooling and dry mode, the indoor fan runs at low speed After one hour of operation the set temperature will increase by 1℃.One hour later, the set temperature will increase by 1℃ once more. The unit will then continue operating at 2℃ above the set temperature.

When the air conditioner is in heating mode , the indoor fan runs at low speed. After one hour of operation the set temperature will decrease by 2℃. One hour later, the set temperature will decrease by 2℃ once more. The unit will then continue operating at 4℃ below the set temperature.

Sleep mode 1 1

When the air conditioner is in cooling and dry mode and 23℃≥st≥16℃,during the 3 hours after sleep mode 1 start up ,the set temperature will increase by 1℃ every hour .The unit will continue operating at 3℃ above the set temperature. 8 hours later, the set temperature will decrease 2℃.The unit will then continue operating at this temperature.

When 24℃≥st≥27℃, during the 2 hours after sleep mode 1 start up, the set temperature will increase by 1℃ every hour .The unit will continue operating at 2℃ above the set temperature.8 hours later, the set temperature will decrease 2℃,the unit will continue operating at this temperature.

When 28℃≥st≥31℃,the unit will operate at the set temperature all along.

When the air conditioner is in heat mode and18℃≥st≥16℃, the unit will operate at the set temperature all along.

When 19℃≥st≥25℃, during the 2 hours after sleep mode 1 start up, the set temperature will decrease by 1℃ every hour. The unit will continue operating at 2℃ below the set temperature.8 hours later, the set temperature will increase 2℃, the unit will continue operating at this temperature .

When 26℃≥st≥31℃, during the 3 hours after sleep mode 1 start up, the set temperature will decrease by 1℃ every hour. The unit will continue operating at 3℃ below the set temperature.8 hours later, the set temperature will increase 2℃.The unit will then continue operating at this temperature.

Sleep mode 2 2

When the air conditioner is in cooling and dry mode and 23℃≥st≥16℃, during the 3 hours after sleep mode 2 start up ,the set temperature will increase by 1℃ every hour .The unit will continue operating at 3℃ above the set temperature.7 hours later, the set temperature will decrease 1℃. The unit will then continue operating at this temperature.

When 24℃≥st≥27℃, during the 2 hours after sleep mode 2 start up, the set temperature will increase by 1℃ every hour .The unit will continue operating at 2℃ above the set temperature.7 hours later, the set temperature will decrease 1℃,the unit will continue operating at this temperature .

When 28℃≥st≥31℃,the unit will operate at the set temperature all along.

When the air conditioner is in heat mode and18℃≥st≥16℃, the unit will operate at the set temperature all along.

When 19℃≥st≥25℃, during the 2 hours after sleep mode 2 start up ,the set temperature will decrease by 1℃ every hour .The unit will continue operating at 2℃ below the set temperature.7 hours later, the set temperature will increase 1℃, the unit will continue operating at this temperature .

When 26℃≥st≥31℃, during the 3 hours after sleep mode 2 start up, the set temperature will decrease by 1℃ every hour. The unit will continue operating at 3℃ below the set temperature. 7 hours later, the set temperature will increase 1℃.The unit will then continue operating at this temperature.

CONTROL SPECIFICATION

Sleep mode 3

When the air conditioner is in cooling and dry mode and 23℃≥st≥16℃ , during the 3 hours after sleep mode 3 start up, the set temperature will increase by 1℃ every hour .The unit will continue operating at 3℃ above the set temperature.

When 24℃≥st≥27℃, during the 2 hours after sleep mode 3 start up, the set temperature will increase by 1℃ every hour .The unit will continue operating at 2℃ above the set temperature.

When 28℃≥st≥31℃,the unit will operate at the set temperature all along.

When the air conditioner is in heat mode and18℃≥st≥16℃, the unit will operate at the set temperature all along.

When 19℃≥st≥25℃, during the 2 hours after sleep mode 3 start up ,the set temperature will decrease by 1℃ every hour. The unit will continue operating at 2℃ below the set temperature.

When 26℃≥st≥31℃,during the 3 hours after sleep mode 3start up, the set temperature will decrease by 1℃ every hour. The unit will continue operating at 3℃ below the set temperature.

■ PLASMA function (only applied to plasma series)

When the airconditioner is on, press CLEAN/PLASMA buttonto start or stop plasma function.

The LED ofthe remote controllerdisplays " " while it is initiated and extinguishes while it stops.

■ INOIZER function(only applied to inoizer series)

Press inoizer buttonto start or stop inoizer functionwhen the air conditioner is onor set timer.

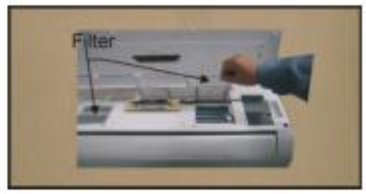
The LED ofthe remote controllerdisplays " "while it is initiated and extinguishes while it stops.

This function canonly be stoppedby pressing inoizerbutton or turningoff the air conditioner.

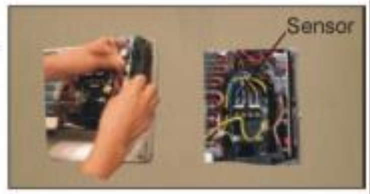
TO DISASSEMBLE MECHANICAL PARTS

Stop operation of the air conditioner and remove the power cord before repairing the unit.
The following pictures taking P1 as an example are presented just for the purpose of illustration.

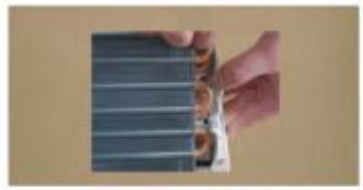
Indoor unit

No	Parts	Procedure	Remark
1	Front grille	1.Stop the air conditioner operation and block the main power. 2.Contract the second finger to the left ,and right handle and pull to open the inlet grille.	
		3.Draw away signal line.	
		4.Take the left and right filter out.	
		5. Loosen two fixing screw of front grille.	
		6.Put hands at the two ruts of the body, then pull the front panel out .	

TO DISASSEMBLE MECHANICAL PARTS

No	Parts	Procedure	Remark
2	Electrical parts	1.Loosen the earth screw in evaporator.	
		2.Loosen the stepping motor line, and pull softly the indoor pipe temperature sensor out from the pipe casing.	
		3.Push the hook outside to take the electrical box out easily.	
		4.Separate the electrical box from the indoor unit.	
3	Ass'y tray drain	1.Push the left and right hooks to make the ass'y pulled out.	

TO DISASSEMBLE MECHANICAL PARTS

No	Parts	Procedure	Remark
		2.Separete the ass'y tray drain from the body.	
4	Evaporator	1.Push the left hook and separate the left part out of evaporator.	
		2.Push the right hook and separate the right part out of evaporator.	
		3.Separate the evaporator from the indoor unit.	
5	Fan motor and cross fan	1.Separate the fan motor from the fan.	

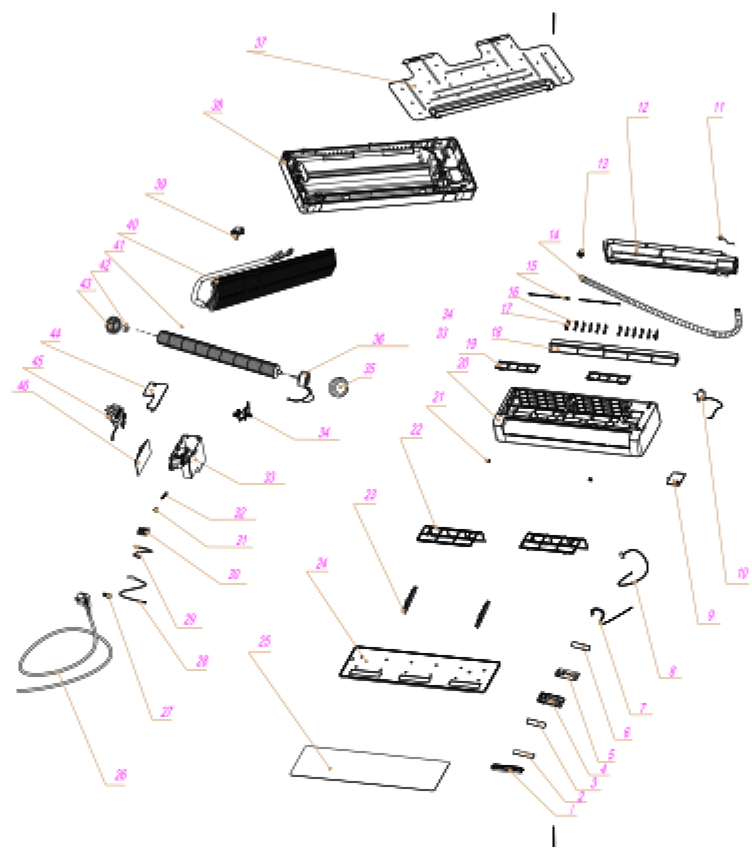
TO DISASSEMBLE MECHANICAL PARTS

Outdoor unit

No	Parts	Procedure	Remark
1	Cabinet	1.Turn off the unit and remove the power cable. 2.Remove the upper cabinet, the front cabinet and back cabinet.	
2	Fan motor & propeller fan	1.Remove the nut flange. (Turn to the right to remove as it a left turned screw) 2.separate the propeller fan from fan motor. 3.Loosen the fixed screw of fan motor,separate the fan motor from outdoor unit	 
3	Ass'y control out	1.Loosen the fixing screw of the base-electrical control . 2.separate the connector. 3.Separate the ass' y control out from the outdoor unit.	  

Exploded Views and Parts List

Indoor unit



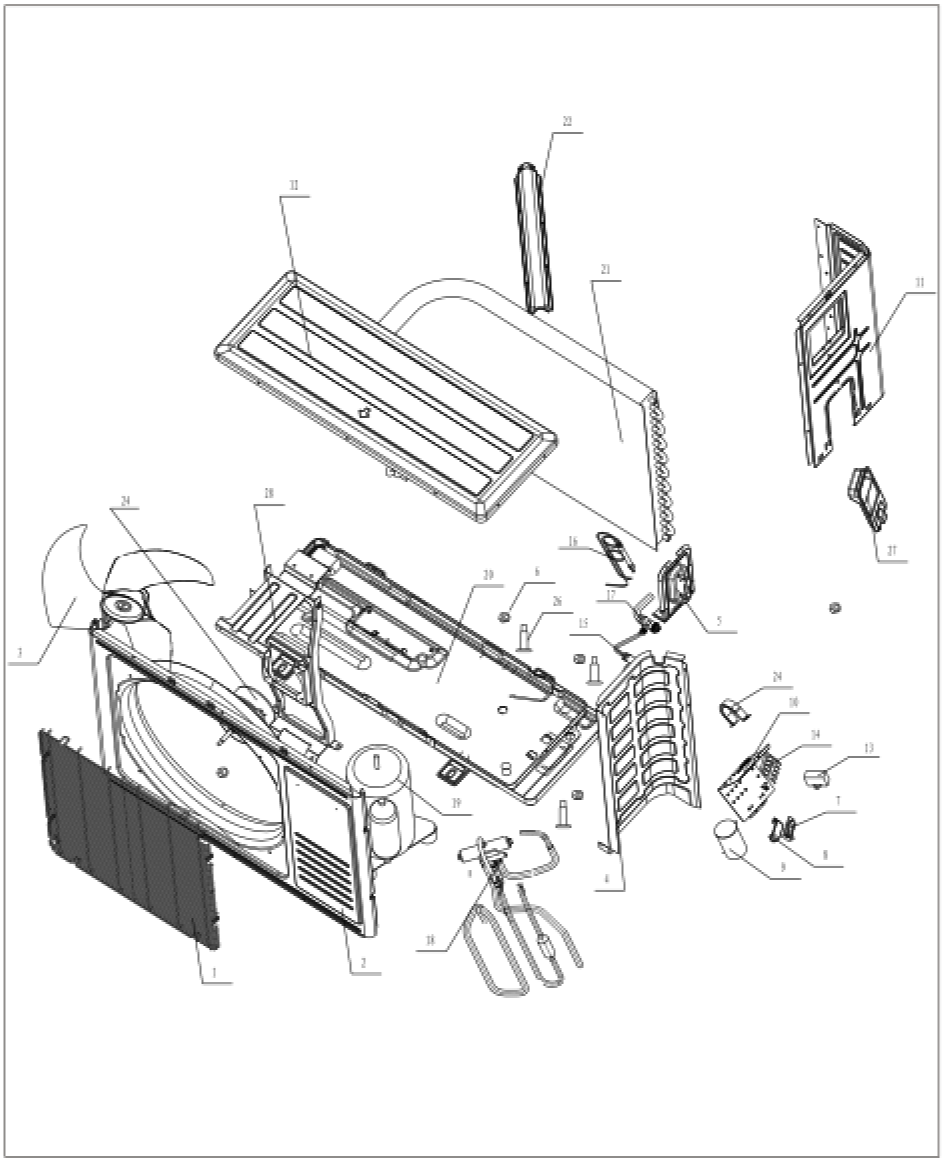
Exploded Views and Parts List

Indoor unit

No.	English Part Name	Quantity	No.	English Part Name	Quantity
1	Electrical control box with air sensitive display (optional)	1	28	Temperature sensor	1
2	Air sensitive display panel(optional)	1	29	Temperature sensor	1
3	Air sensitive display piece(optional)	1	30	Terminal block	1
4	Display electrical control box	1	31	Spring piece	2
5	LED	1	32	Grounded terminal	1
6	Display piece	1	33	Electrical control box for P1	1
7	Connecting wire for LED	1	34	Electrical supporter	1
8	Connecting wire	1	35	Rubber shock absorption base	1
9	Cover for front panel	1	36	Fan motor	1
10	Stepping motor	1	37	Mounting plate	1
11	Ionizer(optional)	1	38	Bottom enclosure	1
12	Water collecting tray for P1	1	39	Air sensitive detecting assembly(optional)	1
13	Drain cap	1	40	Evaporator	1
14	Drain hose	1	41	Indoor unit fan	1
15	Connecting pole	2	42	Oil bearing	1
16	Air leading vane	10	43	Rubber bear support	1
17	Air leading plectrum	2	44	Cover of electrical control box for P1	1
18	Swing louver for P1	1	45	Transformer	1
19	Air filter supporter	2	46	Main control board	1
20	P1 front panel	1			
21	Screw cover for B3	2			
22	Air filter	2			
23	Supporter for front panel	2			
24	Front panel for P series(optional)	1			
25	Decorating board for front panel of P series	1			
26	Power supply cord	1			
27	Power supply cord clip	1			

Exploded Views and Parts List

Outdoor unit MUP-09-HI AND MUP-12-HI



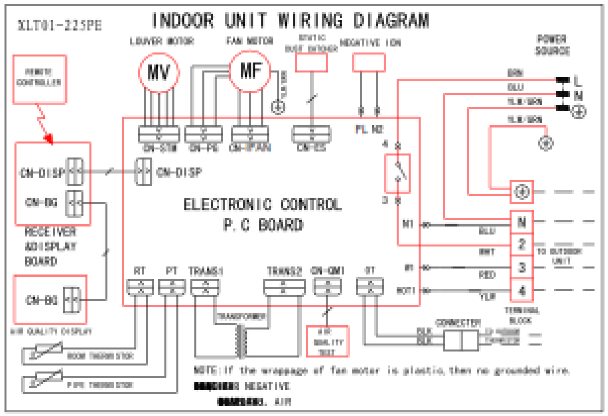
Exploded Views and Parts List

Outdoor unit MUP-09-HI AND MUP-12-HI

No.	English Part Name	Quantity	No.	English Part Name	Quantity
1	Air outlet grille	1	26	Right handle	1
2	Front panel	1	27	Outdoor fan motor supporter	1
3	Outdoor unit fan	1			
4	Partition	1			
5	Valve board	1			
6	Compressor screw	3			
7	Power supply cord fixs	1			
8	Power supply cord clip	1			
9	Capacitor for compressor	1			
10	Electrical install board	1			
11	Right side board	1			
12	Top cover	1			
13	fan motor capacitor	1			
14	Outdoor unit terminal block	1			
15	High pressure valve	1			
16	Capillary assembly	1			
17	Low pressure valve	1			
18	Four way valve	1			
19	Compressor	1			
20	Bottom board	1			
21	Condenser	1			
22	Uphold board	1			
23	Capacitor fixing clip	1			
24	Fan screw nut M6	1			
25	Fan screw nut M8	3			

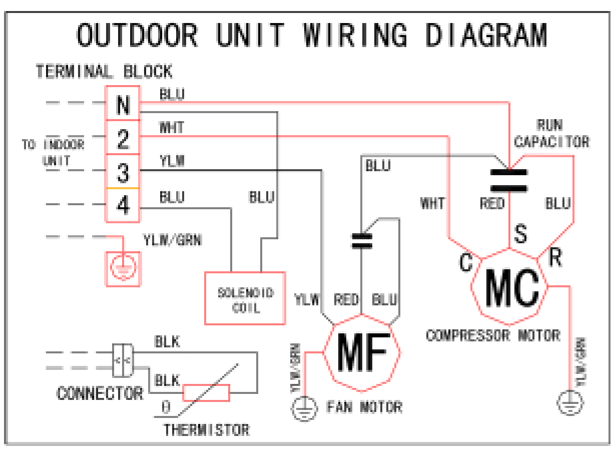
Wiring Diagrams

Indoor unit MUP-09-HI AND MUP-12-HI



Wiring Diagrams

Outdoor unit MUP-09-HI AND MUP-12-HI



ANNEX 2: SPLIT AC COMMISSIONING CHECKLIST & TEST SHEET

Company's name		Date
Address		Client's Name
Email/Tel:		Address
Make/Model/Capacity of Air Conditioning Unit		
Procedure for Comissioning:=		
A	items to be checked prior to comissioning	Remarks (Tick as appropriate)
	Indoor and outdoor units are insta1led properly on solld bases.	
	No refrigerant gas leaks.	
	Refregerant gas and liquid pipes and indoor drain hose extension are thermally insulated.	
	Draining line is properly installed.	
	System is properly earthed.	
	The specified wires are used for interconnecting wire connections.	
	Indoor and outdoor unit's air intake or exhaust has clear path of air.	
	Shut- off valves are opened.	
	Indoor unit properly receives remote control commands.	
B	Commissioning	
1	Measure the supply voltage and make sure that it falls in the specified range.	
2	Make sure the swing flap opens and closes smoothly when putting power to the unit.	
3	Check that all shut- off valves are open	
4	Trial operation should be carried out in either cooling or heating mode	
4a	In cooling mode,select the lowest programmable temperature; in heating mode	
4b	In heating mode select the highest programmable temperature	
5	Trial operation may be disable in either mode depending on the room temperature	
	Use the remote control trial operation as described below	
6	After trial operation is completed, set the temperature to a normal level(23℃ to 25 ℃ in heating mode).	
7	For protection,the system disables restart operation for 3 minutes after it is turned off.	
8	Carry out the test operation in accordance with the Operation in accordance with the operation manual to ensure that all functions and parts, such as louver movement, are working properly.	
9	The air conditioner requires a small amount of power in its standby mode. If the system is not used for some time after installation, shut off the circuit breaker to eliminate unecessary power consumption.	
10	If the circuit breaker trips to shut off the power to the air conditioner, the system will restore the original operation mode when the circuit breaker is restored again.	

Test Operation Data Sheet

	Indoor Unit	Outdoor Unit
Model		
Serial Number		

1. Items to be measured before power ON

Item		Criterea	Measurement
Insulation resistance	Power Supply terminal	1MΩ or more	MΩ
			MΩ

1. Items to be measured after power ON

Item		Criterea	Measurement	
Power Supply voltage	In none-operation	±10%	V	Voltage drop (calculated value)
			V	
	In operation	Voltage drop of less than 2%	V	V
			V	V

Indoor unit	Suction temperature		
	Discharge temperature		
	Temperature difference (Sucction temp. - discharge temp.)	15°C±3°C	
Outdoor unit	Suction temperature		
	Discharge temperature		
	Temperature difference (Sucction temp. - discharge temp.)	15°C±3°C	

This is to confirm that the above mentioned had been duly commissioned and the above reports reflects the status of the Air conditioning equipment at commissioning stage.

Company Name:

Technician name:

Signature:

ANNEX 3: SPLIT UNIT AC MAINTENANCE CHECKLIST & SCHEDULE

Maintenance

Introduction To ensure an optimal operation it is required to maintain the installation on a regular base by a skilled AC technician.

List of all critical items which should be checked in basic installation maintenance.

Maintenance to the indoor unit

Step	Item	Frequency
1	Cleaning the air filter	Once every 3 months
2	Cleaning the heat-exchanger The cleaning can be done with a mixture of water and neutral soap	Only required if heat-exchanger is dirty
3	Check the functioning of the thermostat	Once a year
4	Measure the suction and discharge air of the indoor unit and compare with previous measuring data.	Once a year
5	Check if the drain piping is not blocked	Once a year
6	Check if the electrical connections on the terminal are all still tight. Check if all other connections on the PCB are still OK	Once a year

Maintenance to outdoor unit

Step	Item	Frequency
1	Cleaning of the heat exchanger. The cleaning should be done with low-pressure fresh tap water.	Once every 4 months

2	Removing the corrosion from the casing. Before adding new paint, all the corrosion should be removed with a steel brush or rough sandpaper.	Once a year

Maintenance to outdoor unit (continued)

3	Removing the corrosion from the fan-motor. Same remark as for step 2	Once a year
4	Check the condition of the screws. All rusted screws should be replaced	Once a year
5	Remove all the dust from the PCB boards. PCB boards, which have indication of corrosion, should be cleaned and protected with a layer. The cleaning liquid and protection layer, which is currently used, can be used in the future.	3 times a year
6	Check if the electrical connections on the terminal are all still tight. Check if all other connections on the PCB are still OK	Once a year

General items

Step	Item	Frequency
1	Repair or replace the interconnection insulation if required	Once a year
2	Check for oil traces at the flair connections. This is an indication for possible leaks	Once a year
3	Measure the high and low pressure and compare with the previous measuring data	Once a year
4	Measure the current of the operating compressor and fan motor and compare with previous measuring data	Once a year

Checklist

Checklist Split

Complaint / error code	

General information

Service Technician			
Company name		Visit date	
Installation ID		Service ID	

Installation conditions

Installation date	
Level difference	
Piping length	

Measurements

		Outdoor unit	Indoor unit
Type			
Serial number			
Compressor current	(A)		
Input current	(A)		
Compressor frequency (only (Hz) inverter)			
Refrigerant charge	(Kg)		
Low pressure	(bar)		
Suction pipe temperature	(°C)		

High pressure	(bar)		
Discharge pipe temperature	(°C)		
Liquid temperature	(°C)		
Intake air temperature	(°C)		
Outlet air temperature	(°C)		
Room humidity	(%RH)		
Heat exchanger temperature	(°C)		

Checklist, continued

Actions taken

Refrigerant taken out	
Refrigerant put in	
Leak test done	
Heat exchanger cleaned	
Replaced parts	
Others	

Remarks

Energy Efficiency Management Office

Routine Maintenance Schedule - Air Conditioning

Split, cassette, high-wall units – Not related to BWoF

Maintenance activity to be undertaken in consultation with product maintenance manual

Asset detail (make, model, serial number)

Technician

Date of service

/ / DD/MM/YYYY

This service (select one)

3 month ☐ 6 month ☐ 9 month ☐ 12 month ☐

Checklist

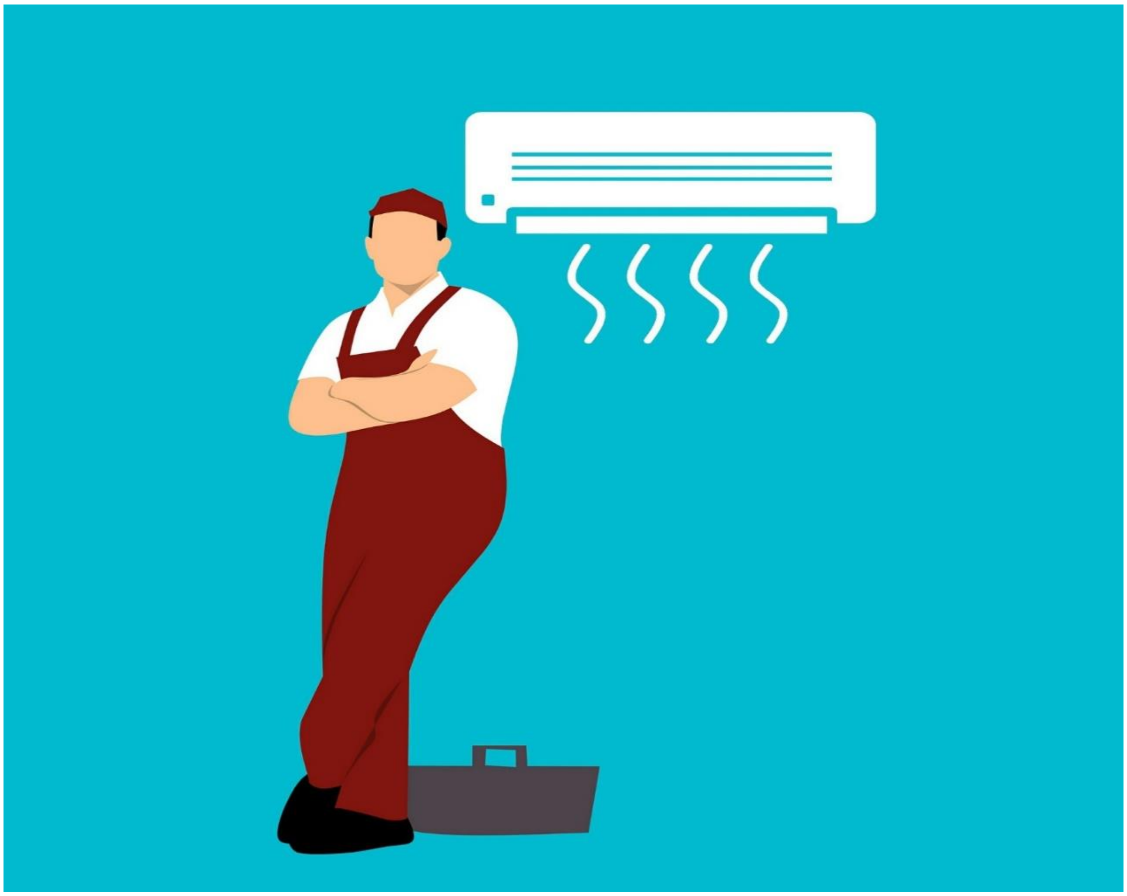
3, 6, 9 monthly – Tick the adjacent box for completed items.

- ☐ Inspect & clean air filter as per unit maintenance manual.
- ☐ Check unit heats & cools.
- ☐ Check unit for noise and vibration (both indoor and outdoor units)
- ☐ Remove rubbish & dust accumulation from outdoor coil fins
- ☐ Check refrigerant pipe connection for sign of leakage
- ☐ Check and clean indoor unoit condensate tray and drain.

12 monthly – Tick the adjacent box for completed items

- ☐ Carry out 3 monthly tasks
- ☐ Clean coil and straighten damaged fins on both the indoor and outdoor units.
- ☐ Check all electrical connections, controls and safety functions.
- ☐ Check operation of de-ice controls, HP, LP safety controls & compressor contactor.
- ☐ Check suction & discharge operating pressure

Comments (remedial/additional work completed, faults, follow-up required etc



DISCLAIMER

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