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B.Tech (III – II SEM)

MECHANICAL ENGINEERING

REFRIGERATION AND AIR CONDITIONING

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UNIT-I

INTRODUCTION TO REFRIGERATION AND V.C.R.S

Introduction

The mechanism used for lowering or producing low temp. in a body or a space, whose temp. is already below the temp. of its surrounding, is called the refrigeration system.

Here the heat is being generally pumped from low level to the higher one & is rejected at high temp.

Refrigeration

The term refrigeration may be defined as the process of removing heat from a substance under controlled conditions.

It also includes the process of reducing heat & maintaining the temp. of a body below the general temp. of its surroundings.

In other words the refrigeration means a continued extraction of heat from a body whose temp is already below the temp. of its surroundings.

Refrigerator & Refrigerant

A refrigerator is a reversed heat engine or a heat pump which takes out heat from a cold body & delivers it to a hot body.

The refrigerant is a heat carrying medium which during their cycle in a refrigeration system absorbs heat from a low temp. system & delivers it to a higher temp. system.

Refrigeration Cycle

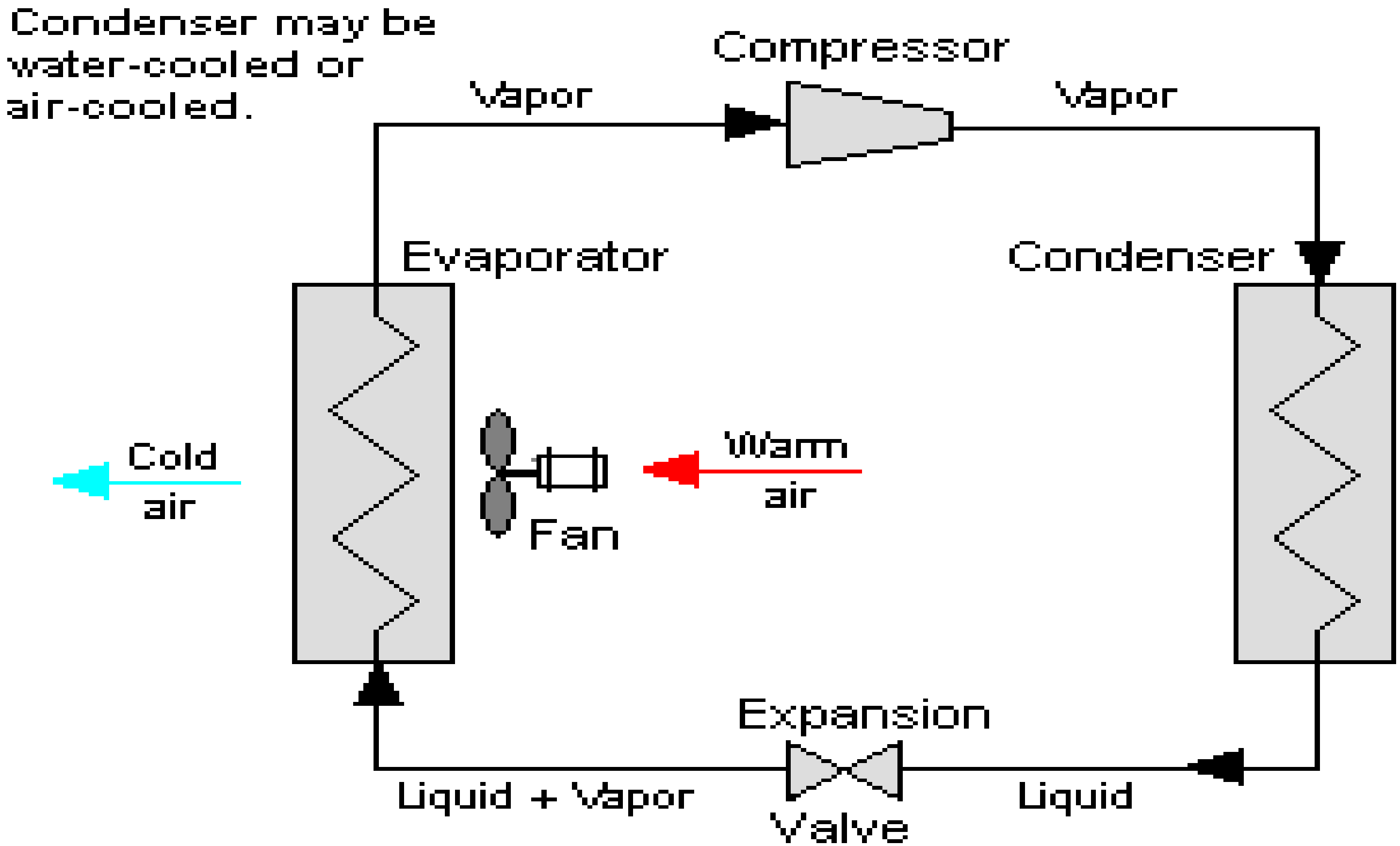
In refrigeration system the heat is being generally pumped from low level to higher one & rejected at that temp.

This rejection of heat from low level to higher level of temp. can only be performed with the help of external work according to second law of thermodynamics.

The total amount of heat being rejected to the outside body consist of two parts:-

- the heat extracted from the body to be cooled .

- the heat equivalent to the mechanical work required for extracting it.



TYPICAL SINGLE-STAGE
VAPOR COMPRESSION REFRIGERATION

A refrigerator is a reverse heat engine run in the reverse direction by means of external aid.

Every type of refrigeration system used for producing cold must have the following four basic units:-

Low temp. thermal sink to which the heat is rejected for cooling the space.

Means of extracting the heat energy from the sink, raising its level of temp. before delivering it to heat receiver.

A receiver is a storage to which the heat is transferred from the high temp., high pressure refrigerant.

Means of reducing the pressure & temp. of the refrigerant before it return to the sink.

The processes of the cycle are evaporation, compression, condensation & expansion.

By reversing the heat engine cycle completely & by changing the working agent, a refrigeration cycle is obtained.

Refrigeration Systems

- Vapour compression refrigeration system
- Vapour absorption refrigeration system
- Thermo electric refrigeration system

Vapour Compression Refrigeration

- This is the most important system from the point of commercial & domestic utility & most practical form of refrigeration.

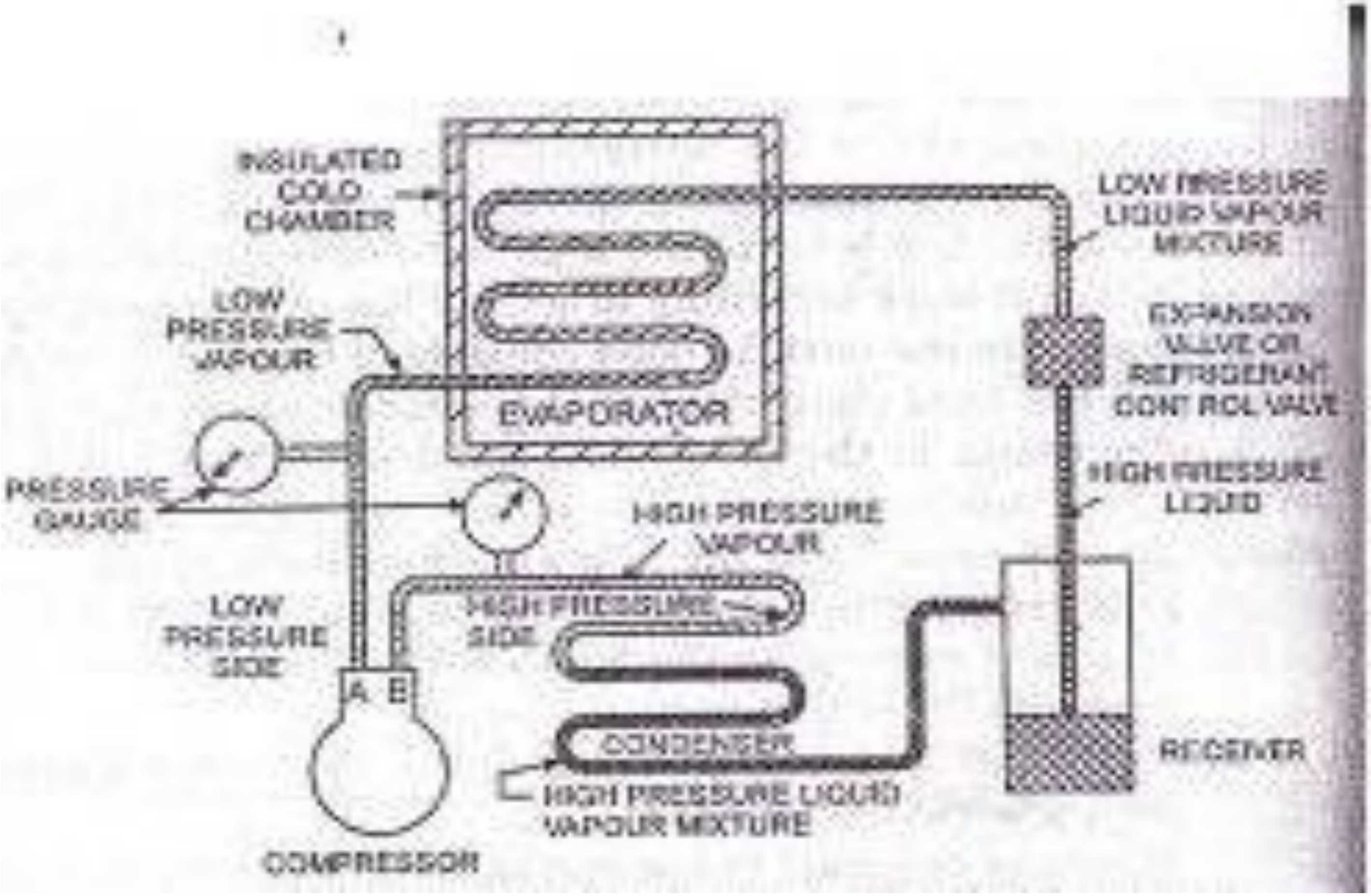
- The working fluid refrigerant used in this refrigeration system readily evaporates & condenses or changes alternatively between the vapour & liquid phases without leaving the refrigerating plant

- During evaporation it absorbs heat from the cold body or in condensing or cooling it rejects heat to the external hot body .

- The heat absorbed from cold body during evaporation is used as its latent heat for converting it from liquid to vapour.

- Thus a cooling effect is created in working fluid.

Vapour Compression Refrigeration Cycle



- This system of refrigeration thus act as latent heat pump since its pump its latent heat from the cold body or brine & rejects it or deliver it to the external hot body or the cooling medium.

- According to the law of thermodynamics , this can be done only on the expenditure of energy which is supplied to the system in the form of electrical energy driving the compressor.

- The vapour compression cycle is used in most of the modern refrigeration systems in large industrial plants.

- The vapour in this cycle is circulated through the various components of the system, where it undergoes a number of changes in its state or condition.

- Each cycle of operation consists of the four fundamental changes of state or processes:-

➢ Expansion
➢ Vaporisation
➢ Compression
➢ Condensation

UNIT –II

Components of Vapour Compression Systems

Compressor

The low pressure & temp. refrigerant from evaporator is drawn into the compressor through the inlet or suction valve , where it is compressed to a high pressure & temp.

The high pressure & temp vapour refrigerant is discharged into the condenser through the delivery or discharge valve.

Condenser

The condenser or the cooler consists of coils of pipe in which the high pressure & temp. vapour refrigerant is cooled & condensed.

The refrigerant while passing through the condenser, rejects its latent heat to surrounding condensing medium which is normally air or water.

Thus hot refrigerant vapour received from compressor is converted into liquid form in condenser.

Receiver

The condensed liquid refrigerant from the condenser is stored in a vessel, known as receiver, from where it is supplied to the expansion valve or refrigerant control valve.

Expansion Valve

The function of this valve is to allow the liquid refrigerant under high pressure & temp. to pass at a controlled rate after reducing its pressure & temp.

some of liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporised in the evaporator at the low pressure & temp.

Evaporator

An evaporator consists of coils of pipes in which the liquid vapour refrigerant at low pressure & temp. is evaporated & changed into vapour refrigerant at low pressure & temp.

During evaporation process, the liquid vapour refrigerant absorbs its latent heat of vaporization from the medium which is to be cooled.

Advantages

- Smaller size for a given refrigerating capacity
- Higher coeff. of performance
- Lower power requirements for a given capacity
- Less complexity in both design & operation
- It can be used over large of temp.

Domestic Refrigerator

- The application of refrigeration for domestic purposes are mainly in the form of domestic refrigerators & home freezers.
- The main purpose of this type of refrigeration is to provide low temp. for storage & distribution of foods & drinks.
- It represents a significant portion of the refrigeration industry due to the use of these units in large number.

- For domestic preservation, the storage is generally short term. The domestic refrigerators used for the purposes are usually small in sizes with rating in ranges from 1/20 to ½ tonne.

- The unit is usually self contained and hermetically sealed.

- Due to short term storage the domestic refrigerator load is intermittent.

The requirement of domestic refrigerator is that:-

- it should be simple in construction
- automatic in action
- nominal in initial cost

- dependable and without any necessity of expert inspection & repair.

- Non irritant & non toxic refrigerant should be used.

- Generally methylene chloride, freon-12, freon -11 are used as refrigerants.

- The common type of domestic refrigerator have a cabinet shaped with compressor motor-fan assembly, the condensed and receiver fitted in their basement.

- The expansion valve evaporator coils are exposed in the storage cabinet with the piping, carrying liquid refrigerant passing through the body.

- The heat of the bodies to be cooled is carried to the evaporator coils by means of air trapped in the cabinet.

- Refrigeration is not only provided with double walled cabinet packed with materials having high thermal insulation such as fibre glass or expanded rubber but also all around the inside of door flap soft rubber seal is used which makes rubber air tight.

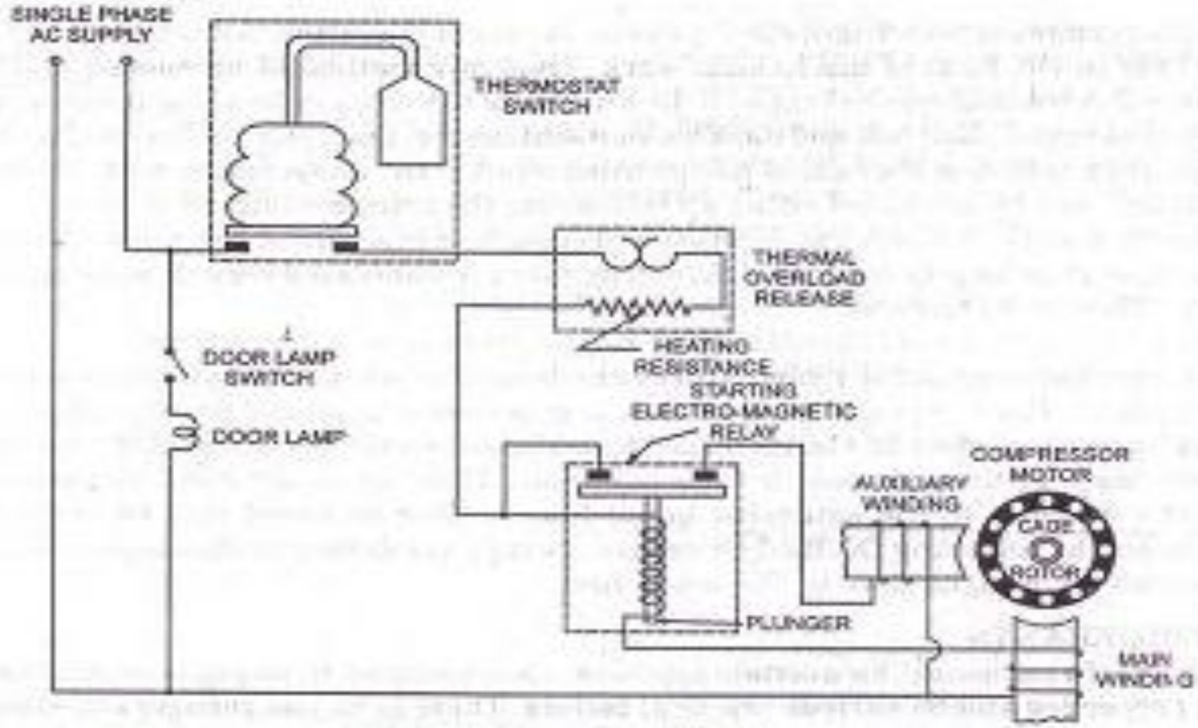
Electrical Circuit

- Refrigerator is provided with a door push switch, which closes on opening of refrigerator and puts the lamp on.

- Capacitor start single phase induction motor is used in open type refrigerators and split phase induction motor is used in sealed unit refrigerators.

- Electromagnetic relay is provided to connect auxiliary winding on the start & disconnect it when the motor picks up the speed.

Circuit



Electrical Circuit of a Refrigerator

- Thermal overload release is provided to protect the motor from damage against flow of over current.

- Thermostat switch is provided to control the temp. inside the refrigerator.

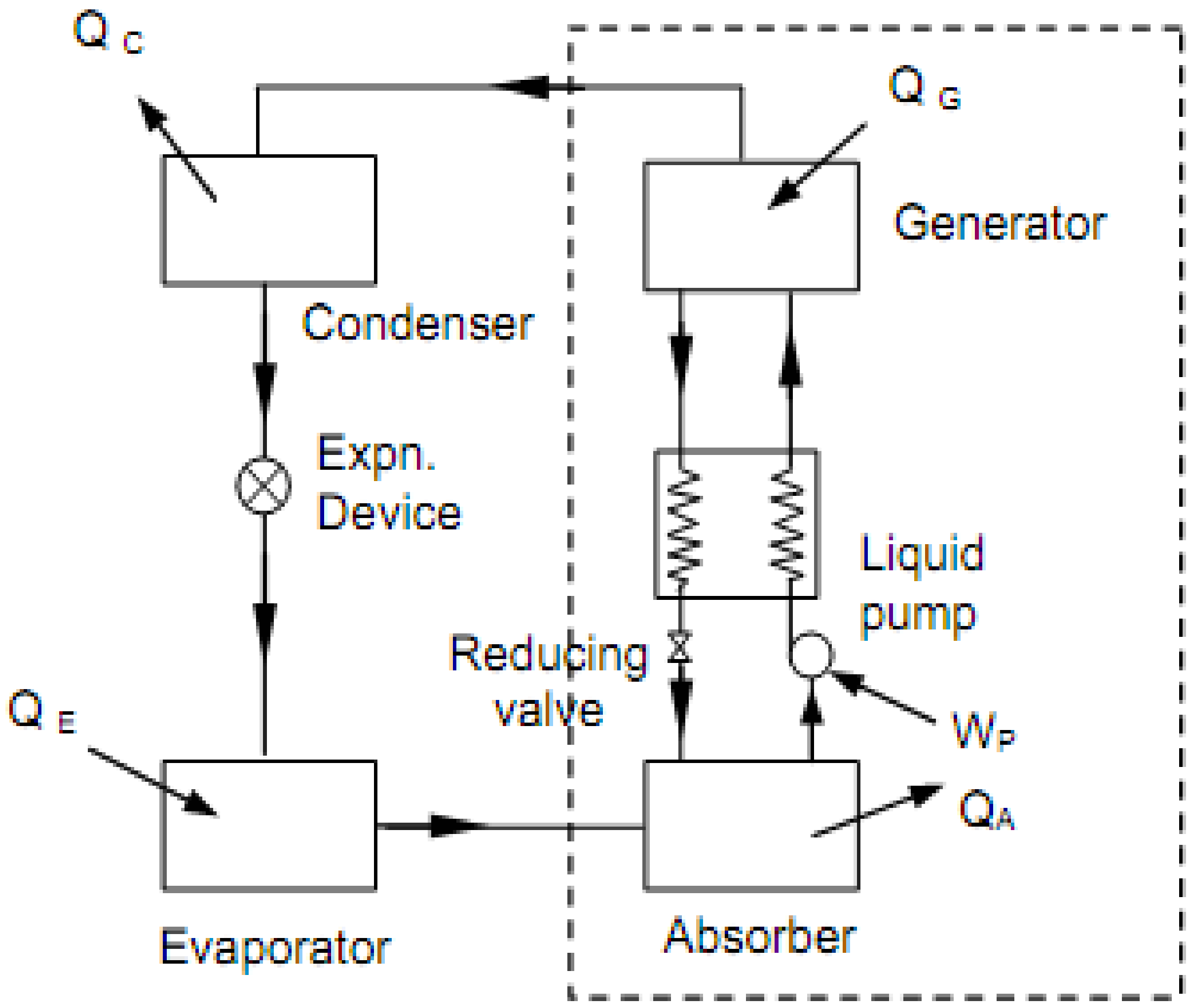
- Temp. inside the refrigerator can be adjusted by means of temp. control screw.

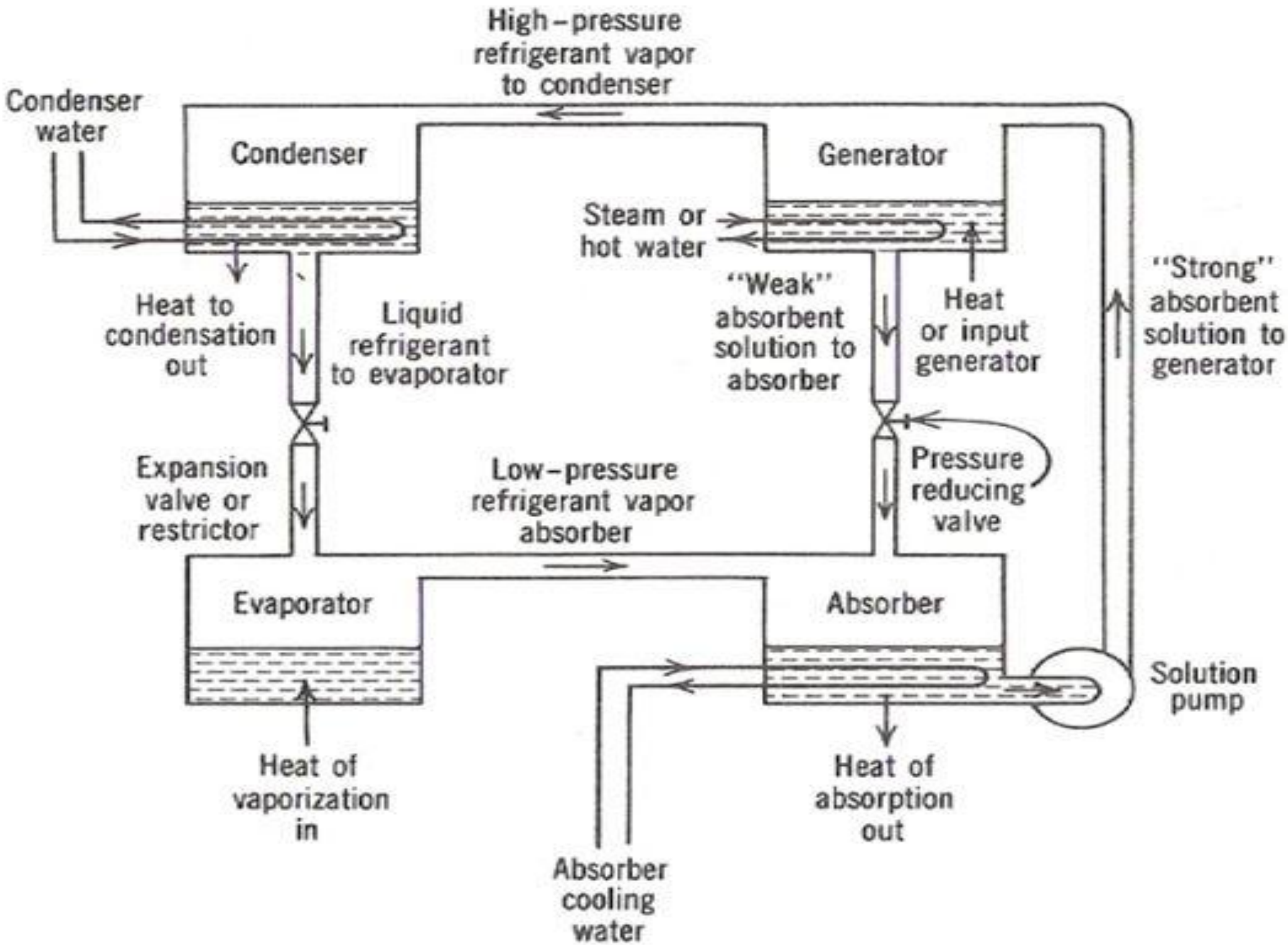
- To protect the motor against under voltage use of automatic voltage regulator is essential since in case of fall in applied voltage, motor will draw heavy current to develop the required torque and will become hot, thermal overload relay will therefore repeatedly disconnect and connect the motor to supply, eventually burning it out.

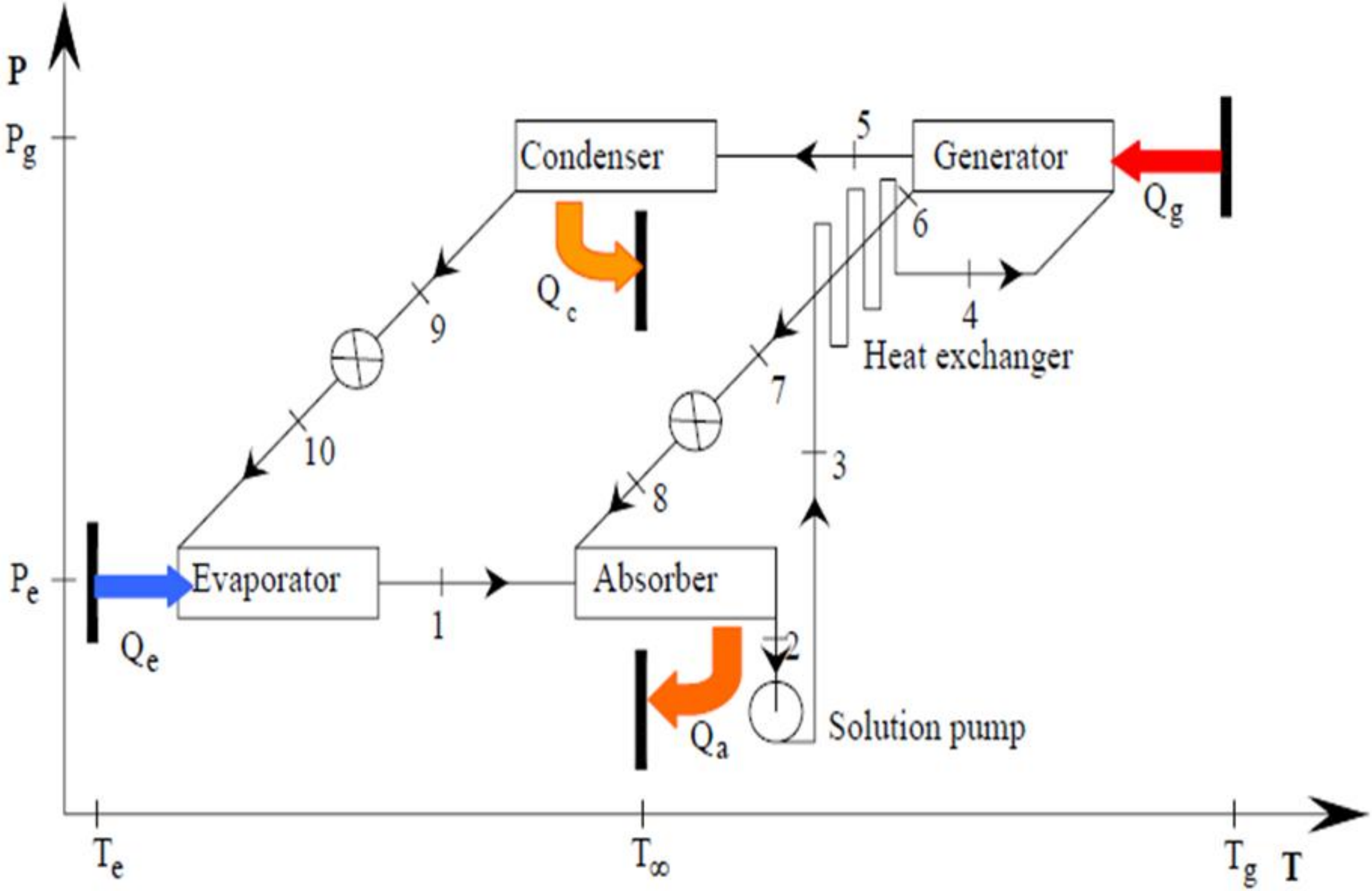
UNIT - III

VAPOUR ABSORPTION REFRIGERATION

Simple Vapor-Absorption Refrigeration System




High-pressure refrigerant vapor to condenser
Condenser water
Condenser
Generator
Steam or hot water
Heat to condensation out
Liquid refrigerant to evaporator
"Weak" absorbent solution to absorber
Heat or input generator
"Strong" absorbent solution to generator
Expansion valve or restrictor
Low-pressure refrigerant vapor absorber
Pressure reducing valve
Evaporator
Absorber
Solution pump
Heat of vaporization in
Heat of absorption out
Absorber cooling water



Basic vapour absorption refrigeration system with a solution heat exchanger on a pressure vs temperature diagram

COP for Ideal Vapor Absorption Refrigeration System

- $$\text{C.O.P} = \frac{\text{Heat absorbed in evaporator}}{\text{Work done by pump} + \text{Heat supplied in generator}}$$
- According to first law of thermodynamics

$$Q_c = Q_g + Q_e$$

Q_c : Heat discharged to the atmosphere or cooling water from the condenser and absorber.

Q_g : Heat given to the refrigerant in the generator.

Q_e : Heat absorbed by the refrigerant in the evaporator.

T_g : Temperature at which heat(Q_g) is given to the generator.

T_c : Temperature at which heat (Q_c) is discharged to atmosphere

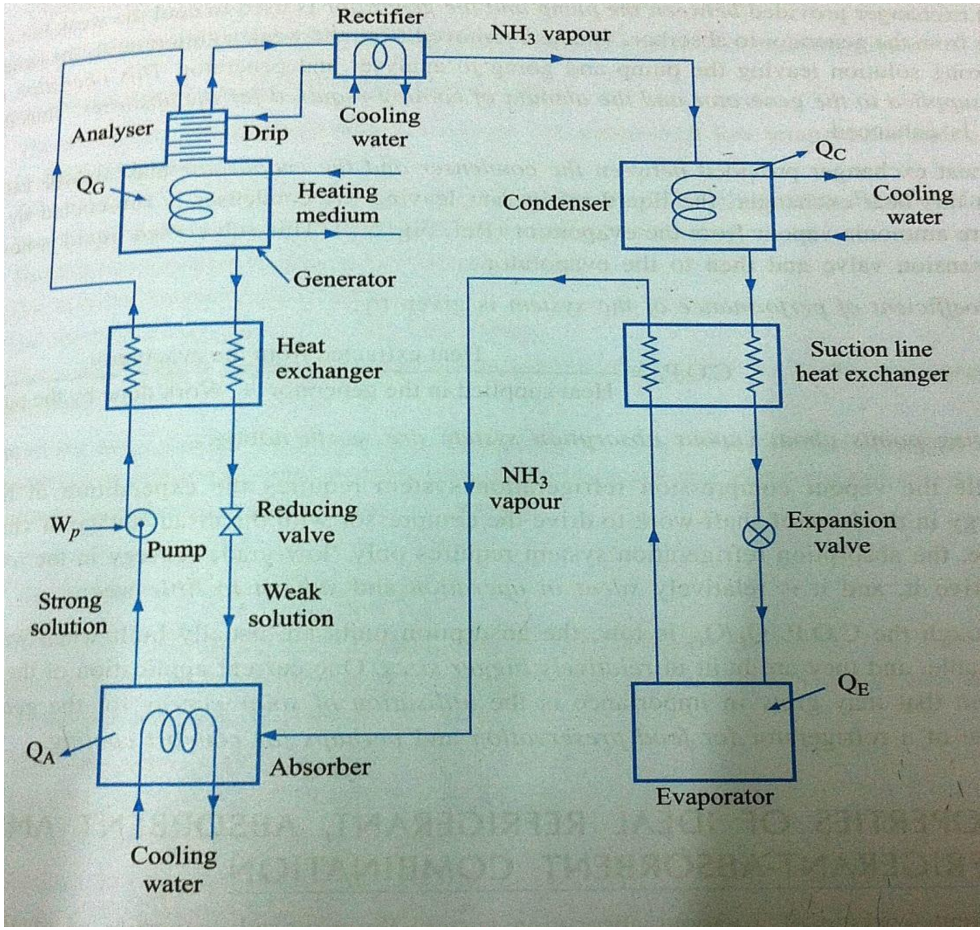
T_e : Temperature at which heat (Q_e) is absorbed in the evaporator.

Practical Vapor – Absorption Refrigeration System

Analyser : Strong solution flows down the trays. Due to high saturation temperature water condenses down and NH_3 vapours escape through.

Rectifier : A water cooled heat exchanger which further condenses water vapour. (If any are left)

Heat Exchanger : Used to cool weak solution from generator. It also heats the strong solution coming from pump, thereby Reducing heat to be supplied at generator.



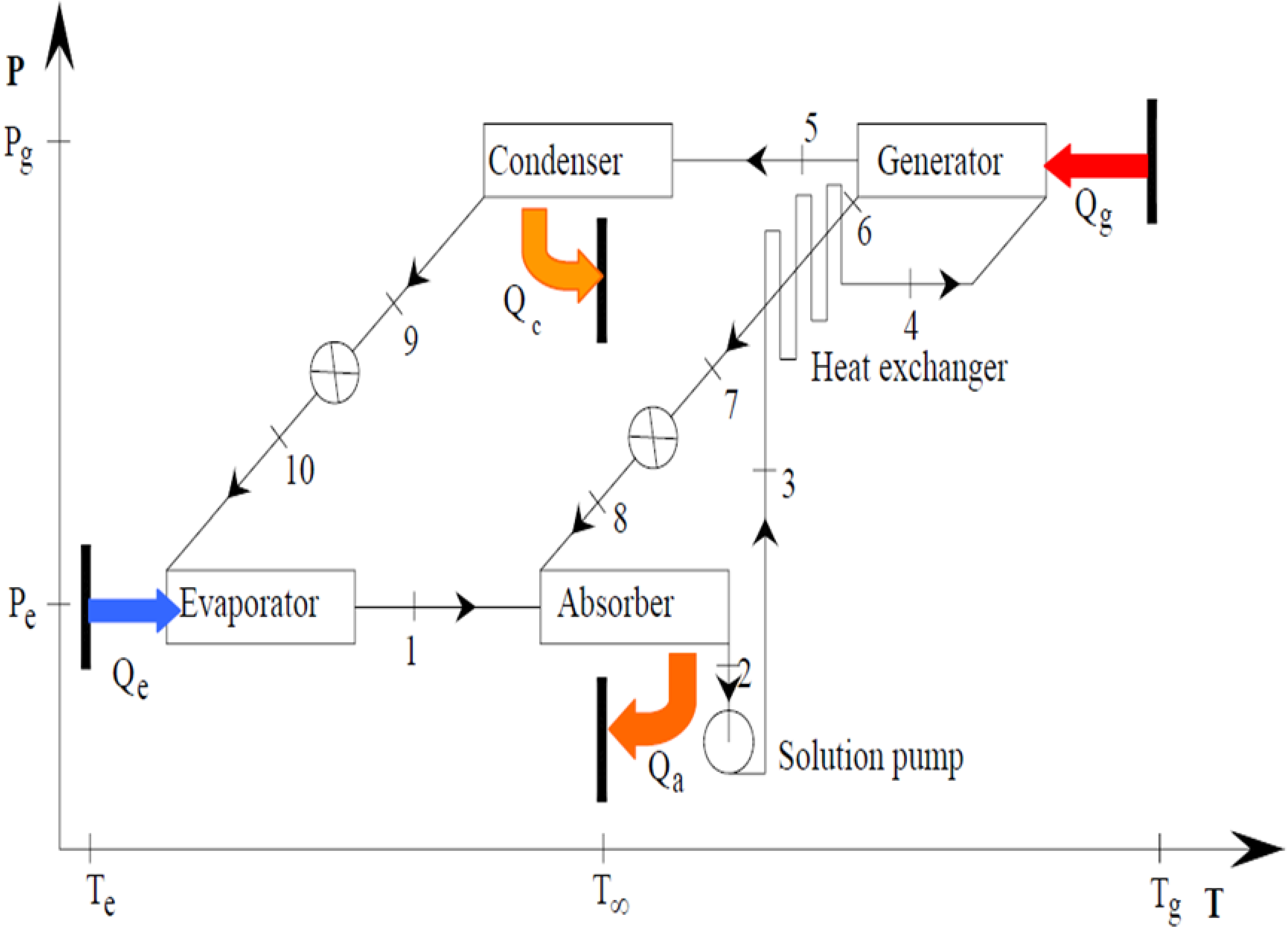
Vapour Absorption Refrigeration Systems Based On Water-Lithium Bromide Pair

VARS based on H_2O – LiBr Pair

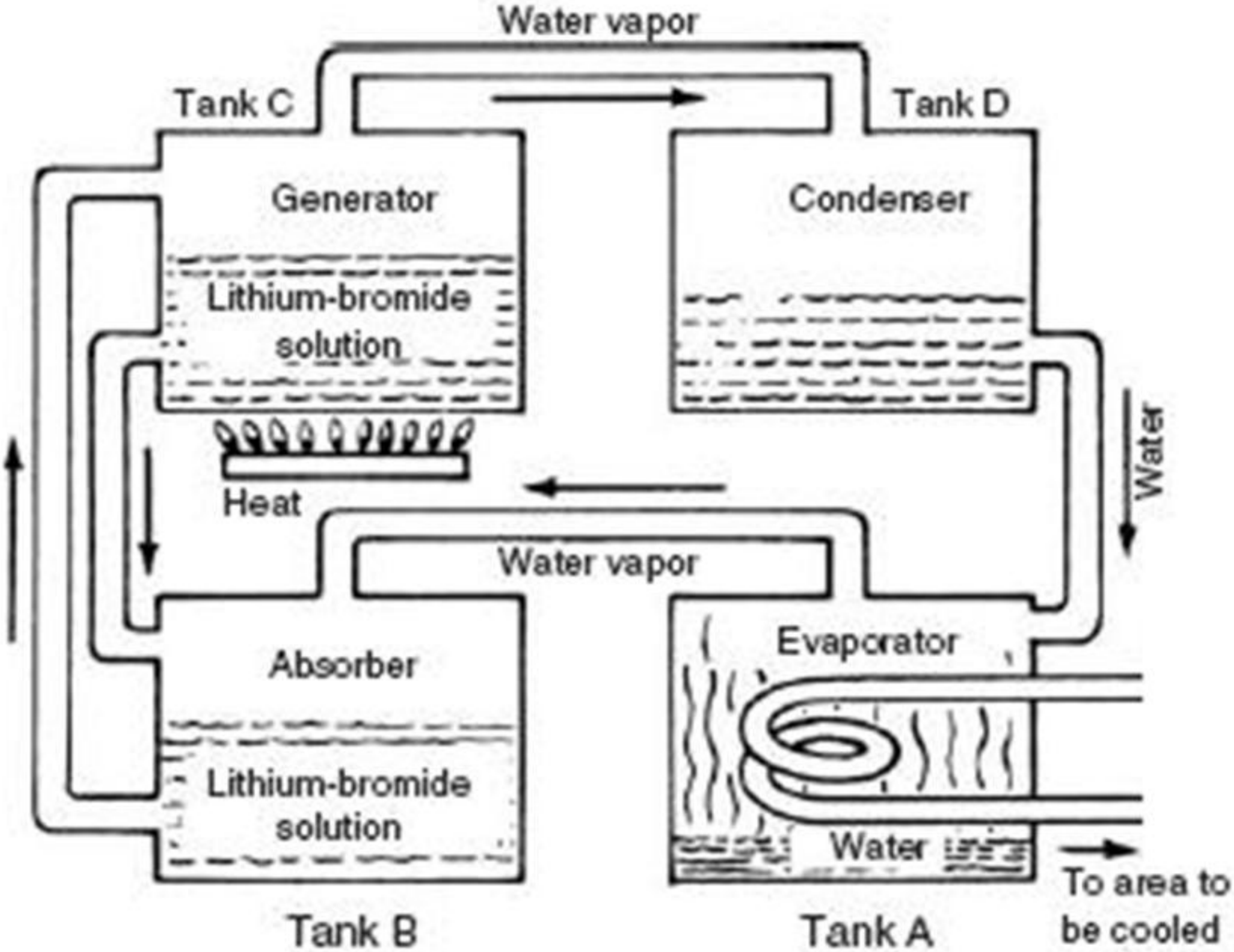
- Vapour absorption refrigeration systems using water-lithium bromide pair are extensively used in large capacity air conditioning systems.

- In these systems water is used as refrigerant and a solution of lithium bromide in water is used as absorbent.

- Since water is used as refrigerant, using these systems it is not possible to provide refrigeration at sub-zero temperatures. Hence it is used only in applications requiring refrigeration at temperatures above 0^oC.



H_2O-LiBr system with a solution heat exchanger on Dühring plot



Lithium-bromide system of refrigeration.

Sample Problem in Simple VARS

a) $$COP = Q_e/Q_g = 100/160 = \mathbf{0.625} \qquad \textbf{(Ans.)}$$

$$\text{Total heat rejection rate} = Q_a + Q_c = Q_e + Q_g = 100 + 160 = \mathbf{260\ kW} \quad \textbf{(Ans.)}$$

b) According to the inventor's claim, the COP_{claim} is given by:

$$COP_{claim} = Q_e/Q_g = 100/80 = \mathbf{1.25}$$

However, for the given temperatures, the maximum possible COP is given by:

$$COP_{ideal\ VARS} = \left(\frac{Q_e}{Q_g}\right)_{max} = \left(\frac{T_e}{T_o - T_e}\right)\left(\frac{T_g - T_o}{T_g}\right)$$

Substituting the values of operating temperatures, we find that:

$$COP_{max} = \left(\frac{T_e}{T_o - T_e}\right)\left(\frac{T_g - T_o}{T_g}\right) = \left(\frac{273}{313 - 273}\right)\left(\frac{50}{363}\right) = 0.94$$

Since $COP_{claim} > COP_{max} \Rightarrow$ Inventor's claim is FALSE **(Ans.)**

UNIT - IV

INTRODUCTION TO AIR CONDITIONING

PSYCHROMETRIC PROPERTIES

- The properties of moist air are called *psychrometric properties* and the subject which deals with the behaviour of moist air is known as *psychrometry.*

- *Moist air* is a mixture of dry air and water vapour. They form a binary mixture. A mixture of two substances requires three properties to completely define its thermodynamic state, unlike a pure substance which requires only two. One of the three properties can be the composition. Water vapour is present in the atmosphere at a very low partial pressure. At this low pressure and atmospheric temperature, the water vapour behaves as a perfect gas.

- Since the water vapour part is continuously variable, all calculations in air- conditioning practice are based on the dry air part.

- For calculating and defining the psychrometric properties, we may consider a certain volume *V* of moist air at pressure *p* and temperature *T* , containing *ma* kg of dry air and *mv* kg of water vapour as shown in Figure 6.3. The actual temperature *t* of moist air is called the *dry bulb temperature* (DBT). The total pressure *p* which is equal to the *barometric pressure* is constant

Specific Humidity or Humidity Ratio

Specific or *absolute humidity* or *humidity ratio* or *moisture content* is defined as the ratio of the mass of water vapour to the mass of dry air in a given volume of the mixture. It is denoted by the symbol ω.

Dew Point Temperature

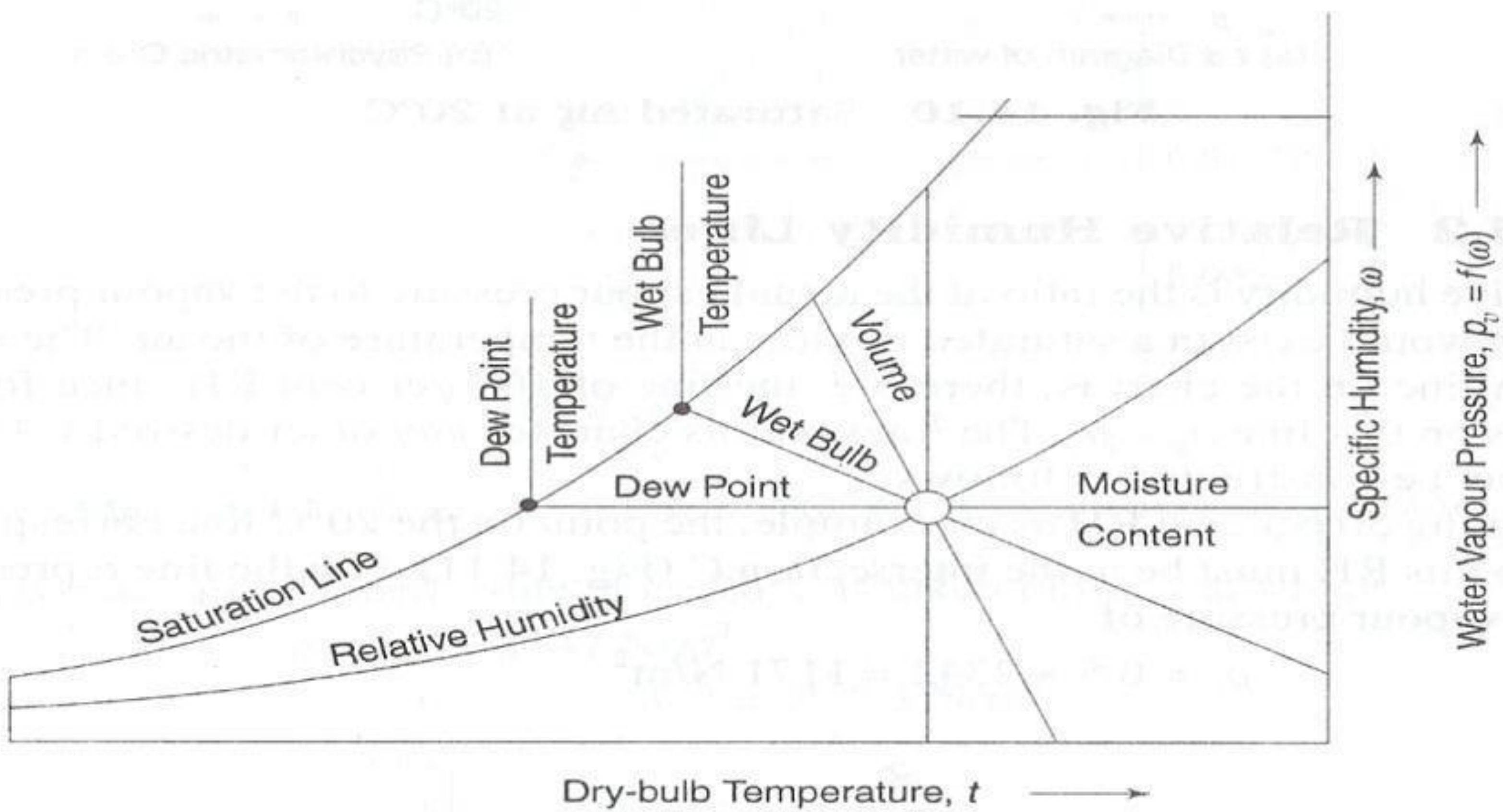
The normal thermodynamic state 1 as shown in the of moist air is considered as *unsaturated air.* The water vapour existing at temperature T of the mixture and partial pressure *pv* of the vapour in the mixture is normally in a superheated state.

Relative Humidity

The relative humidity is defined as the ratio of the mole fraction of water vapour in moist air to mole fraction of water vapour in saturated air at the same temperature and pressure.

PSYCHROMETRIC CHART

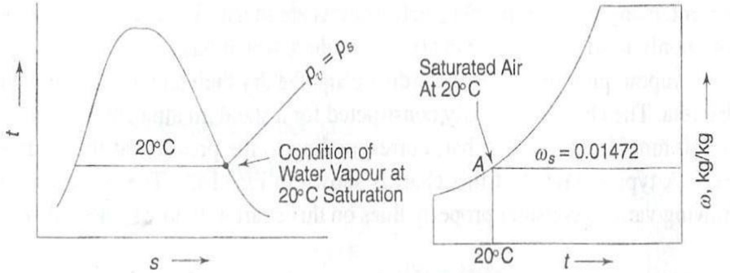
All data essential for the complete thermodynamic and psychrometric analysis of air- conditioning processes can be summarised in a psychrometric chart. At present, many forms of psychrometric charts are in use. The chart which is most commonly used is the ω-t chart, i.e. a chart which has specific humidity or water vapour pressure along the ordinate and the dry bulb temperature along the abscissa. The chart is normally constructed for a standard atmospheric pressure of 760 mm Hg or 1.01325 bar, corresponding to the pressure at the mean sea level. A typical layout of this chart is shown in Figure



Wet Bulb
Temperature
Dew Point
Temperature
Volume
Wet Bulb
Dew Point
Moisture
Content
Saturation Line
Relative Humidity
Specific Humidity, ω
Water Vapour Pressure, $p_v = f(\omega)$
Dry-bulb Temperature, t

Saturation Line

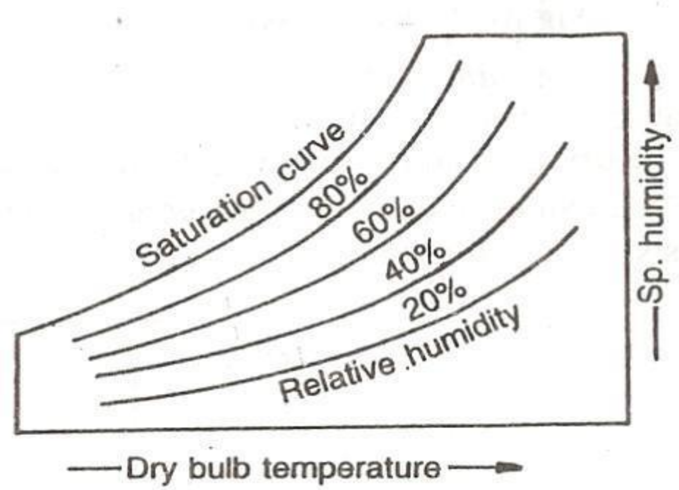
The saturation line represents the states of saturated air at different temperatures. As an example of fixing such a state on the chart, consider an atmosphere A at 20 oC and saturation as shown in Figure 6.9. From the steam tables at 20 oC, water vapour pressure



(a) t-s Diagram of water
(b) Psychrometric Chart

Relative Humidity Lines

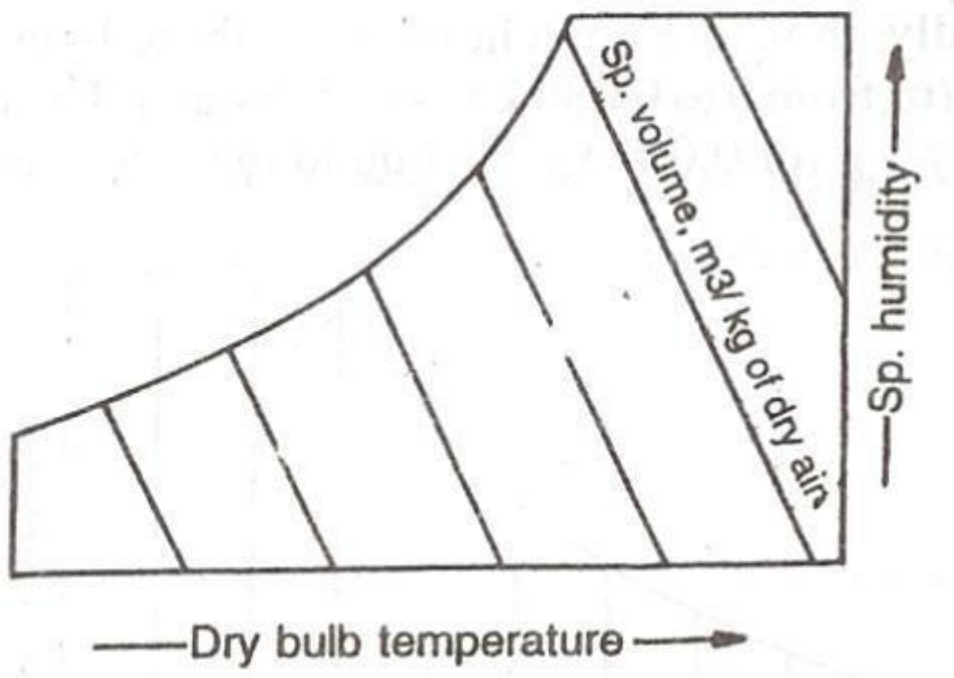
The relative humidity is defined as the ratio of the mole fraction of water vapour in moist air to mole fraction of water vapour in saturated air at the same temperature and pressure.



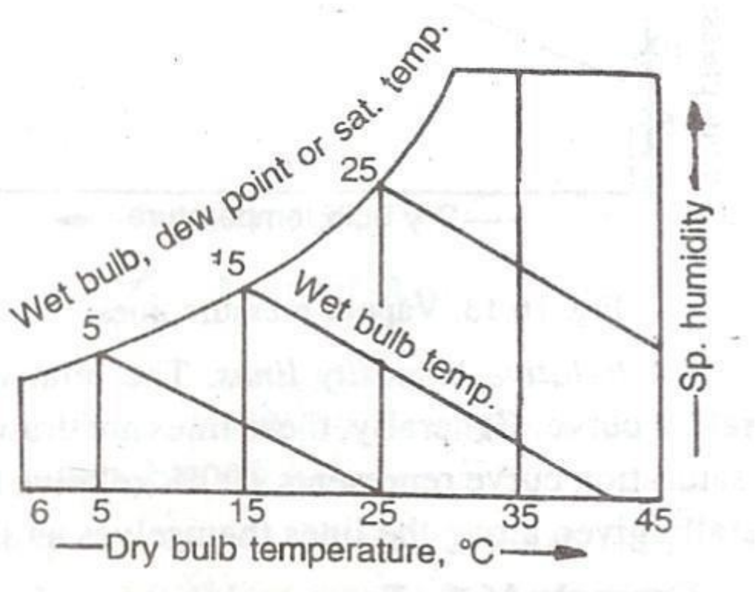
Constant Specific Volume Lines

The constant specific volumes lines are obliquely inclined straight lines and uniformly spaced as shown in Figure These lines are drawn up to the saturation curve. To establish points on a

line of constant specific volume, 0.90 m3/kg for example, From the perfect-gas equation, the specific volume *v* is substitute 0.90 for *v*, the barometric pressure for pt, and at arbitrary values of T solve for ps. the pairs of ps and *t* values then describe the line of constant *v*.

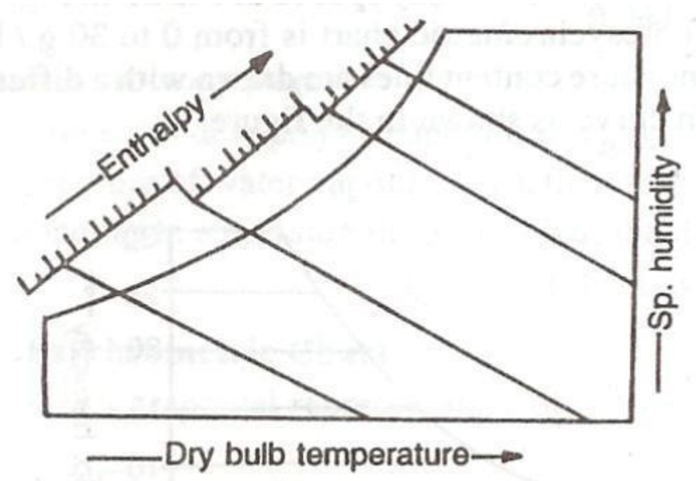

Sp. volume, m3/ kg of dry air
Sp. humidity
Dry bulb temperature

Constant Thermodynamic Wet Bulb Temperature Lines



Constant Enthalpy Lines

The enthalpy (or total heat) lines are inclined straight lines and uniformly spaced as shown in Figure 16.14. These lines are parallel to the wet bulb temperature lines, and are drawn up to the saturation curve. Some of these lines coincide with the wet bulb temperature lines also.



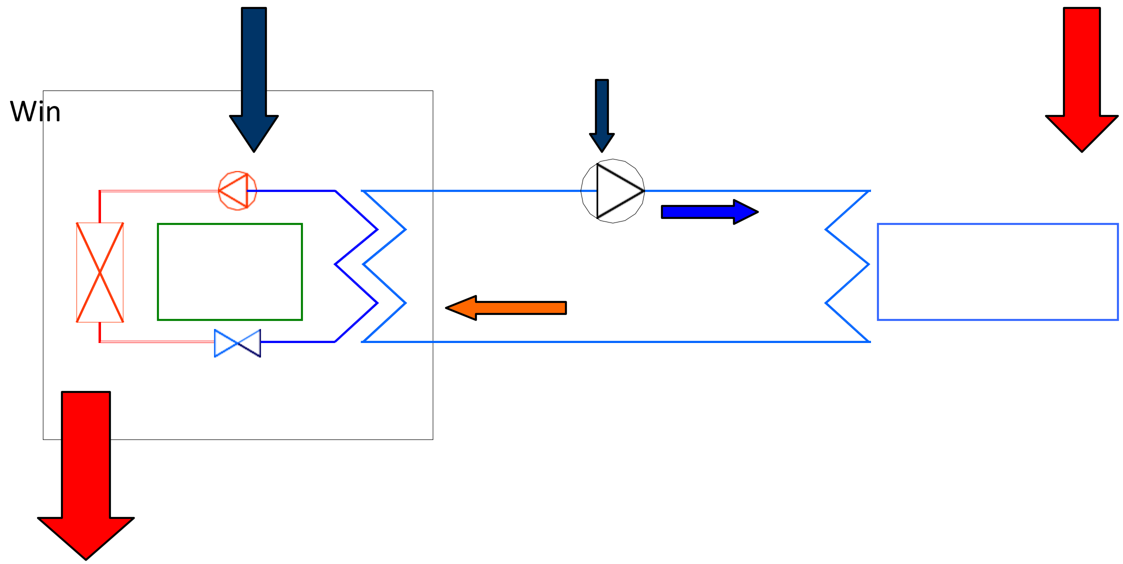
UNIT-V

AIR CONDITIONING SYSTEMS

Introduction:

In order to maintain required conditions inside the conditioned space, energy has to be either supplied or extracted from the conditioned space. The energy in the form of sensible as well as latent heat has to be supplied to the space in winter and extracted from the conditioned space in case of summer. An air conditioning system consists of an air conditioning plant and a thermal distribution system as shown in Fig. 36.1. As shown in the figure, the air conditioning (A/C) plant acts either as a heat source (in case of winter systems) or as a heat sink (in case of summer systems). Air, water or refrigerant are used as media for transferring energy from the air conditioning plant to the conditioned space.

A thermal distribution system is required to circulate the media between the conditioned space and the A/C plant. Another important function of the thermal distribution system is to introduce the required amount of fresh air into the conditioned space so that the required Indoor Air Quality (IAQ) can be maintained.



Classification of air conditioning systems:

Based on the fluid media used in the thermal distribution system, air conditioning systems can be classified as:

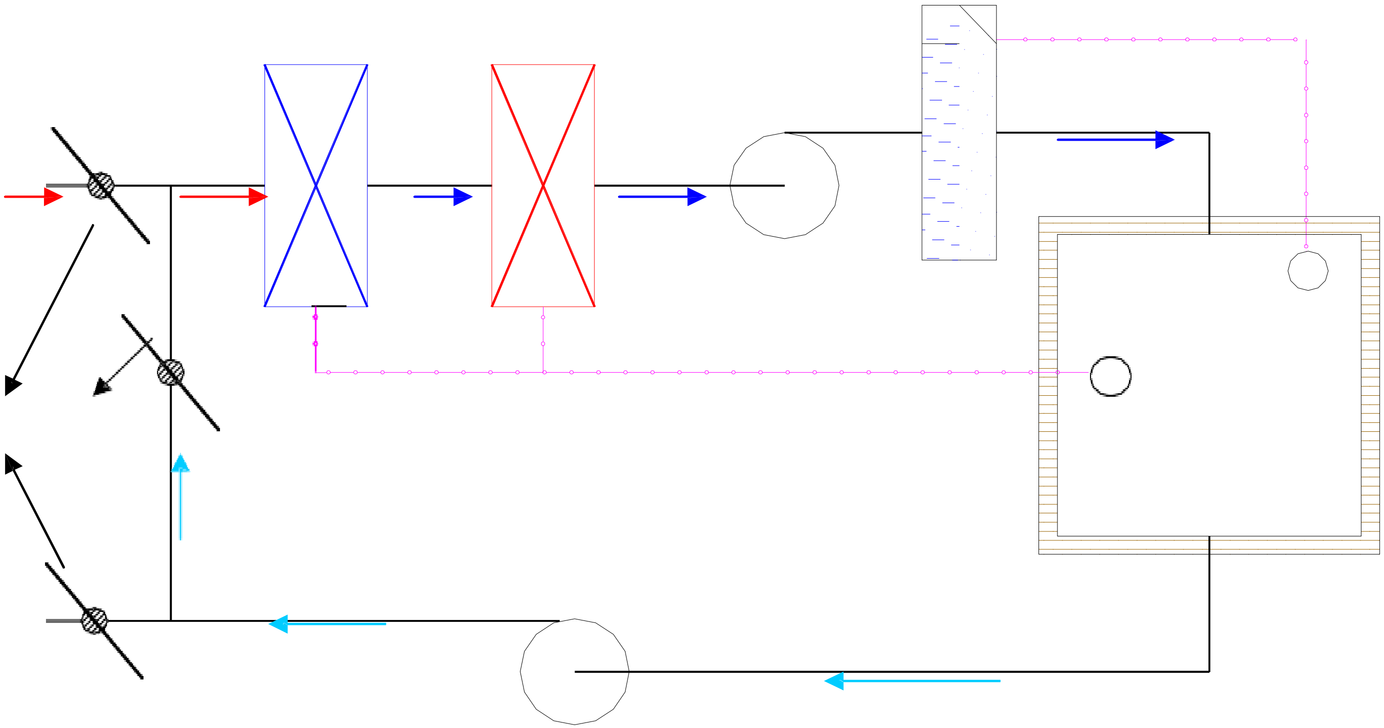
- All air systems
- All water systems
- Air- water systems
- Unitary refrigerant based systems

All Air Systems

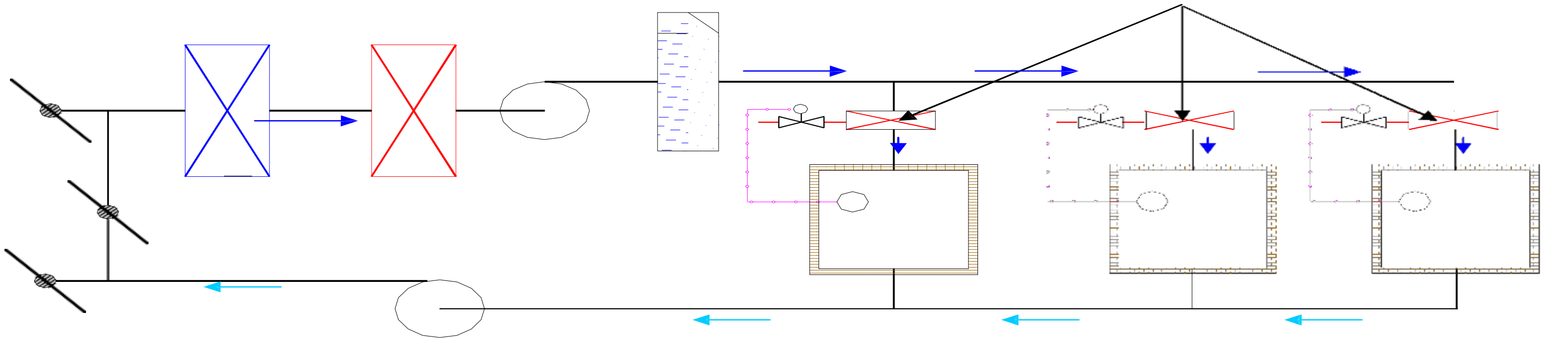
As the name implies, in an all air system air is used as the media that transports energy from the conditioned space to the A/C plant. In these systems air is processed in the A/C plant and this processed air is then conveyed to the conditioned space through insulated ducts using blowers and fans. This air extracts (or supplies in case of winter) the required amount of

- sensible and latent heat from the conditioned space. The return air from the conditioned space is conveyed back to the plant, where it again undergoes the required processing thus completing the cycle. No additional processing of air is required in the conditioned space. All air systems can be further classified into:
- Single duct systems, or
- Dual duct systems

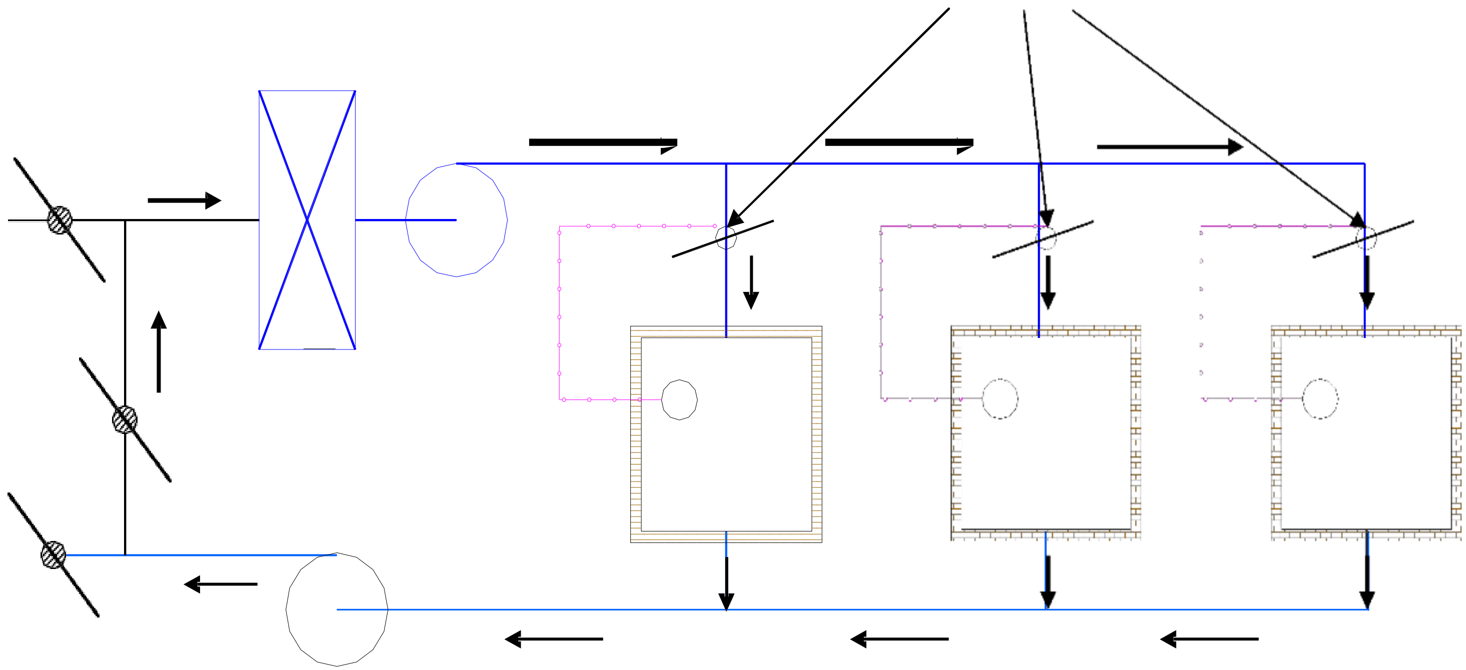
Single duct, constant volume, single zone systems:



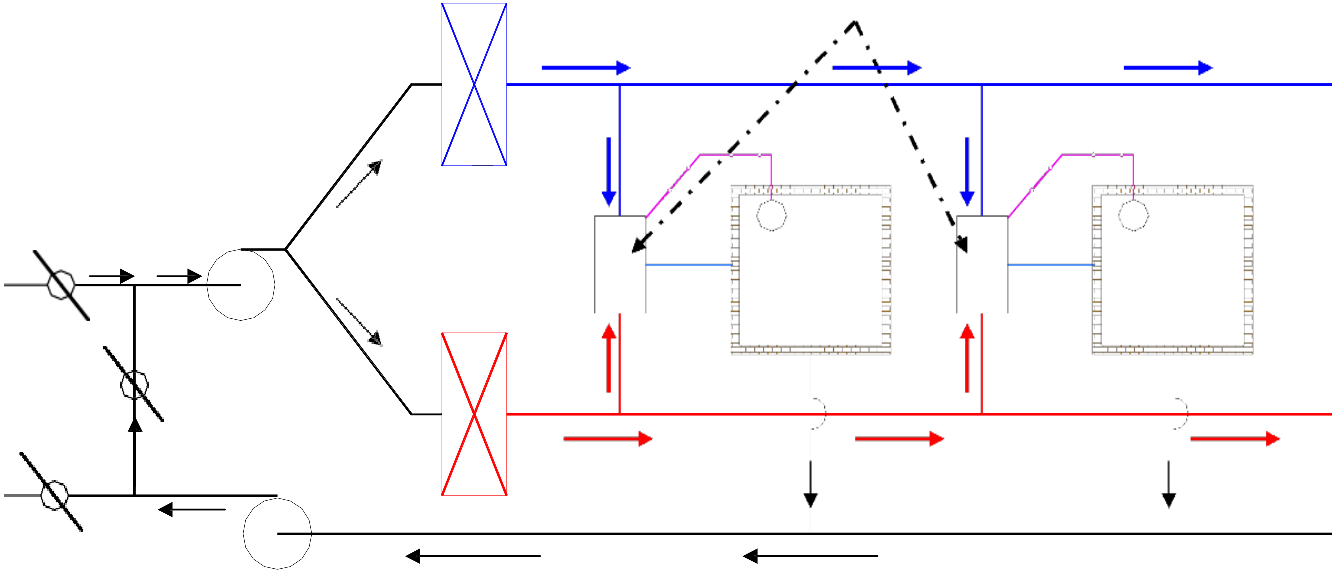
Single duct, constant volume system with multiple zones and reheat coils



Single duct, constant volume system with multiple zones and reheat coils



Dual duct, constant volume systems:



All water systems

In all water systems the fluid used in the thermal distribution system is water, i.e., water transports energy between the conditioned space and the air conditioning plant. When cooling is required in the conditioned space then cold water is circulated between the conditioned space and the plant, while hot water is circulated through the distribution system when heating is required.

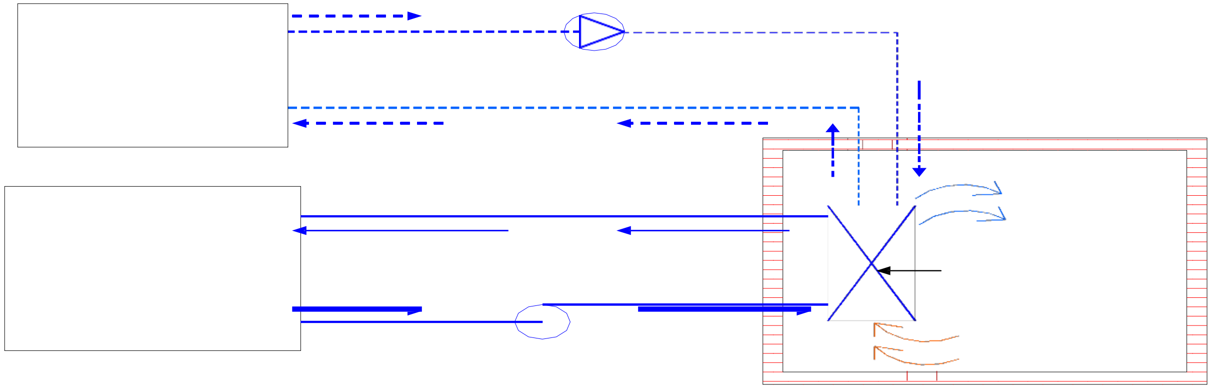
Since only water is transported to the conditioned space, provision must be there for supplying required amount of treated, outdoor air to the conditioned space for ventilation purposes.

Air-water systems

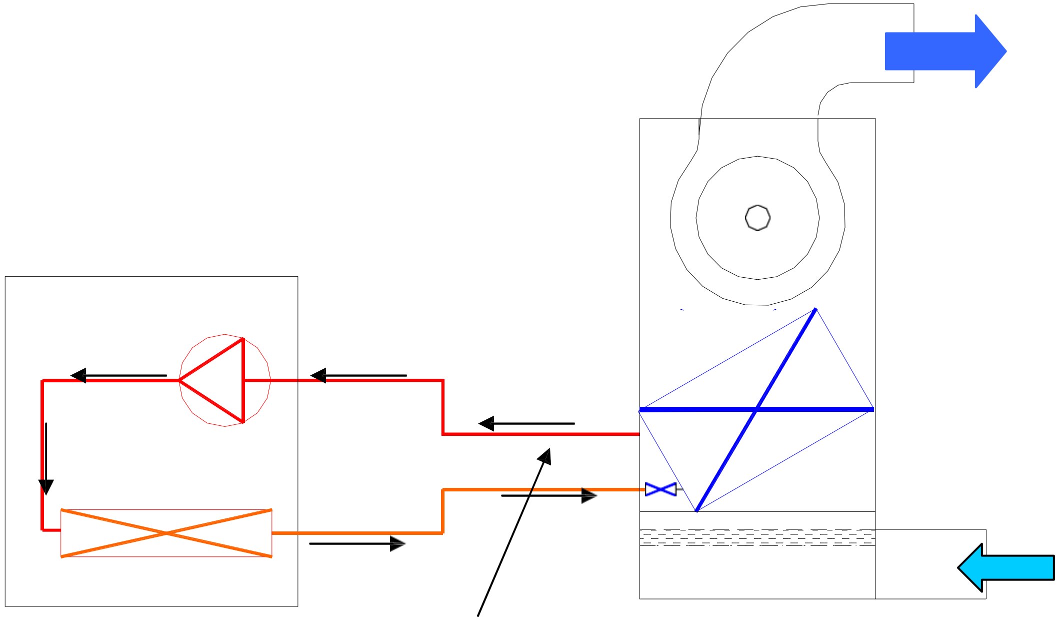
In air-water systems both air and water are used for providing required conditions in the conditioned space. The air and water are cooled or heated in a central plant. The air supplied to the conditioned space from the central plant is called as primary air, while the water supplied from the plant is called as secondary water. The complete system consists of a central plant for cooling or heating of water and air, ducting system with fans for conveying air, water pipelines and pumps for conveying water and a room terminal.

The room terminal may be in the form of a fan coil unit, an induction unit or a radiation panel. Figure shows the schematic of a basic air-

water system. Even though only one conditioned space is shown in the schematic, in actual systems, the air-water systems can simultaneously serve several conditioned spaces.



A typical package unit with remote condensing unit



Advantages of unitary refrigerant based systems

- Individual room control is simple and inexpensive.
- Each conditioned space has individual air distribution with simple adjustment by the occupants.
- System installation is simple and takes very less time.
- Operation of the system is simple and there is no need for a trained operator.
- Initial cost is normally low compared to central systems.

- Retrofitting is easy as the required floor space is small.
- Disadvantages of unitary refrigerant based systems:
- As the components are selected and matched by the manufacturer, the system is less flexible in terms of air flow rate, condenser and evaporator sizes.
- Power consumption per TR could be higher compared to central systems.
- Close control of space humidity is generally difficult.
- Noise level in the conditioned space could be higher.

- Limited ventilation capabilities.

- Systems are generally designed to meet the appliance standards, rather than the building standards.
- May not be appealing aesthetically.
- The space temperature may experience a swing if on-off control is used as in room air conditioners.
- Limited options for controlling room air distribution.
- Equipment life is relatively short.

Applications of unitary refrigerant based systems

Unitary refrigerant based systems are used where stringent control of conditioned space temperature and humidity is not required and where the initial cost should be low with a small lead time. These systems can be used for air conditioning individual rooms to large office buildings, classrooms, hotels, shopping centers, nursing homes etc. These systems are especially suited for existing building with a limitation on available floor space for air conditioning systems.

THANK YOU