12.8.1 Vapour-Compression Refrigeration Systems

The vapour-compression refrigeration system is widely used in refrigeration applications like refrigerator, water cooler, air conditioner and cold storage. The schematic diagram of this system is shown in Fig. 12.1.

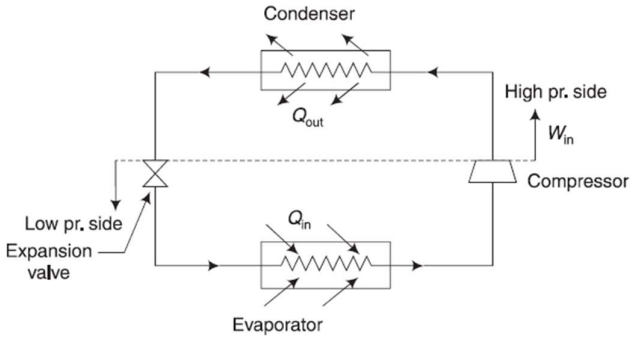

Fig. 12.1 *Vapour-compression refrigeration*

The refrigerant enters the evaporator at a lower pressure and temperature. Here, it absorbs its latent heat of vaporisation from the substances kept around the evaporator, thus cooling them. The chillness thus produced at the evaporator is known as refrigeration effect. The refrigerant usually comes out of the evaporator with its phase changed to dry saturated or slightly superheated state.

12.8.3 Vapour-Absorption Refrigeration System

The vapour-absorption refrigeration system is similar to the vapour-compression refrigeration system except for the manner in which the low-pressure vapour coming out of the evaporator is compressed. This system eliminates the compressor, yet produces the compressor effect by the combined effects provided by an absorber, a pump and a generator. The pump consumes comparatively lesser amount of electric power and the generator can be operated by heat energy obtained from the burning of any low-cost fuel or any heat source including solar energy.

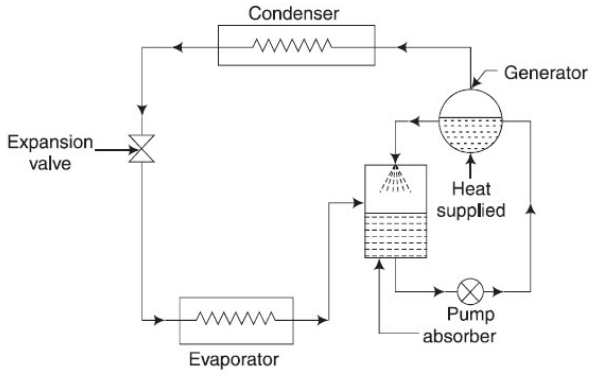

Fig. 12.3 *Vapour-absorption refrigerator*

12.8.2 Domestic Refrigeration System

[Nov 2012; Apr 2015, Regulation 2008; Nov 2014, Regulation 2013]

The layout of a domestic refrigerator is given in Fig. 12.2. It belongs to the vapour compression type. The evaporator which is the coldest part is located in the freezer compartment. A separate door is provided for the freezer where we can store ice, ice-cream and perishable items like mutton, chicken, fish etc. Just below the freezer, usually a chiller tray is provided. Further below and behind the main door, there are several compartments with progressive higher temperatures. The bottom-most compartment is for vegetables where a very low tem

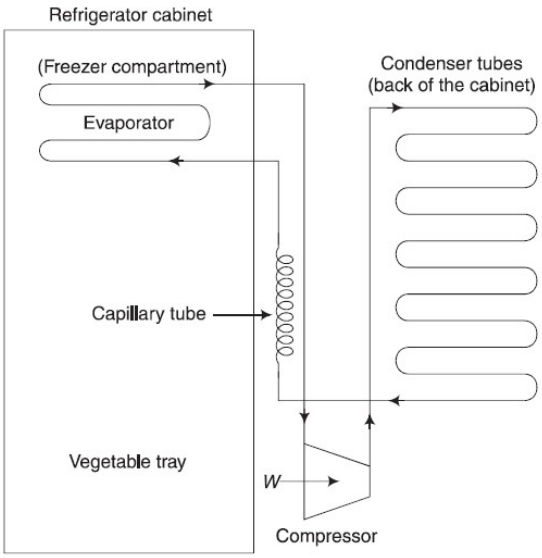

Fig. 12.2 *Domestic refrigerator layout*

12.15 WINDOW AIR CONDITIONER

[May 2012, 2013, 2014, Regulation 2008; Apr 2015, Regulation 2013]

A simple air-conditioning system without ducts, assembled inside a casing suitable for installation on windows or wall openings is called a window air conditioner. The unit consists of a vapour-compression refrigeration system, a double shaft motor, a blower, a fan, air filter, supply air grill, return air grill, fresh air damper, drain tray and a control panel as shown in Fig. 12.4.

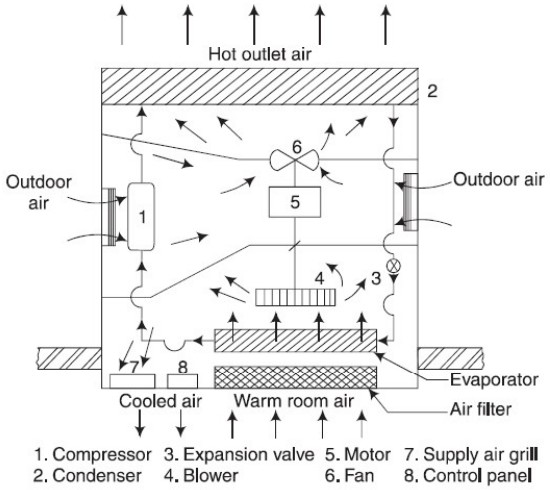

Fig. 12.4(a) *Layout of a window AC*

The blower sucks the warm air from the room through the air filter and the evaporator or cooling coil of the refrigeration system. Then, it delivers the cooled and dehumidified air back into the room through the supply air grill. The moisture condensing out when the inlet air is passed over the evaporator coil is drained out. The operation of the refrigeration system is the same as discussed in Section 12.8.1. The supply air grill has adjustable louvers or deflectors for changing the direction of air upwards or downwards or horizontally. Mechanised louvers are available in some window air conditioners which continuously change the direction of air flow to ensure uniform distribution of conditioned air inside the room. The conditioned air sent into the room mixes with the room air and decreases the temperature and humidity levels in the room and thereby maintains human comfort inside the room. Fresh air is admitted through the adjustable damper for the purpose of ventilation.

12.16 SPLIT AIR-CONDITIONER [May 2014, Regulation 2008]

An air conditioner has four major components, namely, the compressor, condenser throttling device and evaporator. In a window air conditioner, all these four major components are placed inside a single cabinet, with a small partition. In the case of a spilt air conditioner, the components are placed in two cabinets, namely, the indoor unit and outdoor unit as in Fig. 12.5. As the name implies, the indoor unit is to be placed inside the conditioned room while the outdoor unit is to be fixed outside the room. The indoor and the outdoor units are fixed with the help of suitable fixtures or hooks and they are connected with the help of tubes in which high pressure liquid and low pressure vapour

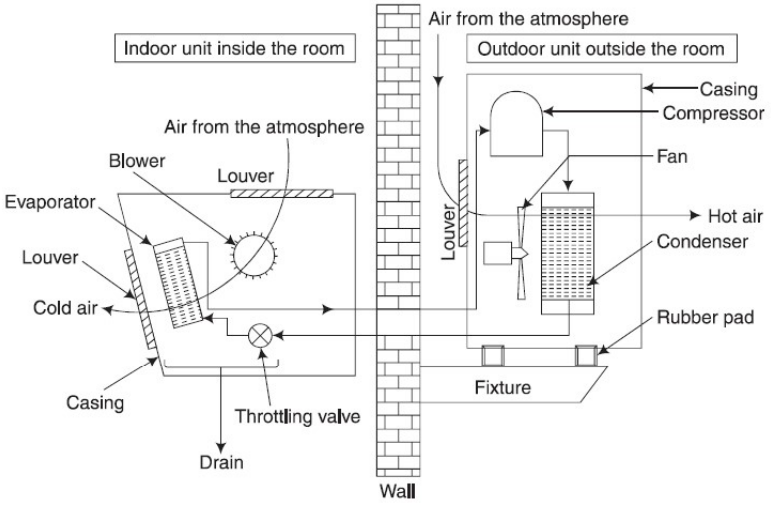

Fig. 12.5 *Split air conditioner*

The main components of the indoor unit are the blower, evaporator, throttling valve and drainage system. The high-pressure liquid refrigerant from the outdoor unit is allowed to flow through the throttling valve to obtain low-pressure vapour refrigerant. The low-pressure wet vapour refrigerant is then allowed to pass through the evaporator. As the blower blows air over the evaporator, low pressure refrigerant obtained from the throttling valve is evaporated, to produce chillness in the surrounding of the evaporator. Air inlet and outlet louvers are placed at suitable locations to enable free cold-air flow.

The main components of the outdoor unit are the fan, condenser and compressor. The low-pressure vapour refrigerant from the evaporator of the indoor unit is allowed to flow through the compressor to obtain high pressure and high-temperature refrigerant. The high pressure and temperature vapour is then allowed to pass through the condenser. As the fan blows air over the condenser, high-pressure vapour condenses to form high-pressure liquid refrigerant. Air inlet and outlet louvers are placed at suitable locations to enable free air flow. Rubber pads are used to mount the outdoor unit, as the working of compressor will produce vibration.

12.4 APPLICATIONS OF REFRIGERATION

1. In water coolers, to supply cold water for drinking.
2. To manufacture ice.
3. For preservation of food, vegetables, milk, ice cream, etc., in houses, hotels, ships, etc.
4. For preservation of perishables like fish, mutton, chicken, etc.
5. Preservation of medicines, blood, tissues, etc., in hospitals.
6. Preservation of dead bodies in mortuaries in hospitals.
7. Different types of industrial applications.
8. For air conditioning in houses, offices, theatres, hospitals, computer centres, etc.

12.5 REFRIGERANTS

A refrigerant is the working fluid in a refrigerator. It is capable of absorbing heat at a lower temperature and rejecting the heat at a higher temperature, in the form of sensible h

12.6 DESIRABLE PROPERTIES OF REFRIGERANTS

[May 2009, 2015, Regulation 2008; Apr 2015, Regulation 2013]

1. Low boiling point, low freezing point, high latent heat of evaporation.
2. Low specific heat and low viscosity.
3. It should be easy to liquefy.
4. Odourless and no hazardous effect on leakage.
5. Chemical stability.
6. Nonflammable.
7. Low cost.

12.7 TYPES OF REFRIGERANTS

[Nov 2009, 2010, Regulation 2008]

Chemical refrigerants are assigned an *R* number which is determined systematically according to molecular structure. Common refrigerants are frequently referred to as Freon (a registered trademark of DuPont).

1. ***Freon-12*** It is dichlorodifluoromethane (CCl_2F_2). This was the most commonly used in domestic refrigerators, water coolers and freezers. It is classified as a refrigerant, which is not eco-friendly.
2. ***R-134a*** It is Tetrafluoroethane ($C_2H_2F_4$). It is now being used as a replacement for R-12 CFC refrigerant in the area of centrifugal, rotary screw, scroll and reciprocating compressors. It is safe for normal handling as it is non-toxic, non-flammable and non-corrosive.
3. ***Freon-22*** It is monochlorodifluoromethane ($CHClF_2$) and it has a boiling point of –41°C. It is mostly used in air conditioners.
4. ***Ammonia*** It is R717 (NH_3). It is mostly used in absorption system. It has a boiling point of –33.3°C.
5. Other refrigerants include carbon dioxide (CO_2), sulphur dioxide (SO_2) and methyl chloride (CH_3Cl). Carbon dioxide is mainly used in marine refrigerators.

12.2 UNIT OF REFRIGERATION

[Nov 2012; May 2014, 2015, Regulation 2008]

The unit of refrigeration is called 'Ton of Refrigeration' (TR) which is defined as the quantity of heat to be removed to produce one ton of ice at 0°C, within 24 hours when the initial condition of water is also at 0°C. In the SI units, 1 TR is equivalent to 210 kJ/min or 3.5 kW. Air conditioners are also specified by the same unit TR.

12.9 COMPARISON BETWEEN VAPOUR-COMPRESSION AND VAPOUR-ABSORPTION SYSTEM

	Vapour Compression	*Vapour Absorption*
1.	Smaller in size	Very large in size for the same capacity
2.	Refrigerant is Freon-12	Ammonia
3.	Electric power is needed to run the compression	Heat input can be supplied by a heater, or by exhaust steam or even by solar energy
4.	COP is higher	Lower
5.	Wear and tear will be more	Less
6.	System produces noise	Silent in operation
7.	Maintenance cost is high	Low

12.12 APPLICATIONS OF AIR CONDITIONING

1. Air conditioning of houses, hotels, theatres, etc.
2. Hospitals, operation theatres and intensive care units are air conditioned.
3. For comfort of passengers in cars, buses, trains, ships and aeroplanes.
4. Air conditioning becomes very essential in many industries like textiles, food, printing, machine tools, etc.

12.13 IMPORTANT TERMINOLOGY IN AIR CONDITIONING **[May 2014, Regulation 2008]**

Dry air — Air without water vapour or moisture.

Moist air — It is a mixture of dry air and water vapour.

Dry-bulb temperature — Actual temperature of a gas, measured by a standard mercury thermometer

Wet bulb temperature — The temperature measured by a mercury thermometer, when the bulb is covered by a moistened cloth

Saturated air — A mixture of dry air along with the maximum possible water vapour, at dry-bulb temperature

Relative humidity — The ratio of the mass of water vapour in a given volume of air at the given temperature to the mass of water vapour present in the same volume under the same temperature of air when it is fully saturated