REFRIGERATION AND AIR CONDITIONING

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RAFRIGERATION AND AIR CONDITIONING

REFRIGERATION:- It is the process of producing and maintaining the temperature of a given space or a substance below that of the immediate surrounding atmosphere.

The system maintained at the lower temperature is known as refrigerated system, while the equipment used to maintain this lower temperature is known as refrigeration system

AIR CONDITIONING:- It is a process by which temperature, humidity, flow and purity of air controlled simultaneously within a space irrespective of outside atmospheric conditions.

Air Conditioning

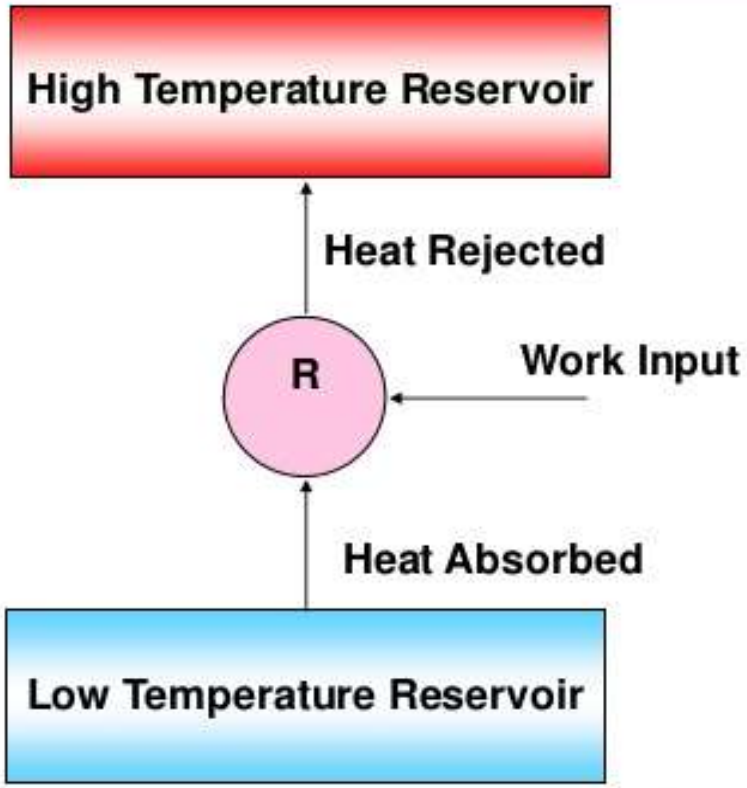
- An **air conditioner** is a system or a machine that treats **air** in a defined, usually enclosed area via a refrigeration cycle in which warm **air** is removed and replaced with cooler and more humid **air**. In construction, a complete system of heating, ventilation, and **air conditioning** is referred to as HVAC.

Introduction

Refrigeration & AC

How does it work?

Refrigeration and air conditioning is used to cool products or a building environment.



Refrigerating Effect (RE)and units of Refrigeration

REFRIGERATION EFFECT:- The cooling effect produced by a refrigerating system in a given time is known as refrigerating or effect. In S.I.units, it is expressed as KJ/s or KJ/min.

UNITS OF REFRIGERATION:- Refrigeration is expressed in terms of ton of refrigeration abbreviated as TR. A ton of refrigeration may be defined as the amount of refrigeration effect produced by the uniform melting of one tonne of ice from and at 0◦ C in 24 hours.

Latent heat of ice=335 KJ/Kg

1TR=1000X335 KJ in hours

$$=\frac{1000X335}{24X60}$$

=232.6 KJ/min.

Coefficient of Performance

CO-EFFICICIENT OF PERFORMANCE:-

It is the ratio of the refrigeration effect to the heat equivalent of the work supplied to the refrigerating system.

$$\text{Theoretical C.O.P.} = \frac{Q}{W}$$

Q= Refrigeration effect in heat units

W= Amount of work done in heat units

Relative C.O.P. :- The ratio of the actual C.O.P to the theoretical C.O.P. is known as relative co-efficient of performance.

$$\text{Relative C.O.P.} = \frac{Actual\ C.O.P}{Theoretical\ C.O.P.}$$

Difference between COP and Efficiency

- There are two type of devices, energy converters and energy transfering devices.
- But the difference is, What types of energies are involved in. There are two types of energies namely, **High Grade Energy and Low grade Energy**.
- For efficiency, the ratios are between (1-(heat out/ heat supplied)) **same form of energies**. That is heat, low grade energy. So it never be grater than 1.
- Whereas the COP deals with the ratio between (**heat removed/electricity supplied**) both are different types. Electricity is a high grade energy. And hence the COP is greater than 1.
- **COP = (Desired effect/ work done)**
- **Efficiency = (work done/ heat supplied)**

Natural and Artificial Refrigeration

- **a) Natural Method:** The natural method includes the utilization of ice or snow obtained naturally in cold climate. Ice melts at 0^0C. So when it is placed in space or system warmer than 0^0C, heat is absorbed by the ice and the space is cooled. The ice then melts into water by absorbing its latent heat at the rate of 335 kJ/kg. But, now-a-days, refrigeration requirements have become so high that the natural methods are inadequate and therefore obsolete.

- **b) Mechanical or Artificial Refrigeration:**
- i) Air systems: Uses air as a working fluid. Air does not undergo any change of phase, but absorbs heat due to temperature difference. ii) Chemical Agent Systems: The working fluid changing its phase while boiling from liquid to vapour state, thereby it absorbs the latent heat.

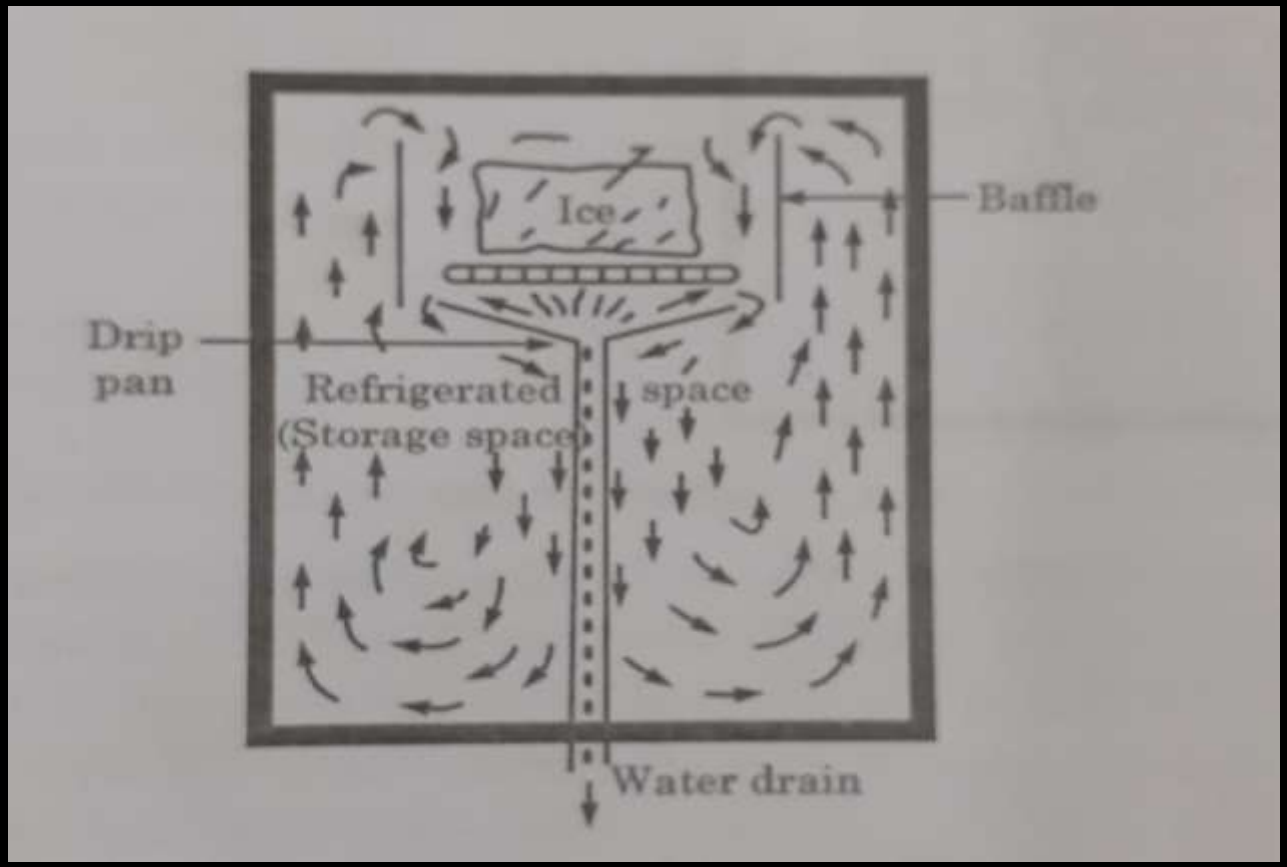
Methods of Refrigeration

- 1. Ice refrigeration
- 2. Dry Ice refrigeration
- 3. Air expansion Refrigeration
- 4. Evaporative refrigeration
- 5. Gas throttling refrigeration
- 6. Steam jet refrigeration
- 7. Liquid gas refrigeration
- 8. Vapour compression refrigeration
- 9. Vapour absorption refrigeration.
- 10. Thermo-Electric Refrigeration.

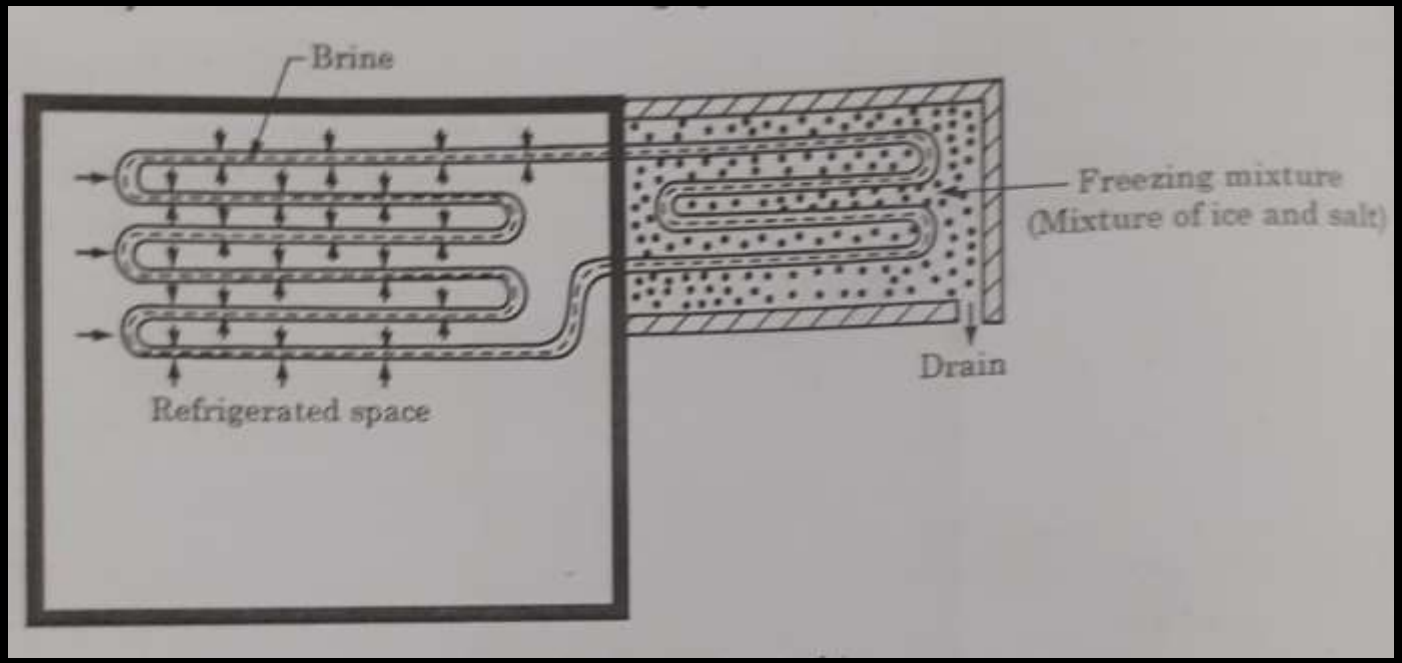
1. Ice Refrigeration

- **1) Ice Refrigeration**: In this method the ordinary ice is used for keeping the space at temperature below the surrounding temperature. The temperature of ice is considered to be 0^0C hence it can be used to maintain the temperatures of about 5 to 10 degree Celsius.
- If the temperature below 0^0C is required, then the mixture of ice and salt is used. This method of cooling is still being used for cooling the cold drinks, keeping the water chilled in thermos, etc.

Simple Ice Refrigerator



Indirect Ice Refrigerator

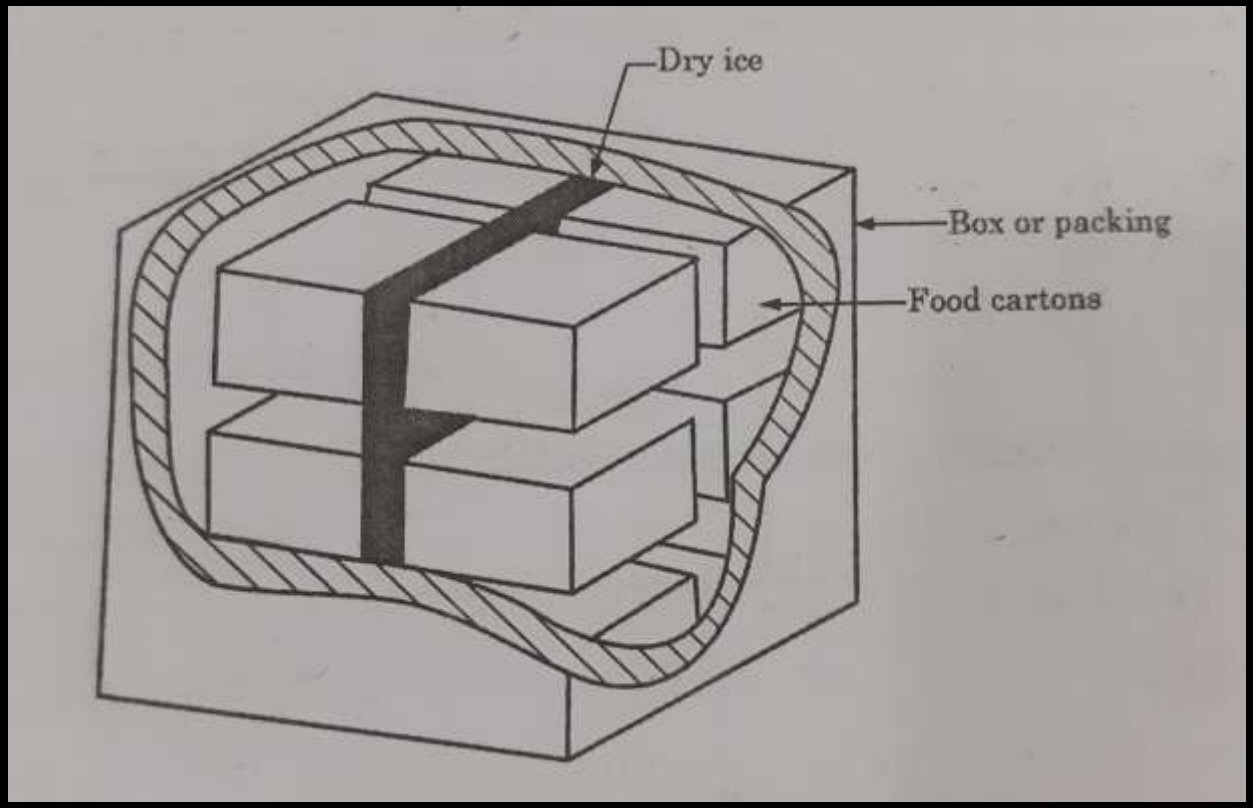


2. Dry Ice Refrigeration

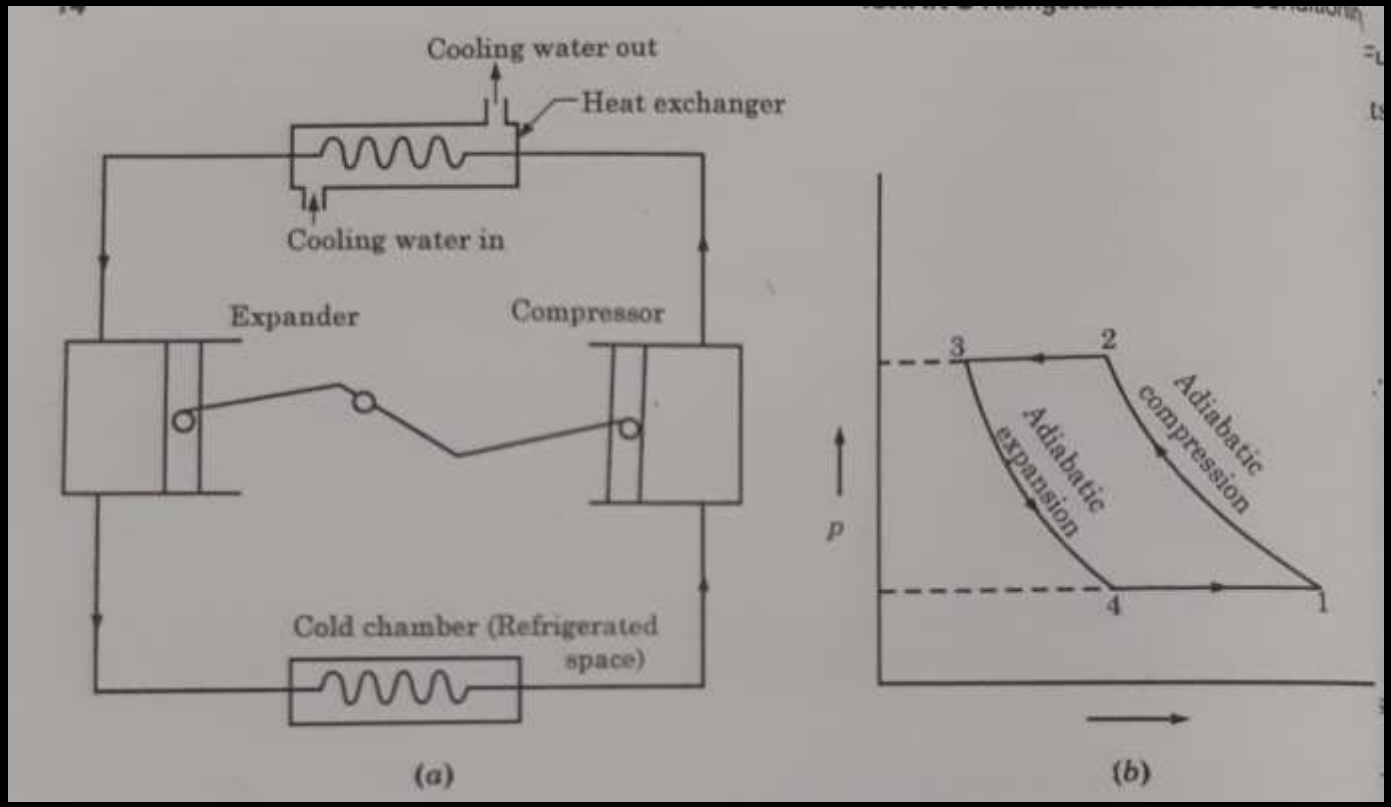
- Dry ice is the solidified form of CO2. It evaporates directly from solid to vapour without liquid phase. This phenomena is called sublimation. In this, the dry ice in the form of flakes or slabs Is placed on the cartons containing food stuffs. When dry ice sublimates, it will absorb heat from food stuff in the cartons and thus keeps them in a frozen condition. This is used for preservation of frozen foods and ice creams in storage and transportation. It has twice the heat absorbing capacity of ice refrigeration. However its cost is high.
- Solid Carbon dioxide (CO_2) is called dry ice and it has a peculiar characteristics that it changes from solid state to vapour state without getting converted into intermediate liquid state (sublimation). Due to the change of state, it absorbs heat equivalent to enthalpy of vaporization.

- The sublimation temperature of dry ice at atmospheric pressure is -78°C.
- Dry ice is used to preserve foodstuff during transportation. Now a days it is universally used to preserve food in air-transportation. Dry ice slabs are usually packed in frozen food cartons on either side or on the top of the food packages, dry ice absorbs heat from the foodstuff and preserve them in the frozen state.

Dry Ice Refrigeration



3. Air Expansion Refrigeration



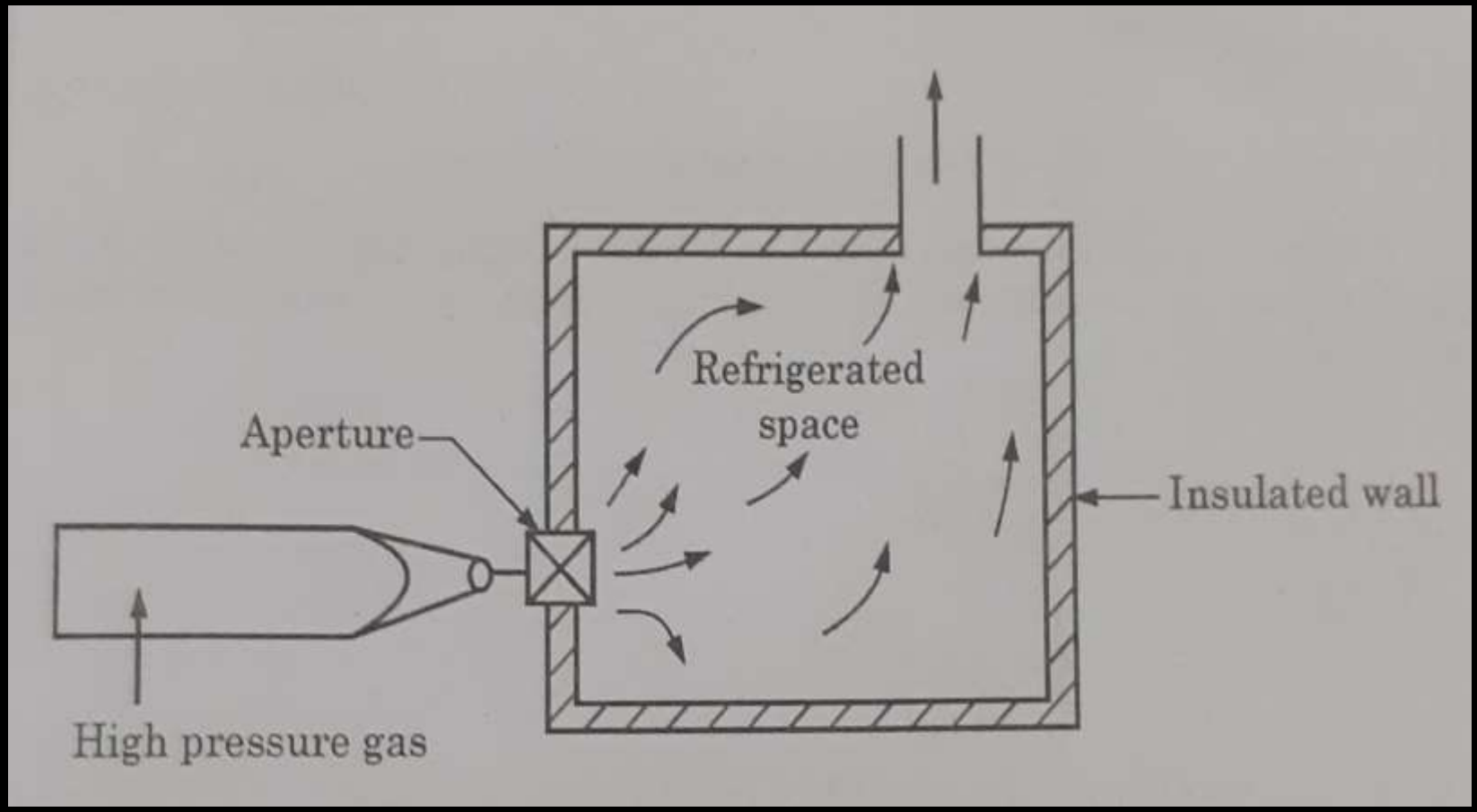
4. Evaporative Refrigeration

- Evaporative refrigeration makes use of the principle that when a liquid
- evaporates, it absorbs heat equivalent to its latent heat of vaporization from the surroundings, thereby cooling it.
- Cooling of water in the earthen pitcher – the water coming out of the pores of the pitcher evaporates when it comes in contact with dry air, thereby cooling the water in the pitcher.
- When a drop of spirit is put on the palm of hand, it evaporates producing cooling effect.
- Evaporation cooling may be defined as the adiabatic transfer of heat from air to water.
- Evaporation cooling may be defined as the adiabatic transfer of heat from air to water.
- It is utilized in cooling towers where condenser water is cooled by spraying it from top and forcing a current of air from below. Another application is evaporative type of condensers. Yet another application is in desert coolers or room coolers. Dry air is passed through wet pads. Due to evaporation, air gets cooled. The principle is also utilized in making artificial snow.

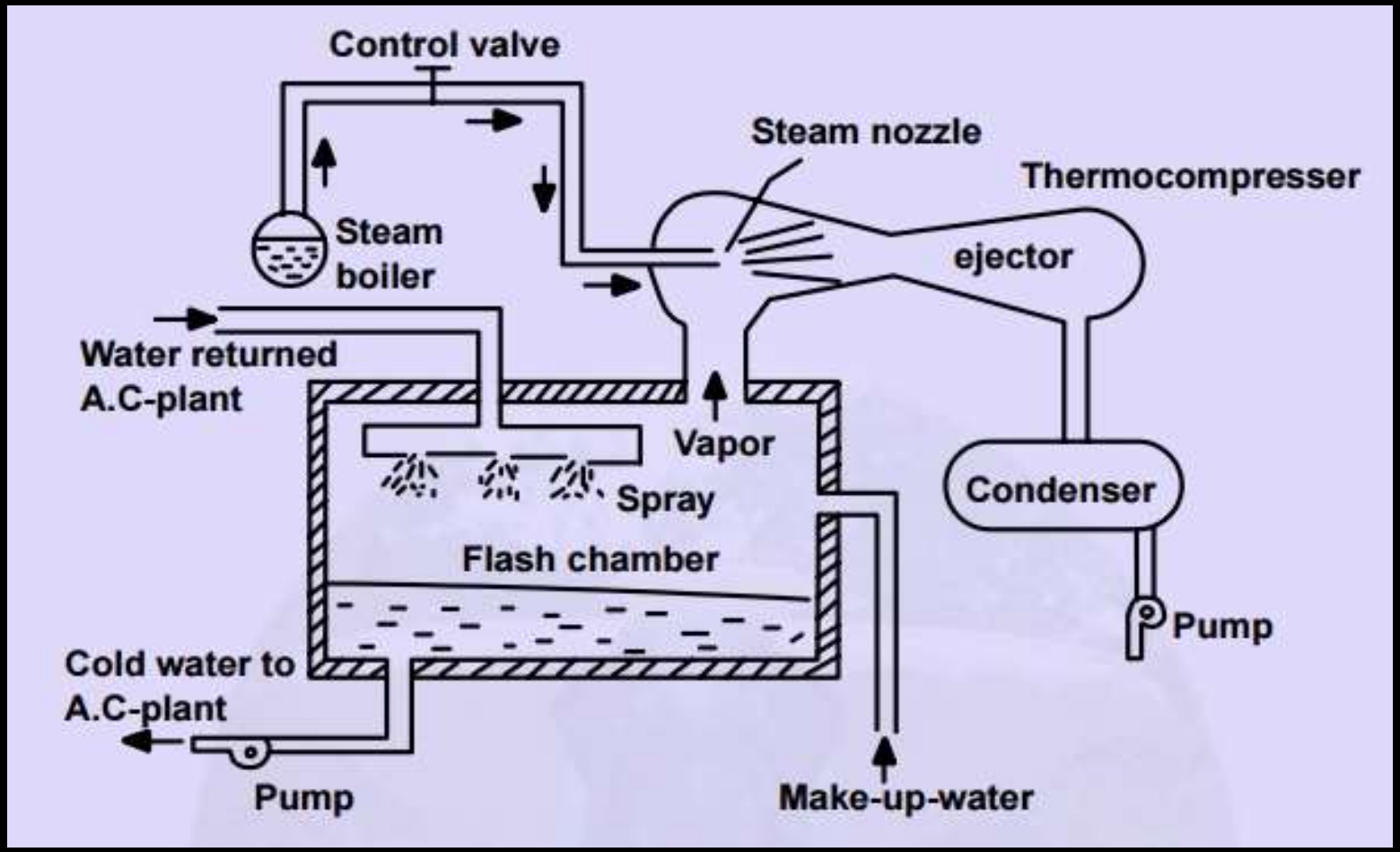
5.Gas Throttling Refrigeration

- **Gas Throttling Refrigeration** : In the gas throttling refrigeration process, there is no change in enthalpy and also for a perfect gas, there is no change in temperature. However, for actual gases there is a substantial change, usually a decrease in temperature. This temperature drop depends upon the Joule- Thomas coefficient, the pressure drop, and the initial state of the gas.
- High pressure gas is throttled through porous plug into the space to be cooled and escapes outside after absorbing heat from the space. This produces the refrigeration effect in the space or the product kept in the space. 196 Mechanical Engineering Technician The gas throttling refrigeration system.

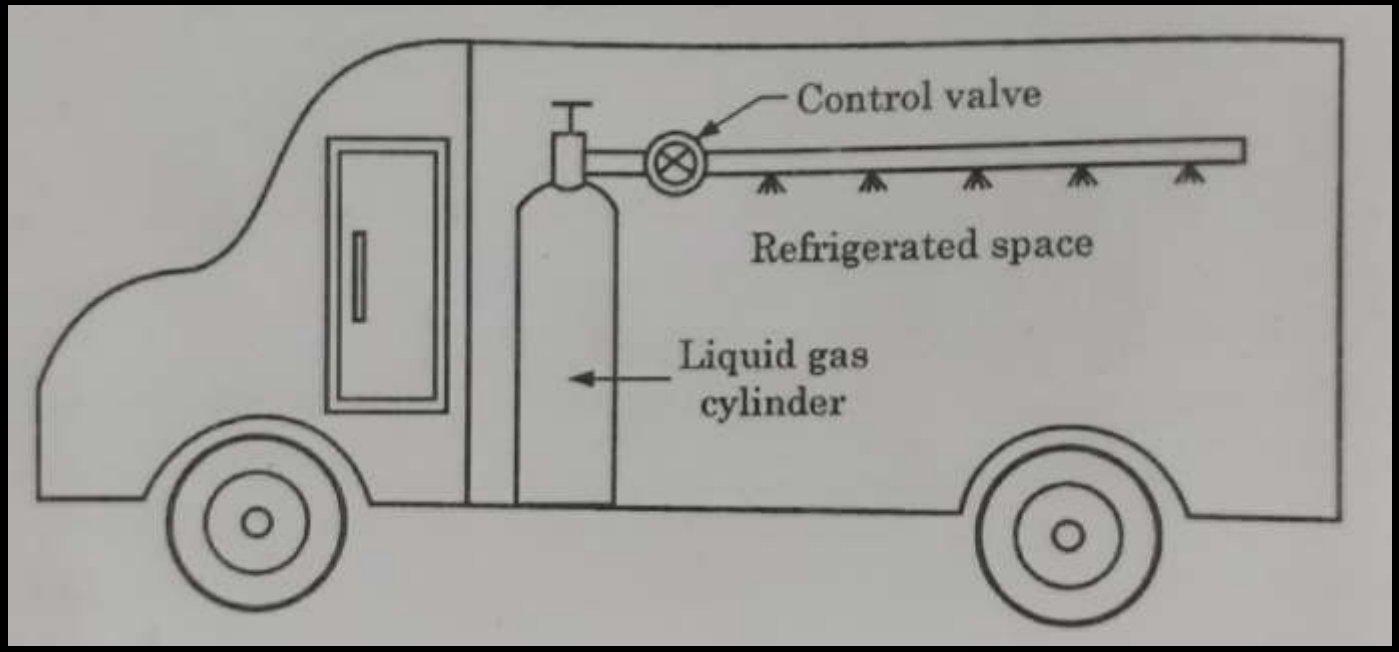
Gas Throttling Refrigeration



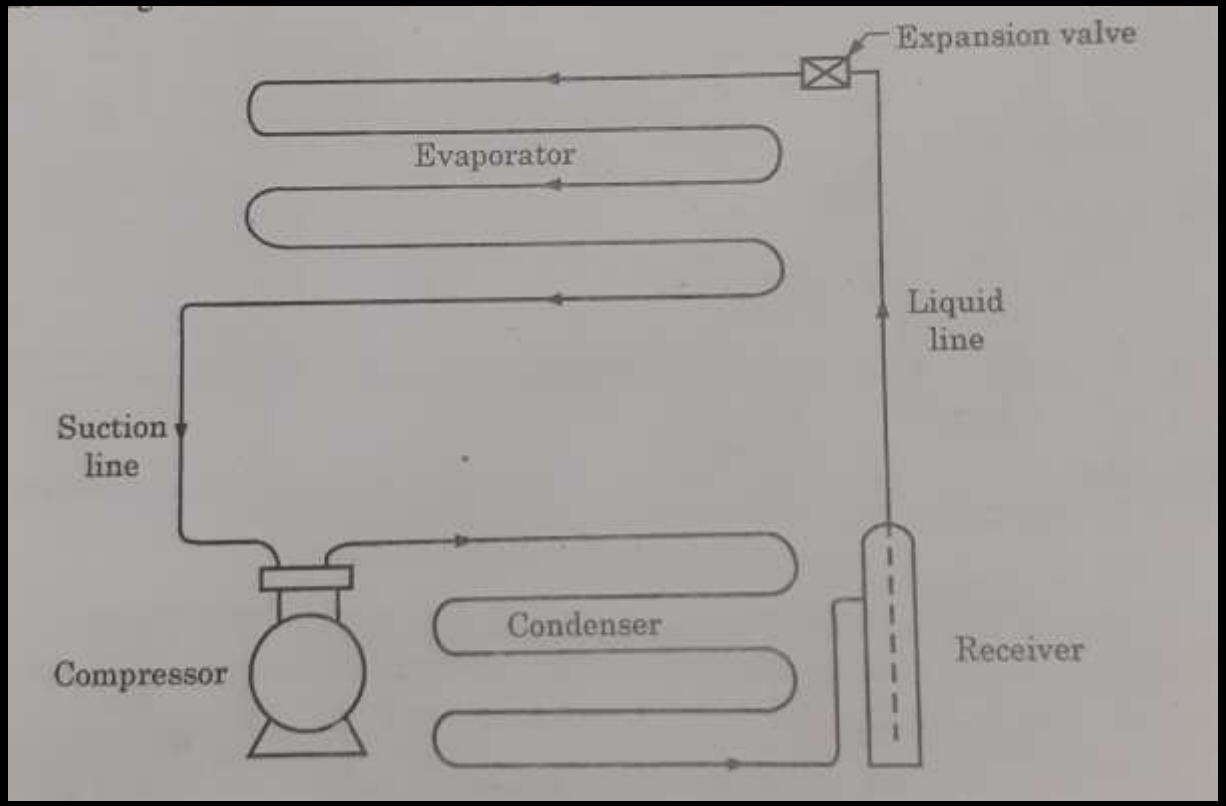
6. Steam Jet Refrigeration



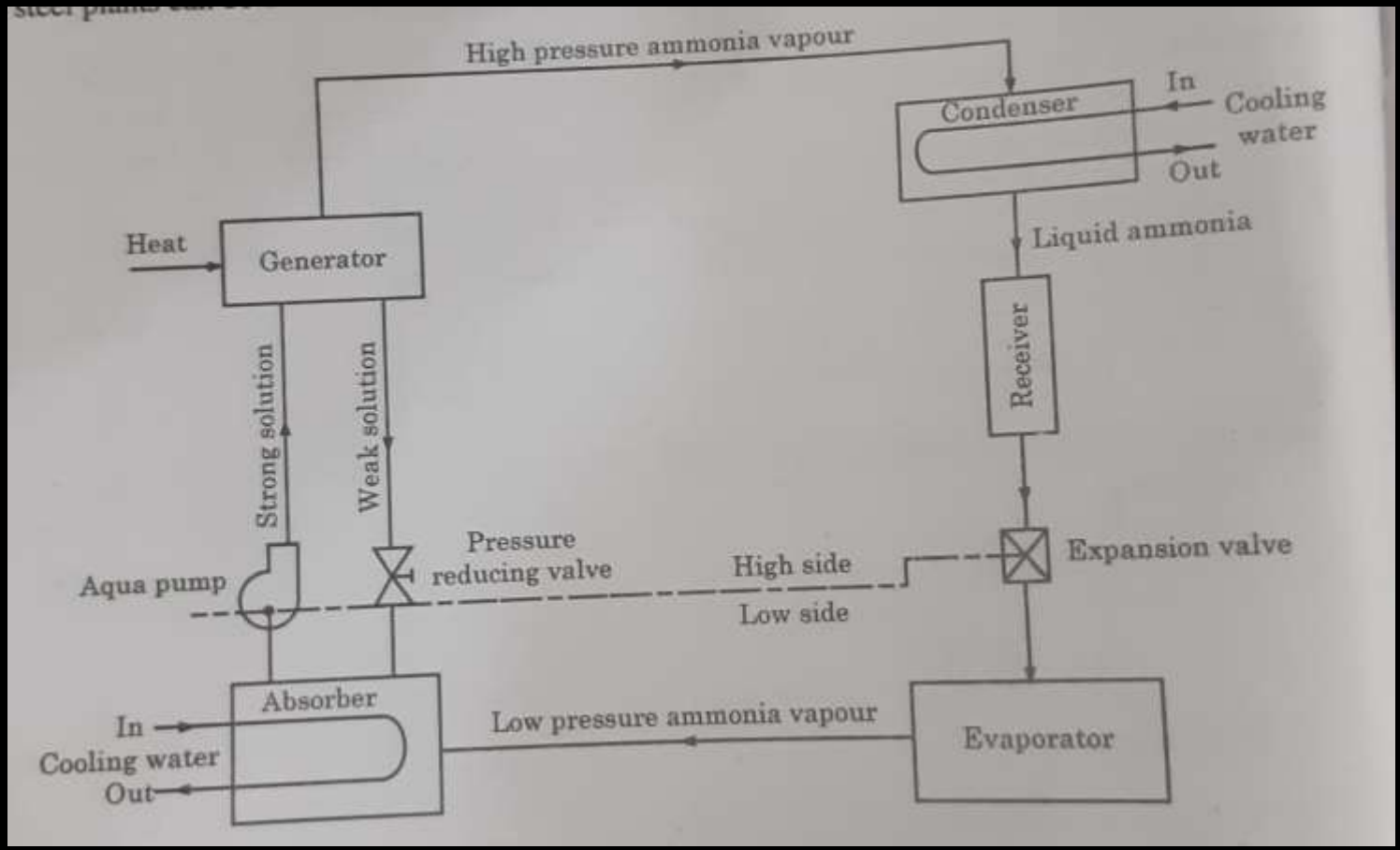
7. Liquid Gas Refrigeration



8. Vapour Compression Refrigeration



9. Vapour Absorption Refrigeration



10. Thermo-electric Refrigeration

- Thermo-electric refrigeration type employs Peltier's effect. when two dissimilar metals are joined on either ends and a direct current is circulated through it, one joint gets cooled while the other gets heated.
- Antimony (Sb) and Bismuth (Bi) are commonly used metals as they are electro-chemically opposite in their polarity. If the cold end is placed in a closed space, it gets cooled. If the magnitude of current is increased and a series of such strips are placed together a good cooling effect can be produced.

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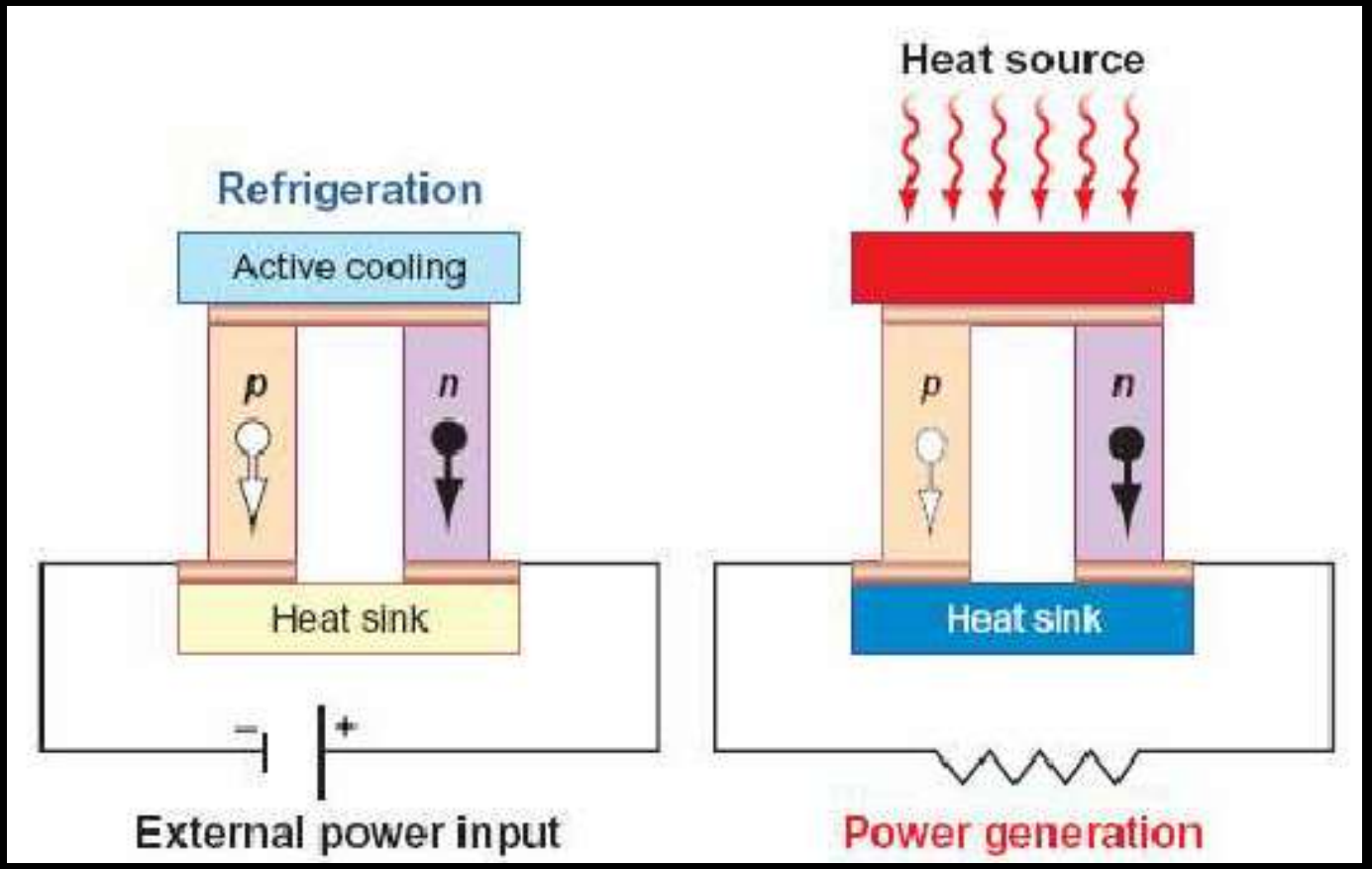
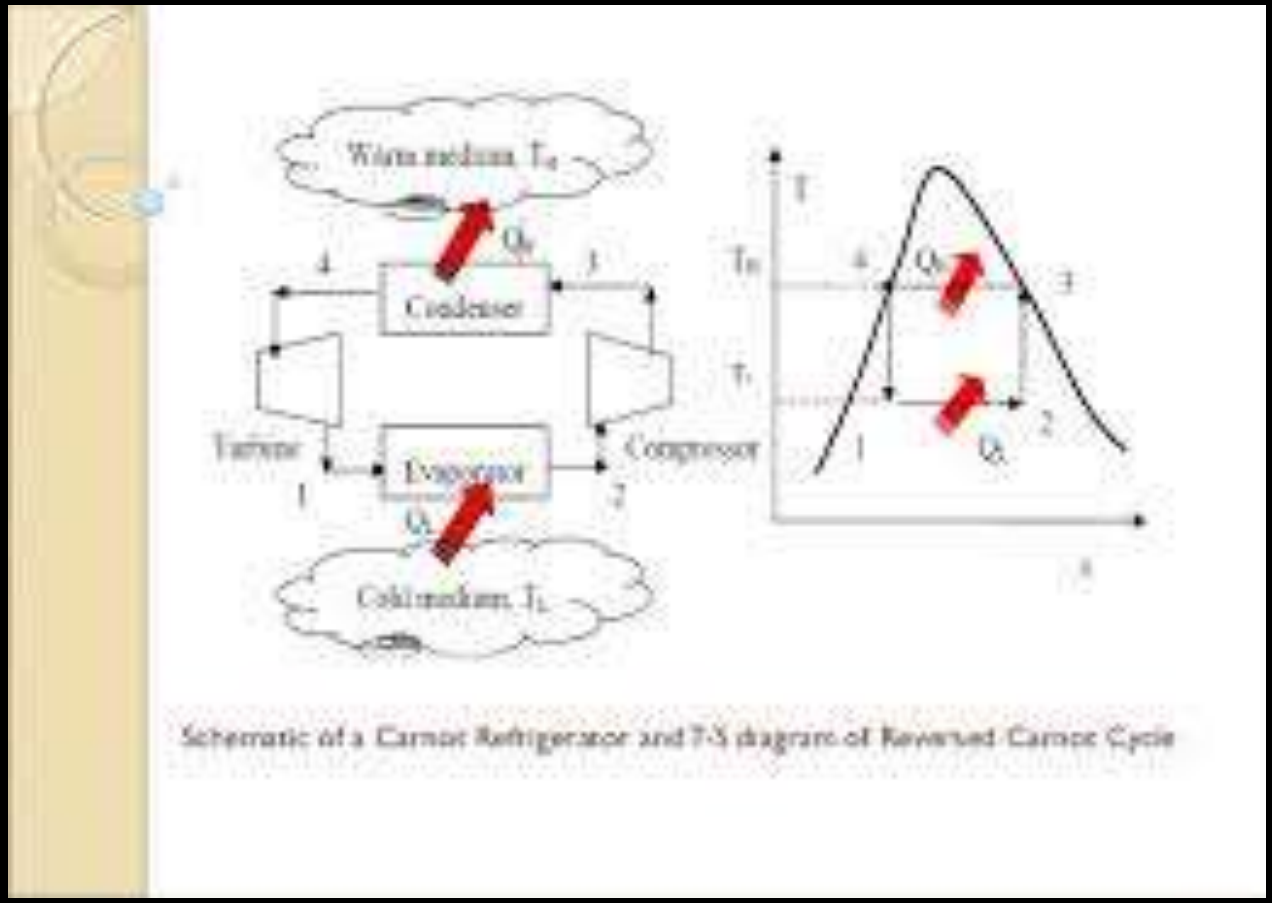
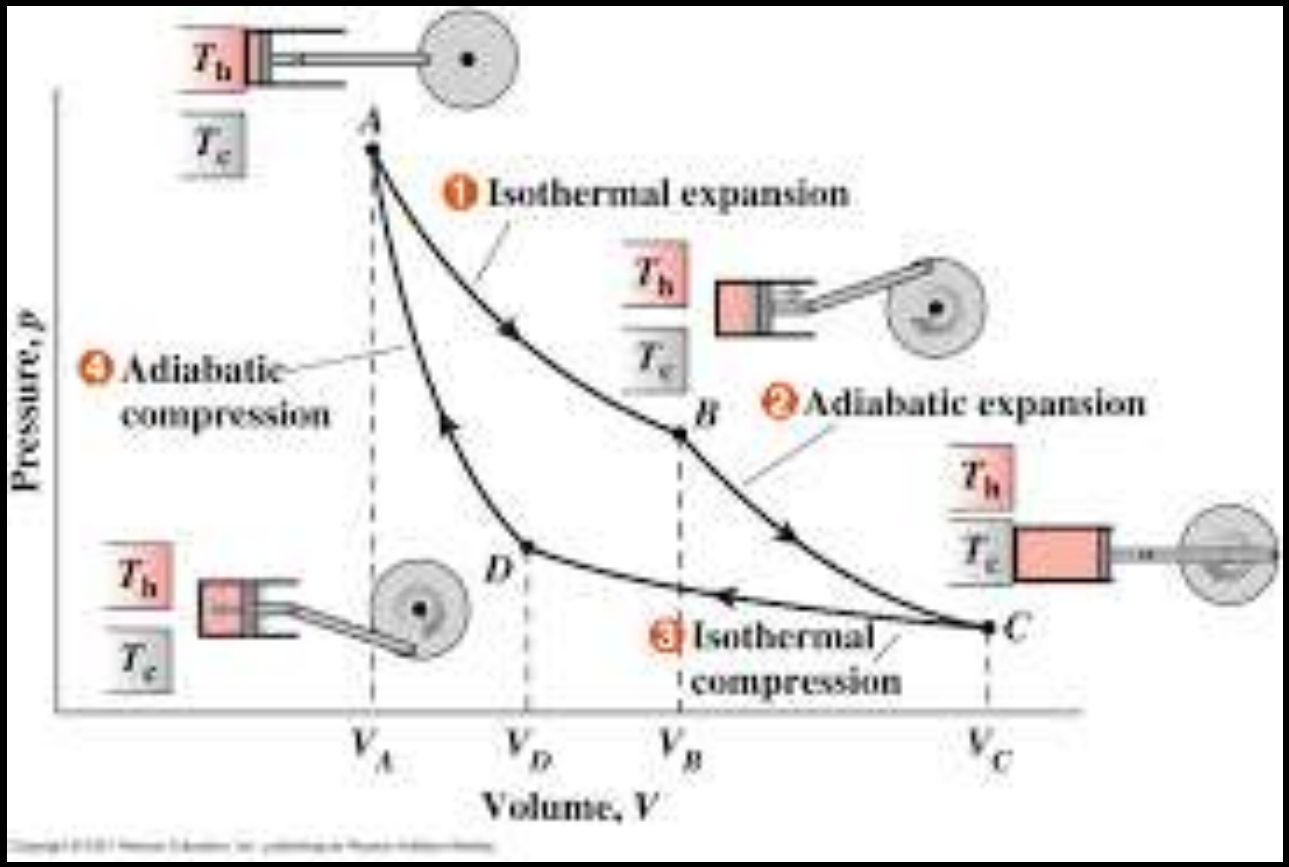

Refrigeration
Active cooling
p
n
Heat sink
−
+
External power input
Heat source
p
n
Heat sink
Power generation

Reversed Carnot Cycle

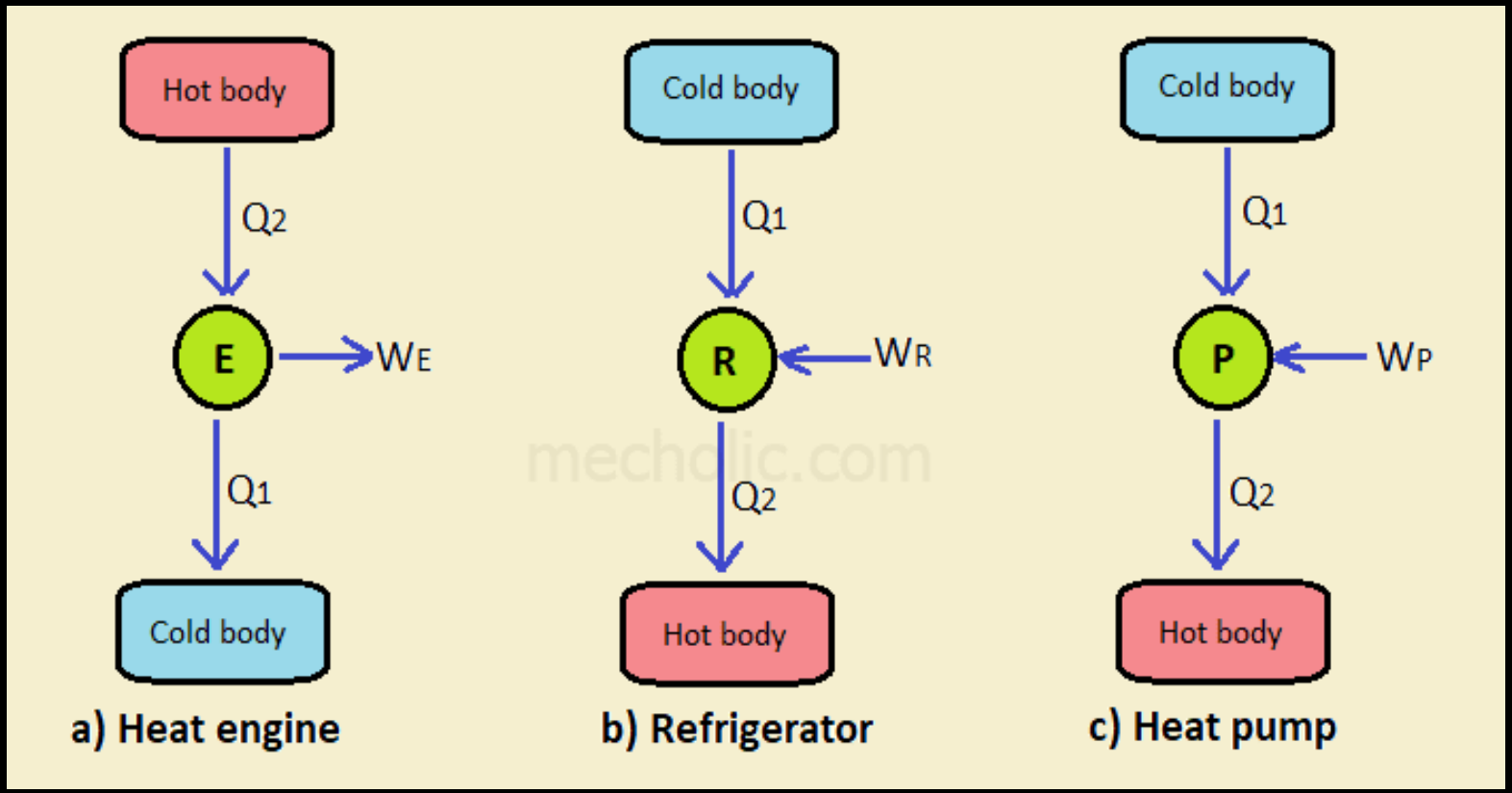


Schematic of a Carnot Refrigerator and T-S diagram of Reversed Carnot Cycle

Cont..


T_h
T_c
A
1 Isothermal expansion
T_h
T_c
4 Adiabatic compression
B
2 Adiabatic expansion
T_h
T_c
T_h
T_c
D
3 Isothermal compression
C
Pressure, p
V_A
V_D
V_B
V_C
Volume, V

Difference bet Heat Engine, Refrigerator and Heat Pump



COP of Heat Engine, Refrigerator and Heat Pump

(*a*) In a heat engine, the heat supplied to the engine is converted into useful work. If Q_2 is the heat supplied to the engine and Q_1 is the heat rejected from the engine, then the net work done by the engine is given by

$$W_E = Q_2 - Q_1$$

In case of a heat engine, the efficiency or C.O.P.,

$$\eta_E \text{ or } (C.O.P.)_E = \frac{\text{Workdone}}{\text{Heat supplied}}$$

$$= \frac{W_E}{Q_2}$$

$$= \frac{Q_2 - Q_1}{Q_2}$$

It is always less than unity.

(*b*) A refrigerator is a reverse of heat engine. It cools or maintains the temperature of a body lower than the atmospheric temperature. It extracts heat (Q_1) from a cold body and delivers heat (Q_2) to a hot body by expending work on the system. Thus,

$$W_R = Q_2 - Q_1$$

$$(C.O.P.)_R = \frac{\text{Amount of heat extracted from the cold body}}{\text{Amount of work done on the system}}$$

$$= \frac{Q_1}{W_R}$$

$$= \frac{Q_1}{Q_2 - Q_1}$$

$$W_p = Q_2 - Q_1$$

Coefficient of performance which is called energy performance ratio (E.P.R.) is given

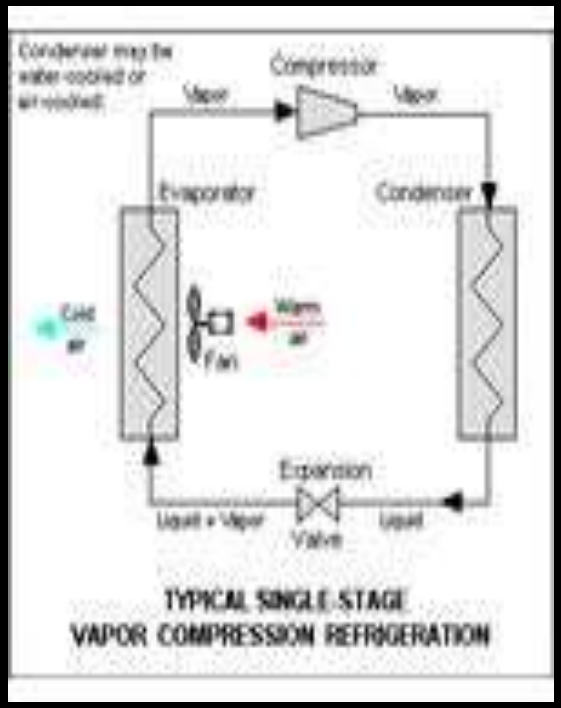
$$(C.O.P.)_P \text{ or } E.P.R. = \frac{\text{Amount of heat delivered to the hot body}}{\text{Amount of work done on the system}}$$

$$= \frac{Q_2}{W_P} = \frac{Q_2}{Q_2 - Q_1}$$

$$= \frac{Q_1}{Q_2 - Q_1} + 1$$

$$= (C.\,O.\,P.)_R + 1$$

Chapter-2 Vapour Compression Refrigeration System



-The **Vapor Compression Refrigeration Cycle** is nearly 200 years old, but it does not seem ready to leave the scene any time soon. While some people have viewed this method as environmentally harmful and inefficient, the cycle is still applicable in the industrial sphere.

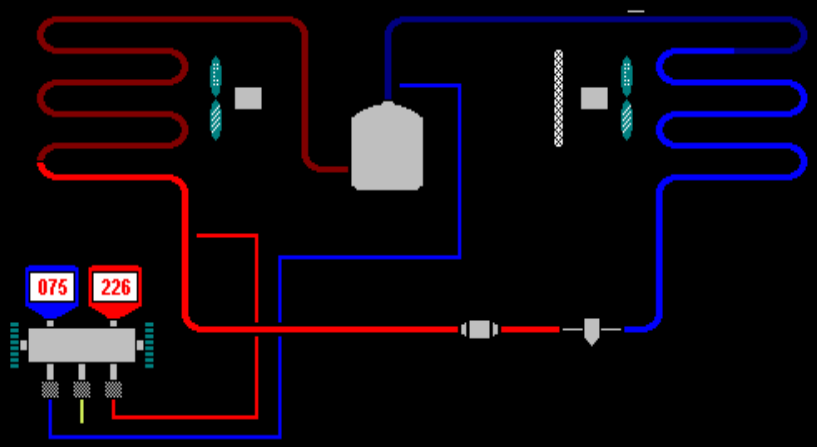
-The simplest explanation of this system is a heat engineworking in reverse, technically referred to as reverse Carnot engine. In other words, it is the transfer of heat from a cold reservoir to a hot one.

-In VCR the refrigerant undergoes phase changes, is one of the many refrigeration cycles and is the most widely used method for air-conditioning of buildings and automobiles. It is also used in domestic and commercial refrigerators, large-scale warehouses for chilled or frozen storage of foods and meats, refrigerated trucks and railroad cars, and a host of other commercial and industrial services

The Refrigeration Cycle

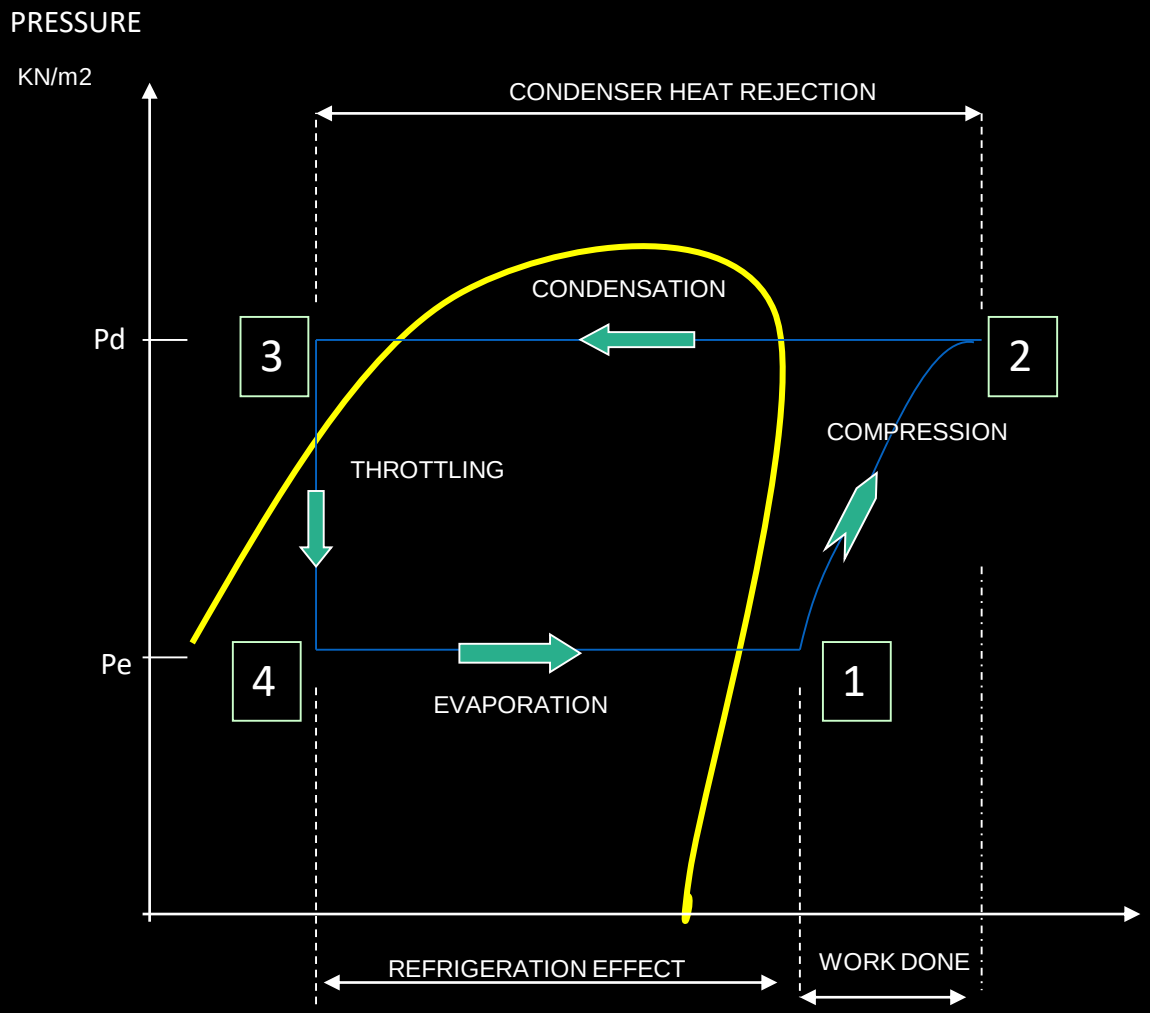
There are four main components in a refrigeration system:

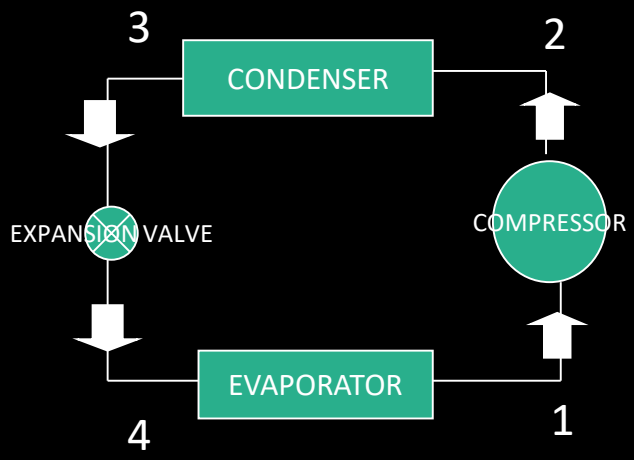
- The Compressor
- The Condensing Coil
- The Metering Device
- The Evaporator

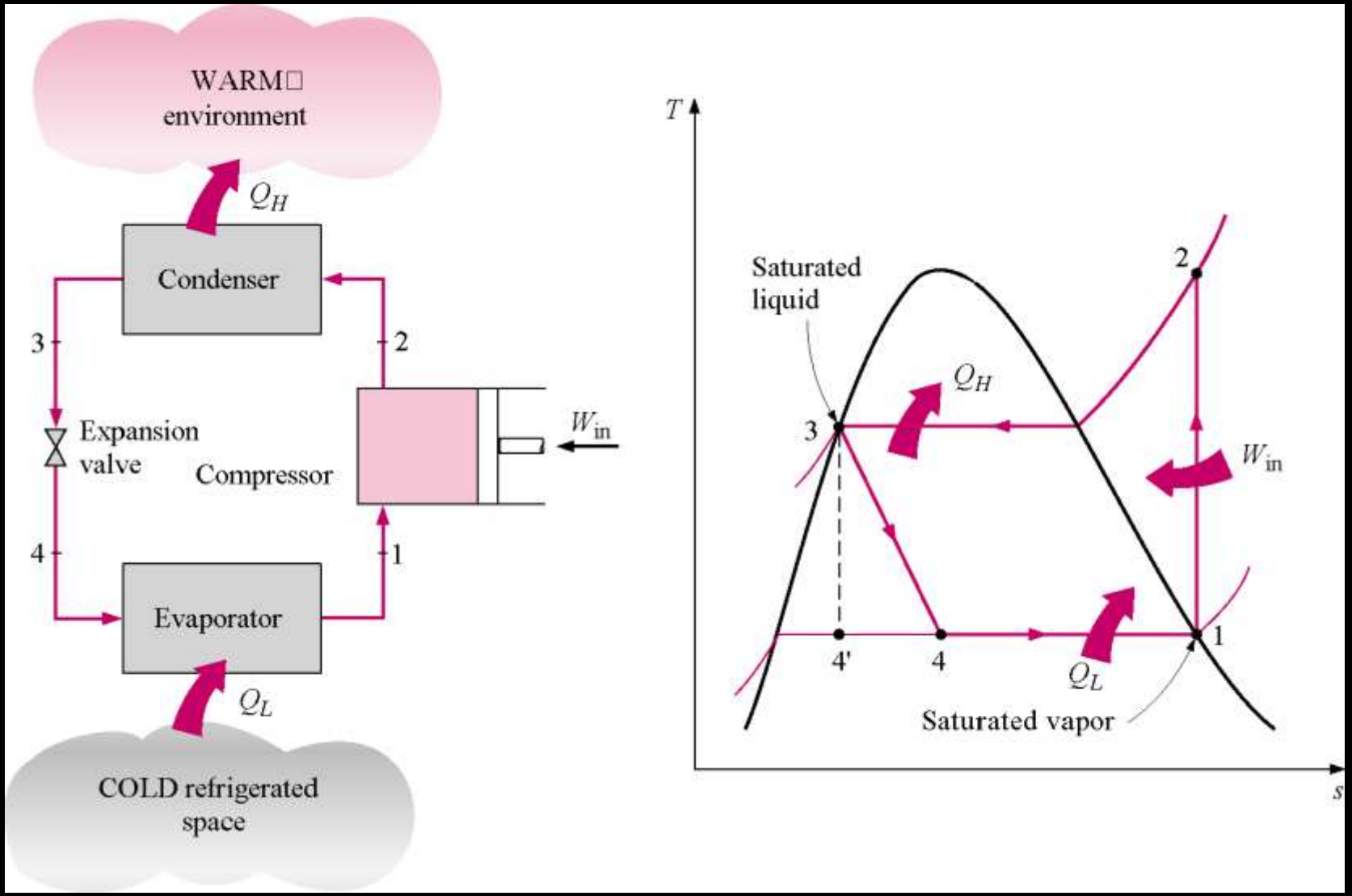


- Two different pressures exist in the refrigeration cycle. The evaporator or low pressure, in the "low side" and the condenser, or high pressure, in the "high side". These pressure areas are divided by the other two components. On one end, is the metering device which controls the refrigerant flow, and on the other end, is the compressor.

Vapour Compression Cycle

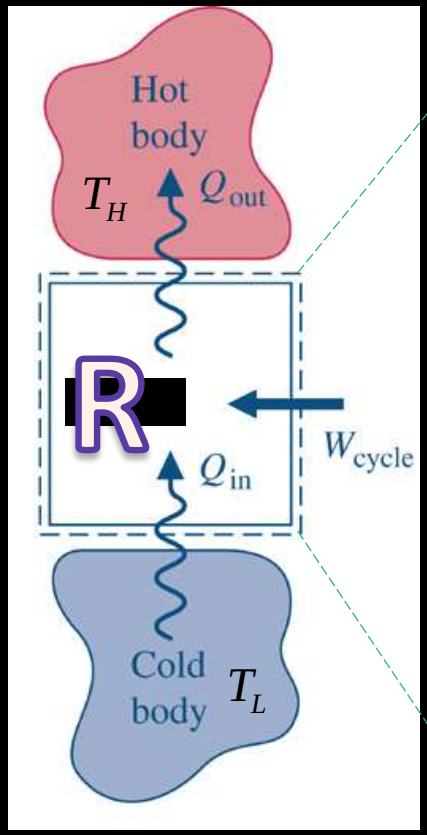


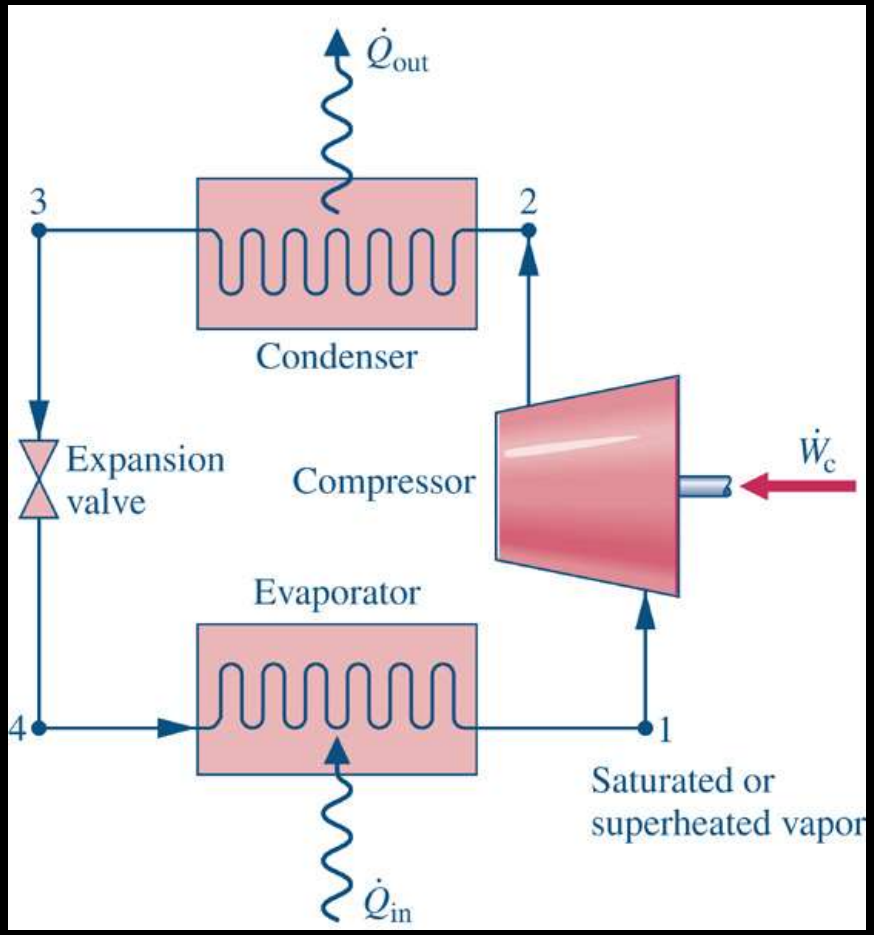




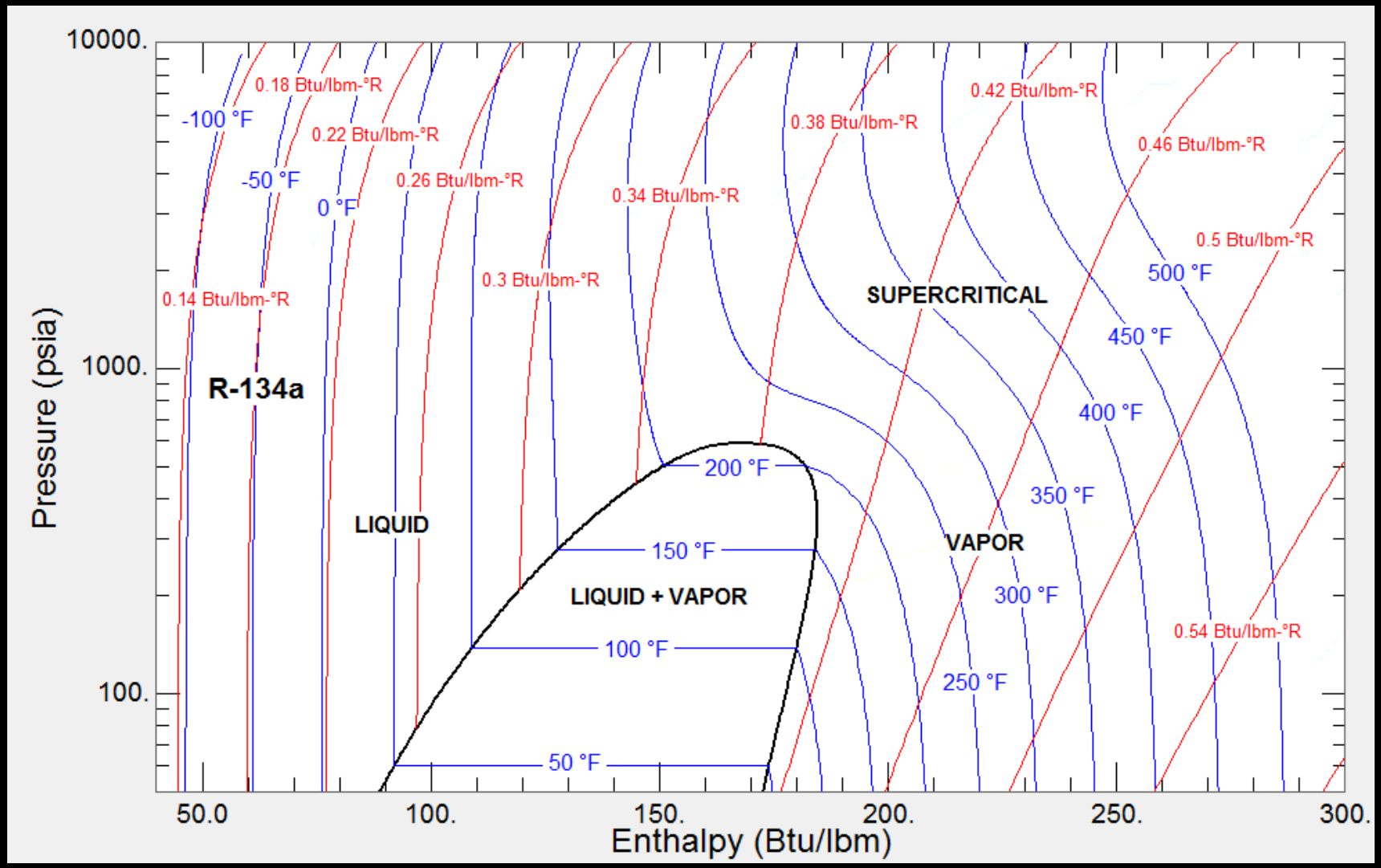
S – entropy means transformation, increases with increase in temperature and decreases with decrease in temperature

ƍ Q = T ds

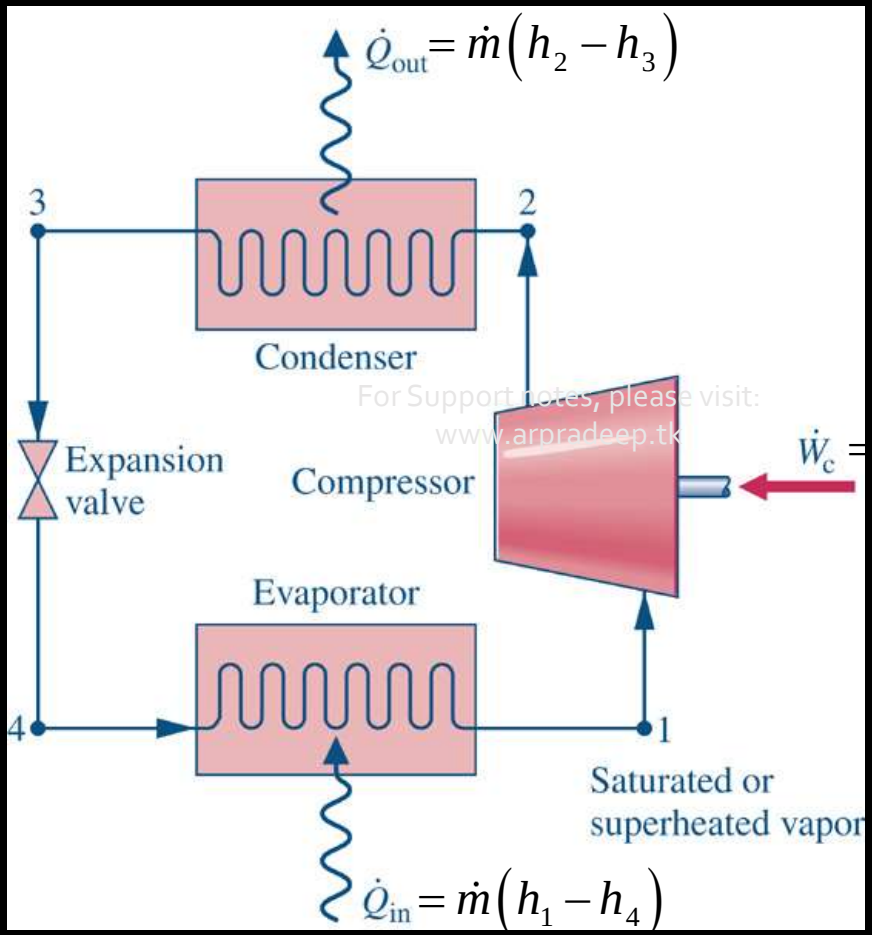

Hot
body
T_H
Q_{out}
R
W_{cycle}
Q_{in}
Cold
body
T_L


$\dot{Q}_{out}$
3
2
Condenser
Expansion
valve
Compressor
$\dot{W}_c$
Evaporator
4
1
Saturated or
superheated vapor
$\dot{Q}_{in}$

The Pressure-Enthalpy Diagram



Vapor Compression Refrigeration Analysis



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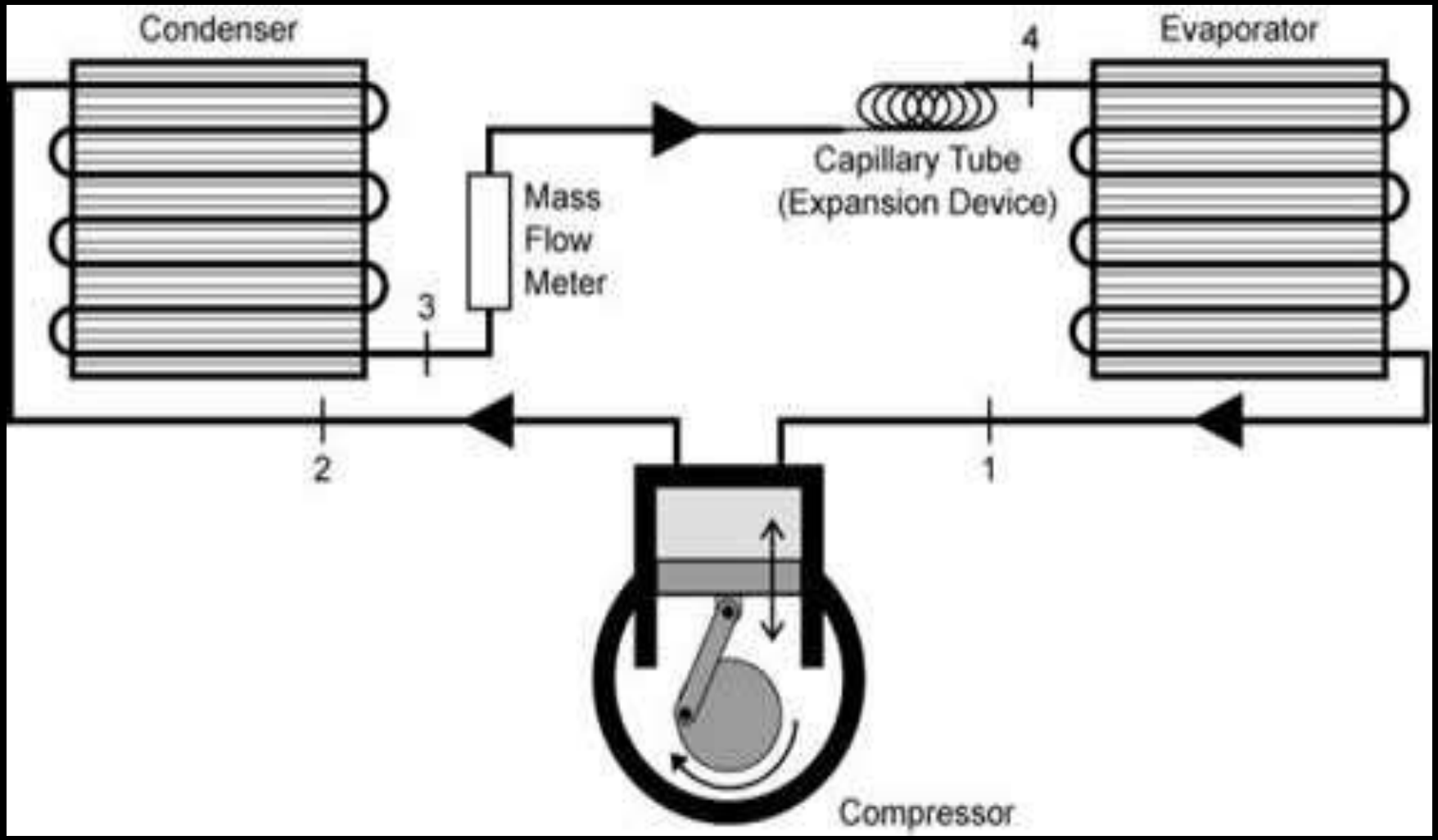
Performance

Vapour Compression Refrigeration System



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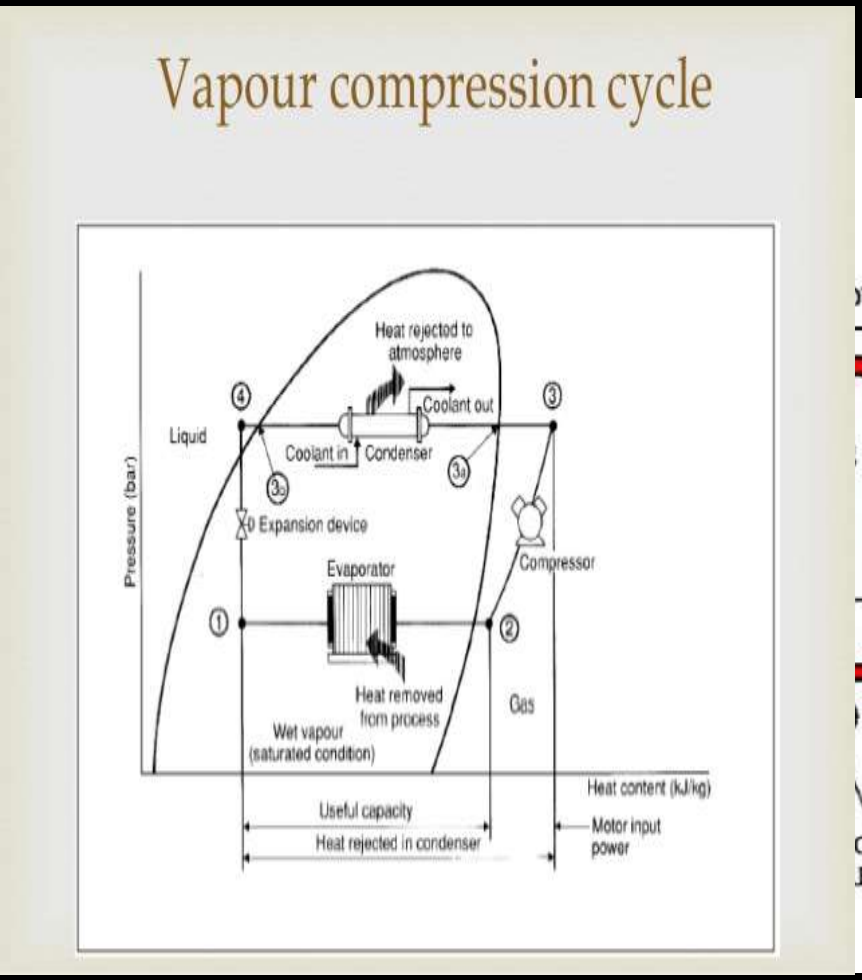
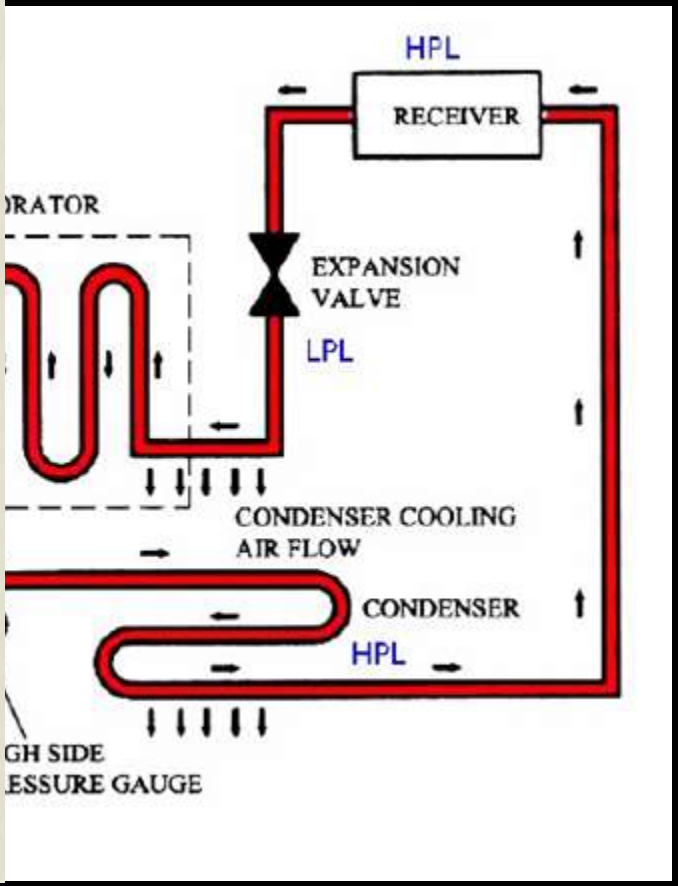
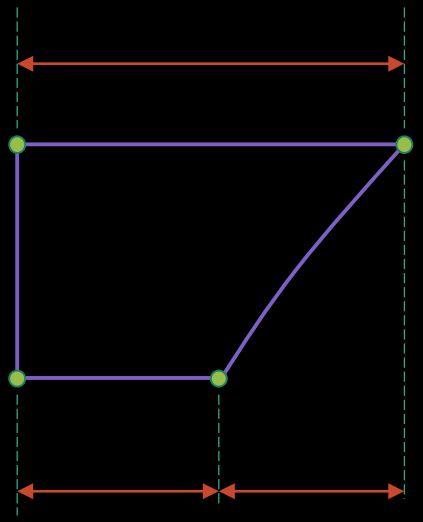
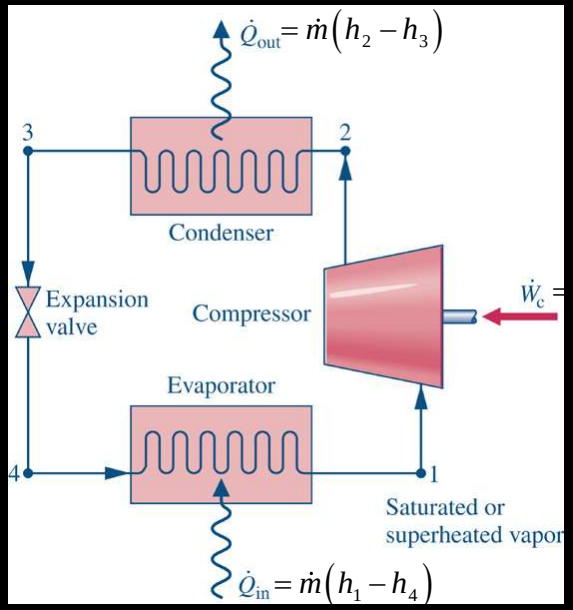

Vapour compression cycle
Heat rejected to atmosphere
Coolant out
Liquid
Coolant in
Condenser
Expansion device
Evaporator
Compressor
Heat removed from process
Gas
Wet vapour (saturated condition)
Pressure (bar)
Heat content (kJ/kg)
Useful capacity
Heat rejected in condenser
Motor input power


HPL
RECEIVER
EXPANSION VALVE
LPL
CONDENSER COOLING AIR FLOW
CONDENSER
HPL

The Ideal VCR Cycle on the P-h Diagram

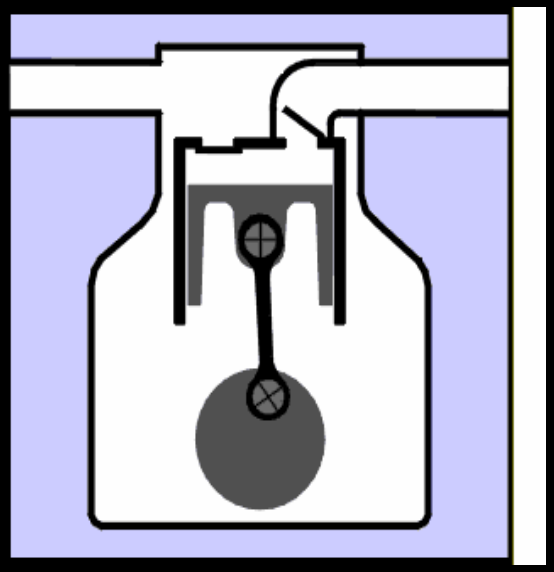


1-2: Isentropic compression
2-3: Isobaric heat rejection
3-4: Isenthalpic expansion
4-1: Isobaric heat addition



Vapour Compression Refrigeration System - Construction

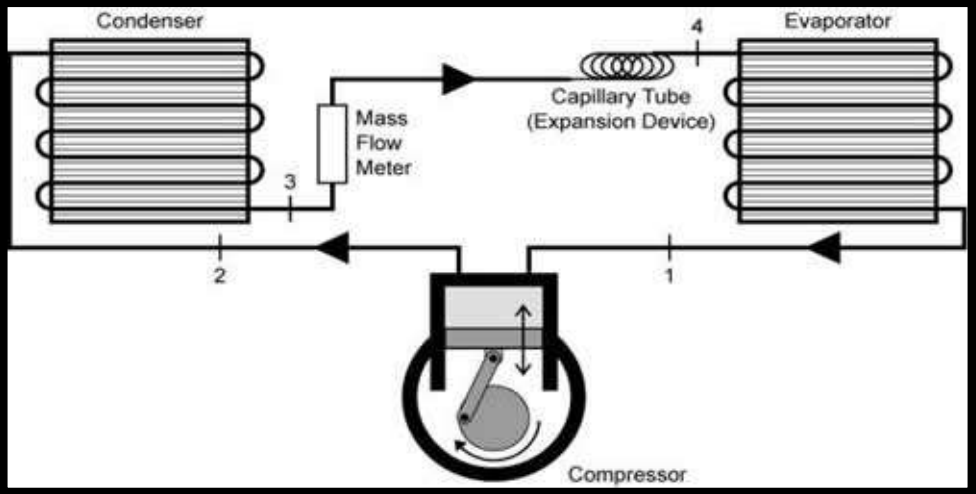
- This system consists of a compressor, condenser, a receiver tank, an expansion valve and an evaporator.
- **Compressor :** Reciprocating compressors generally used. For very big plants centrifugal compressors directly coupled with high speed rotating engines (gas turbine) are used



Vapour Compression Refrigeration System - Construction

- **Condenser :** It is a coil of tubes made of copper.
- **Receiver tank:** It is the reservoir of liquid refrigerant.
- **Expansion Valve:** This is a throttle valve. High pressure refrigerant is made to flow at a controlled rate through this valve.
- **Evaporator :** It is the actual cooler and kept in the space to be cooled. The evaporator is a coil of tubes made of copper.

Vapour Compression Refrigeration System - Working



Working :

1. The low pressure refrigerant vapour coming out of the evaporator flows into the compressor.
2. The compressor is driven by a prime mover.
3. In the compressor the refrigerant vapour is compressed.
4. The high pressure refrigerant vapour from the compressor is then passed through the condenser.
5. The refrigerant gives out the heat it had taken in the evaporator (N)

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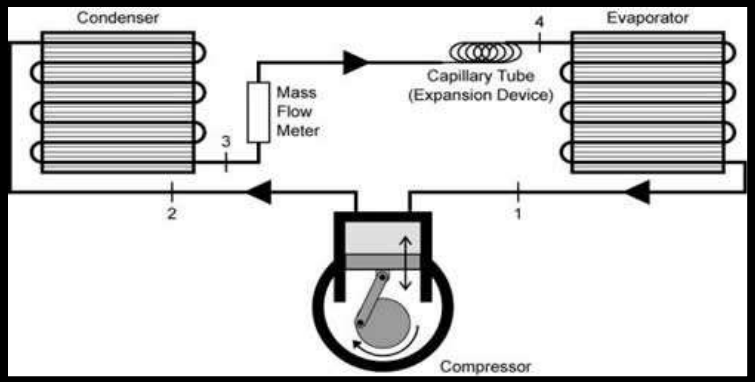
Vapour Compression Refrigeration System - Working



Working :

6. The heat equivalent of work done on it (w) on the compressor.
7. This heat is carried by condenser medium which may be air or water.
8. The high pressure liquid refrigerant then enters the expansion valve.
9. This valve allows the high pressure liquid refrigerant to flow at a controlled rate into the evaporator.
10. While passing though this valve the liquid partially evaporates.

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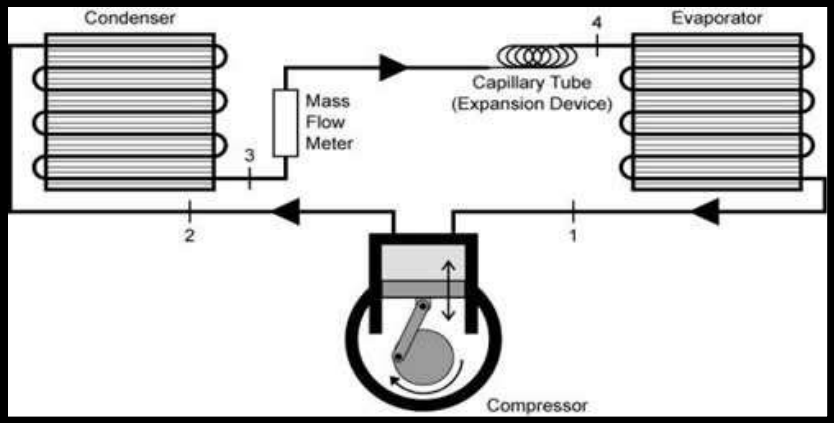
Vapour Compression Refrigeration System - Working



Working :

11. Most of the refrigerant is vapourised only in the evaporator, at a low pressure.

12. In the evaporator the liquid refrigerant absorbs its latent heat of vapourisation from the material which is to be cooled.

13. Thus the refrigerating effect (N) is obtained.

14. Then the low pressure refrigerant enters the compressor and the cycle is repeated.

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Refrigeration Effect and Capacity

Refrigeration **Effect**:

Refrigeration **Capacity**:

Refrigeration capacity is often expressed in **tons** of refrigeration. Definition …

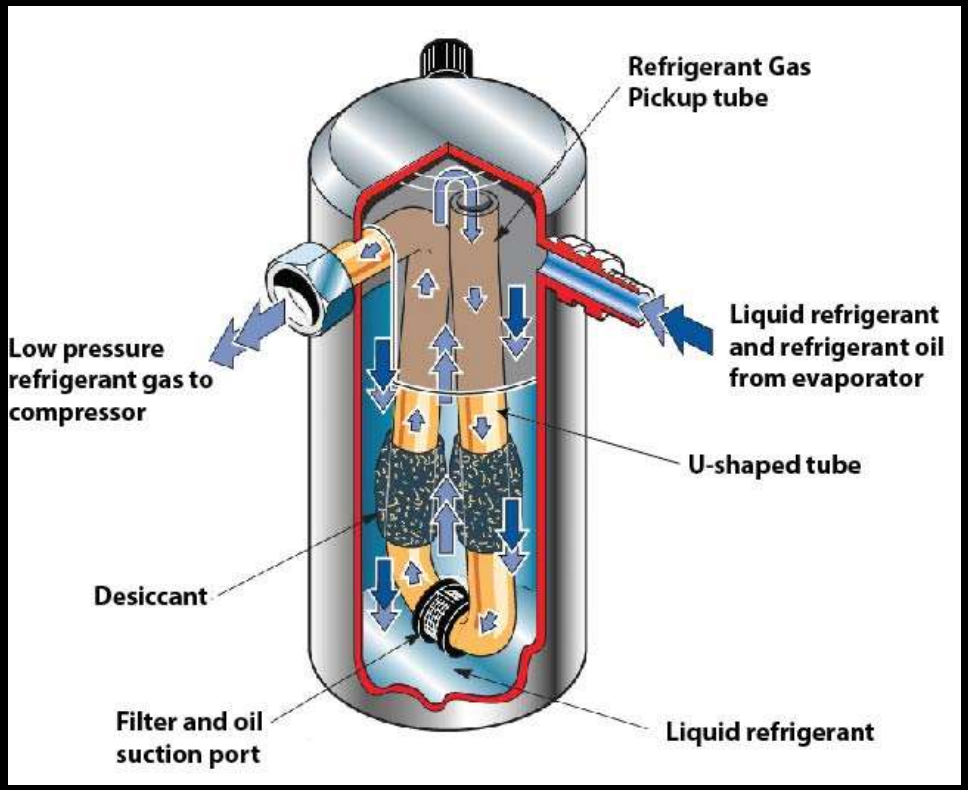
1 ton of refrigeration is the steady state heat transfer rate required to melt 1 ton of ice at 32°F in 24 hours.

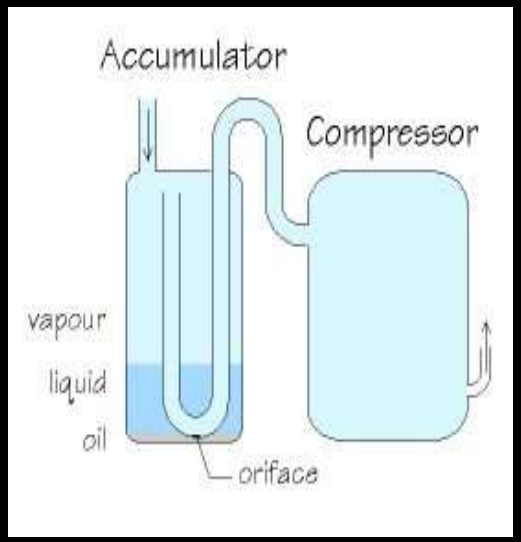
1 ton = 12,000 Btu/hr = 3.516 kW

Use of Accumulator in Refrigeration System

- A suction accumulator is used to prevent liquid refrigerant flood-back to the compressor. Accumulators are commonly used on heat pumps, transport refrigeration systems, low-temperature supermarket refrigeration systems, and in any situation where liquid refrigerant is a concern. The accumulator is installed in the suction line, close to the compressor.
- It usually is a vertical container with top connections. An internal U-tube reaching down near the bottom is installed on the compressor outlet connection so that the tube inlet is near the top of the container. This allows the accumulator to be almost completely full before flood-back can occur.

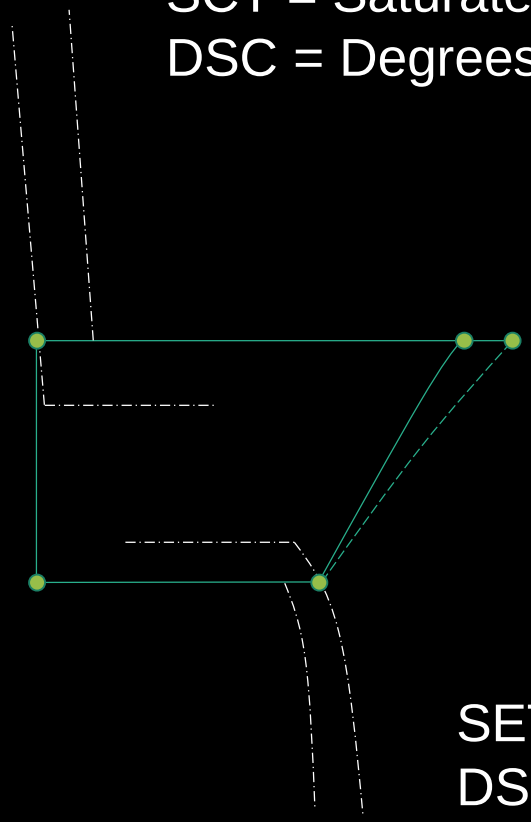
Cont..


Refrigerant Gas
Pickup tube
Liquid refrigerant
and refrigerant oil
from evaporator
Low pressure
refrigerant gas to
compressor
U-shaped tube
Desiccant
Filter and oil
suction port
Liquid refrigerant


Accumulator
Compressor
vapour
liquid
oil
orifice

Practical VCR Cycle

SCT = Saturated Condensing Temperature
DSC = Degrees of Subcooling = SCT – T_3



Subcooling increases the refrigeration capacity

Superheating provides a dry vapor at the compressor inlet

SET = Saturated Evaporating Temperature
DSH = Degrees of Superheat = T_1 – SET

Chapter 3 Refrigerants

- **HISTORY** : A substance capable of absorbing heat from another required substance(space) can be used as Refrigerant. Air was used as refrigerant in olden days in many refrigeration systems because most safest/ cheapest refrigerant.
- First refrigerant used - Ether – employed by Perkins - hand operated vapour compression machine Then ethyl chloride(C_2H_5Cl) – Ammonia -1875.Methyl chloride was used for domestic and commercial purpose until Freon's were available.

Cont..

Refrigerant: Any substance that absorbs heat through expansion and vaporisation process and loses heat due to condensation is a refrigeration process is called refrigerant.

Some examples of refrigerants are:

- *Air*
- *Ammonia (NH_3)*
- *Carbon dioxide (CO_2)*
- *Sulphur dioxide (SO_2)*
- *Freon – 12*
- *Methyl Chloride*
- *Methylene chloride.*

Classification of Refrigerants

Refrigerants are classified as:-

(a) Primary Refrigerants: It is a working medium which is used for cooling the substance by absorption of latent heat.

E.G Ammonia (NH_3), Carbon dioxide (CO_2), Sulphur dioxide (SO_2), Freon 12, etc.,

(b) Secondary Refrigerants: Secondary refrigerant is a substance already cooled by primary refrigerant and then employed for cooling purposes.

E.g Ice, solid carbon dioxide.

These refrigerants cool the substance by absorption of their sensible heat.

Types of Refrigerators

- Ice Refrigerators : Ice is kept in the cabinet of refrigerators and this acts as the refrigerating means.
- Air Refrigerators : Air is used as working agent in these types of refrigerators.

  E.g., Bell Coleman Cycle.
- Vapour Refrigerators: The working agents employed in this type of refrigerators are ammonia, CO_2, SO_2, freons etc.

Applications of Refrigeration

- In chemical industries, for separating and liquefying the gases.
- In manufacturing and storing ice.
- For the preservation of perishable food items in cold storages.
- For cooling water.
- For controlling humidity of air manufacture and heat treatment of steels.
- For chilling the oil to remove wax in oil refineries.
- For the preservation of tablets and medicines in pharmaceutical industries.
- For the preservation of blood tissues etc.,
- For comfort air conditioning the hospitals, theatres, etc.

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Properties of Refrigeration

- A good refrigerant should have high latent heat of vapourisation.
- It should have low boiling and low freezing point.
- It should be non toxic and should non corrosiveness
- It should be non flammable and non explosive.
- It should have high thermal conductivity
- It should be easy to handle
- It should have low specific volume of vapour.
- It should have high co efficient of performance

AMMONIA (NH3) R-717

- **In-expensive Refrigerant best suited for industrial use**
- **Higher refrigeration effect 474 Btu/lb, comparison; R-12 = 50 Btu/lb , R-22 = 70 Btu/lb, R-134a = 64 Btu/lb, R-404A = 48 Btu/lb**

  7- times higher refrigeration effect!!!
- **Specific volume of suction gas is high 8 ft^3/lb compare to 1.2 ft^3/lb of R-22, needs larger pipes, compressors**
- **Higher delivery temperatures 210 ºF, needs water cooled heads for compressor.**

Properties of R22

- **Chlorodifluoromethane** or **difluoromonochloromethane** is a hydrochlorofluorocarbon (HCFC).
- This colorless gas is better known as **HCFC-22**, or **R-22**.
- It is commonly used as a propellant and refrigerant.
- The boiling point of R22 is **-40.8 degree Celsius** (-**41.4 degree F**).
- R22 refrigerant has a boiling point of -**40°F** at 0 psi. hfg at NBP=233.2 kJ/kg
- These applications are being phased out in developed countries due to the compound's ozone depletion potential (ODP) and high global warming potential (GWP)
- Although global use of R-22 continues to increase because of high demand in developing countries.
- R-22 is a versatile intermediate in industrial organofluorine chemistry, e.g. as a precursor to tetrafluoroethylene. R-22 cylinders are colored light green.

Properties of R-134a (HFC)

1	Boiling Point	-14.9°F or -26.1°C
2	Auto-Ignition Temperature	1418°F or 770°C
3	Ozone Depletion Level	0
4	Solubility In Water	0.11% by weight at 77°F or 25°C
5	Critical Temperature	252°F or 122°C
6	Cylinder Color Code	Light Blue
7	Global Warming Potential (GWP)	1200

Latest Development

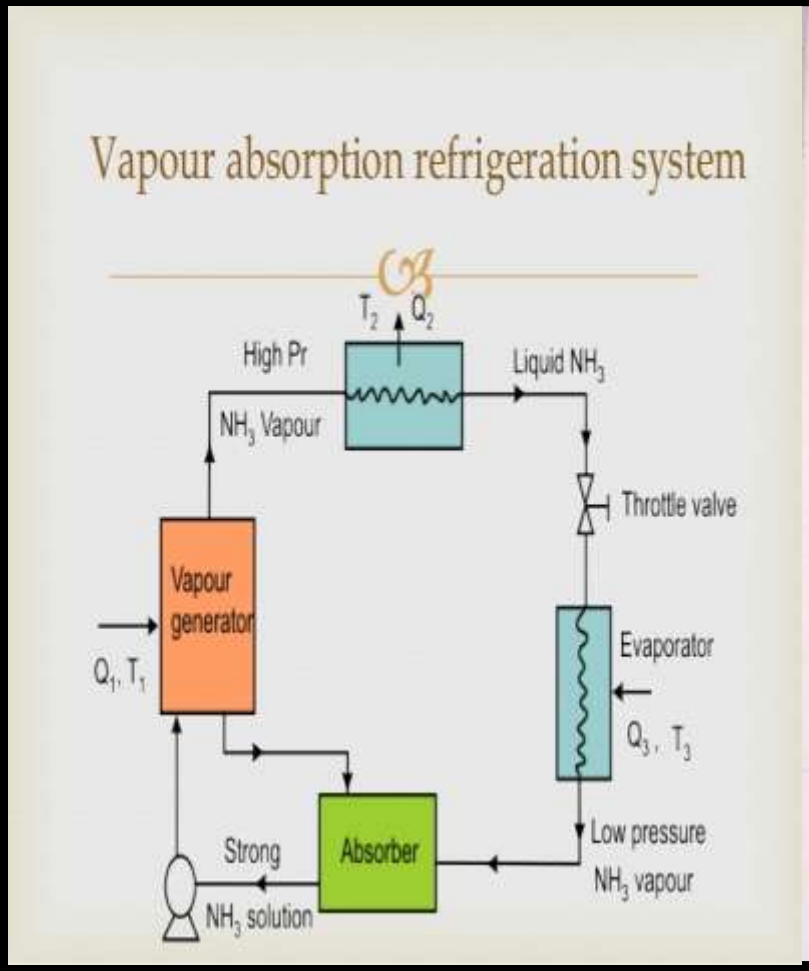
The recent discovery that R-134a contributes to global warming has caused the European Union to ban its use on new cars starting from year 2011. Other countries are expected to follow suit.

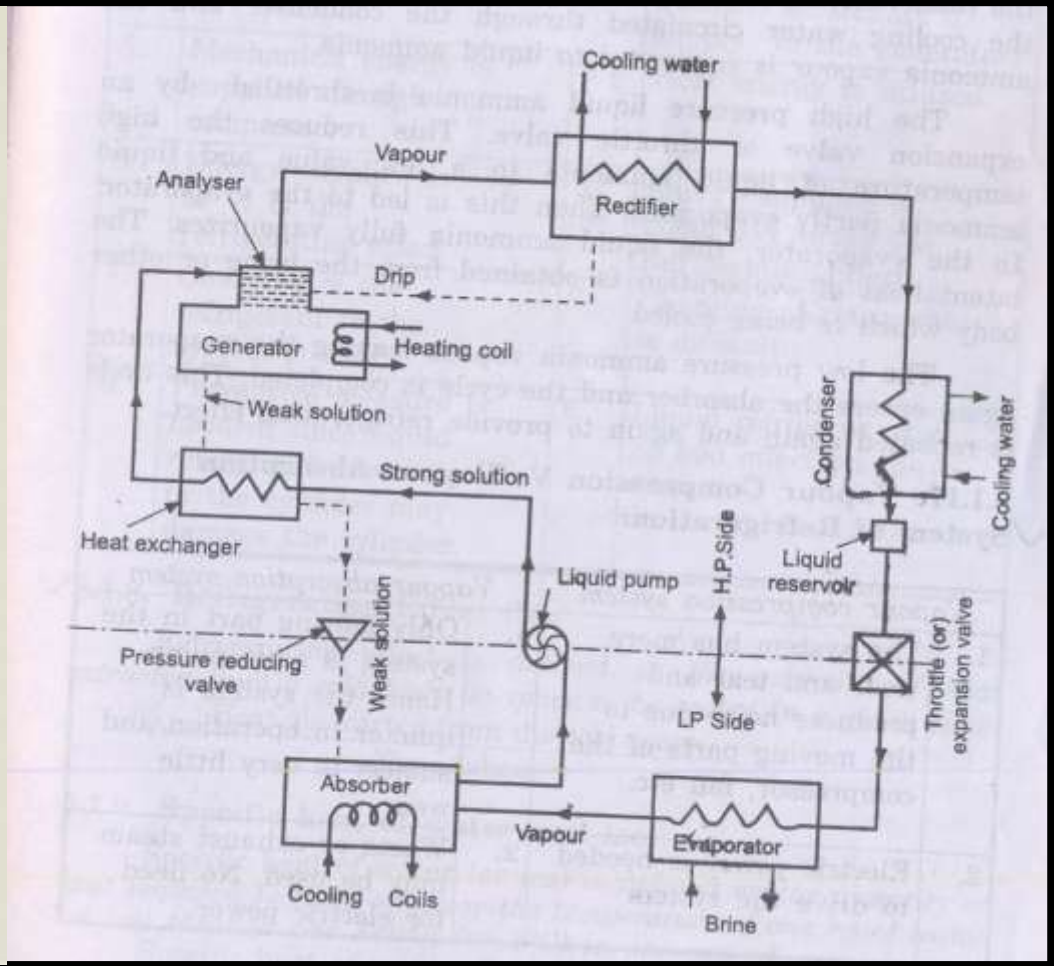
Chapter 4. Vapour Absorption Refrigeration system

In this system compression process of vapour compression cycle is eliminated. Instead of that the following three processes are carried out.

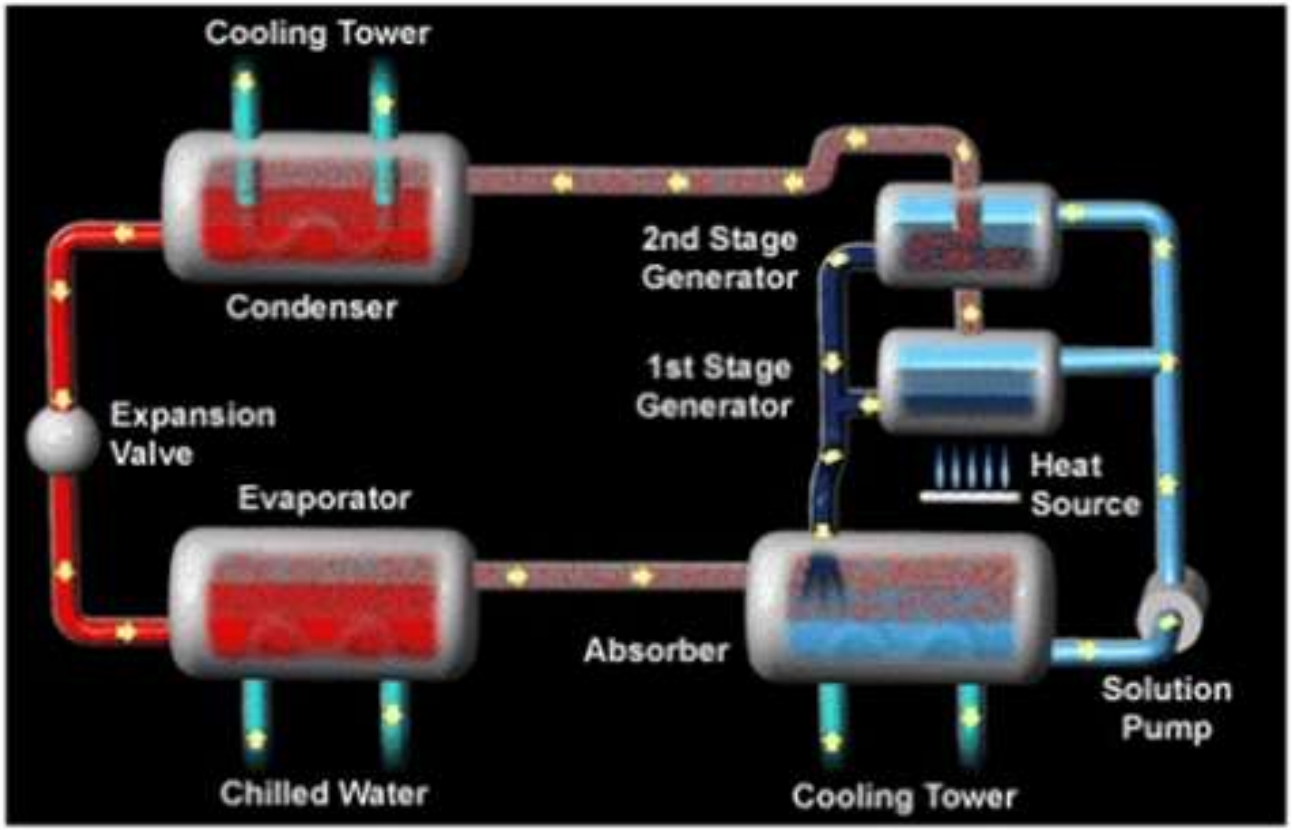
1. Absorbing ammonia vapour into water.
2. Pumping this solution to a high pressure cycle
3. Producing ammonia vapours from ammonia solution by heating.

Vapour Absorption Refrigeration system





Vapour absorption system



Vapour Absorption Refrigeration system - Construction

Construction:

- The vapour absorption system consists of a condenser, an expansion valve and an evaporator.
- They perform the same as they do in vapour compression method.
- In addition to these, this system has an absorber, a heat exchanger, an analyser and a rectifier.

Vapour Absorption Refrigeration system – Working

1. **Working:**
2. Dry ammonia vapor at low pressure passes in to the absorber from the evaporator.
3. In the absorber the dry ammonia vapor is dissolved in cold water and strong solution of ammonia is formed.
4. Heat evolved during the absorption of ammonia is removed by circulating cold water through the coils kept in the absorber.
5. The highly concentrated ammonia (known as Aqua Ammonia) is then pumped by a pump to generator through a heat exchanger.

Vapour Absorption Refrigeration system - Construction

Working:

5. In the heat exchanger the strong ammonia solution is heated by the hot weak solution returning from the generator to the absorber.
6. In the generator the warm solution is further heated by steam coils, gas or electricity and the ammonia vapour is driven out of solution.
7. The boiling point of ammonia is less than that of water.
8. Hence the vapours leaving the generator are mainly of ammonia.

Vapour Absorption Refrigeration system - Construction

Working:

9. The weak ammonia solution is left in the generator is called weak aqua.
10. This weak solution is returned to the absorber through the heat exchanger.
11. Ammonia vapours leaving the generator may contain some water vapour.
12. If this water vapour is allowed to the condenser and expansion valve, it may freeze resulting in chocked flow.
13. Analyser and rectifiers are incorporated in the system before condenser.

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Vapour Absorption Refrigeration system - Construction

Working:

14. The ammonia vapour from the generator passes through a series of trays in the analyser and ammonia is separated from water vapour.
15. The separated water vapour returned to generator.
16. Then the ammonia vapour passes through a rectifier.
17. The rectifier resembles a condenser and water vapour still present in ammonia vapour condenses and the condensate is returned to analyser.
18. The virtually pure ammonia vapour then passes through the condenser.

Vapour Absorption Refrigeration system - Construction

Working:

19. The latent heat of ammonia vapour is rejected to the cooling water circulated through the condenser and the ammonia vapour is condensed to liquid ammonia.
20. The high pressure liquid ammonia is throttled by an expansion valve or throttle valve.
21. This reduces the high temperature of the liquid ammonia to a low value and liquid ammonia partly evaporates.
22. Then this is led to the evaporator.
23. In the evaporator the liquid fully vaporizes.

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Vapour Absorption Refrigeration system - Construction

Working:

24. The latent heat of evaporation is obtained from the brine or other body which is being cooled.
25. The low pressure ammonia vapour leaving the evaporator again enters the absorber and the cycle is completed.
26. This cycle is repeated again to provide the refrigerating effect.

Applications of Refrigeration System

- Preservation of food items like vegetables, milk and eggs.
- Preservation of medicines.
- Preservation of blood, tissues, etc.,
- Preservation and cooling of cool drinks.
- Preservation of chemicals (Chemical industries)
- Cooling of water.
- Industrial and comfort air conditioning.
- Processing of dairy products.

Comparison between Vapour compression & Vapour Absorption refrigeration systems

S.No	Vapour Compression System	Vapour Absorption System

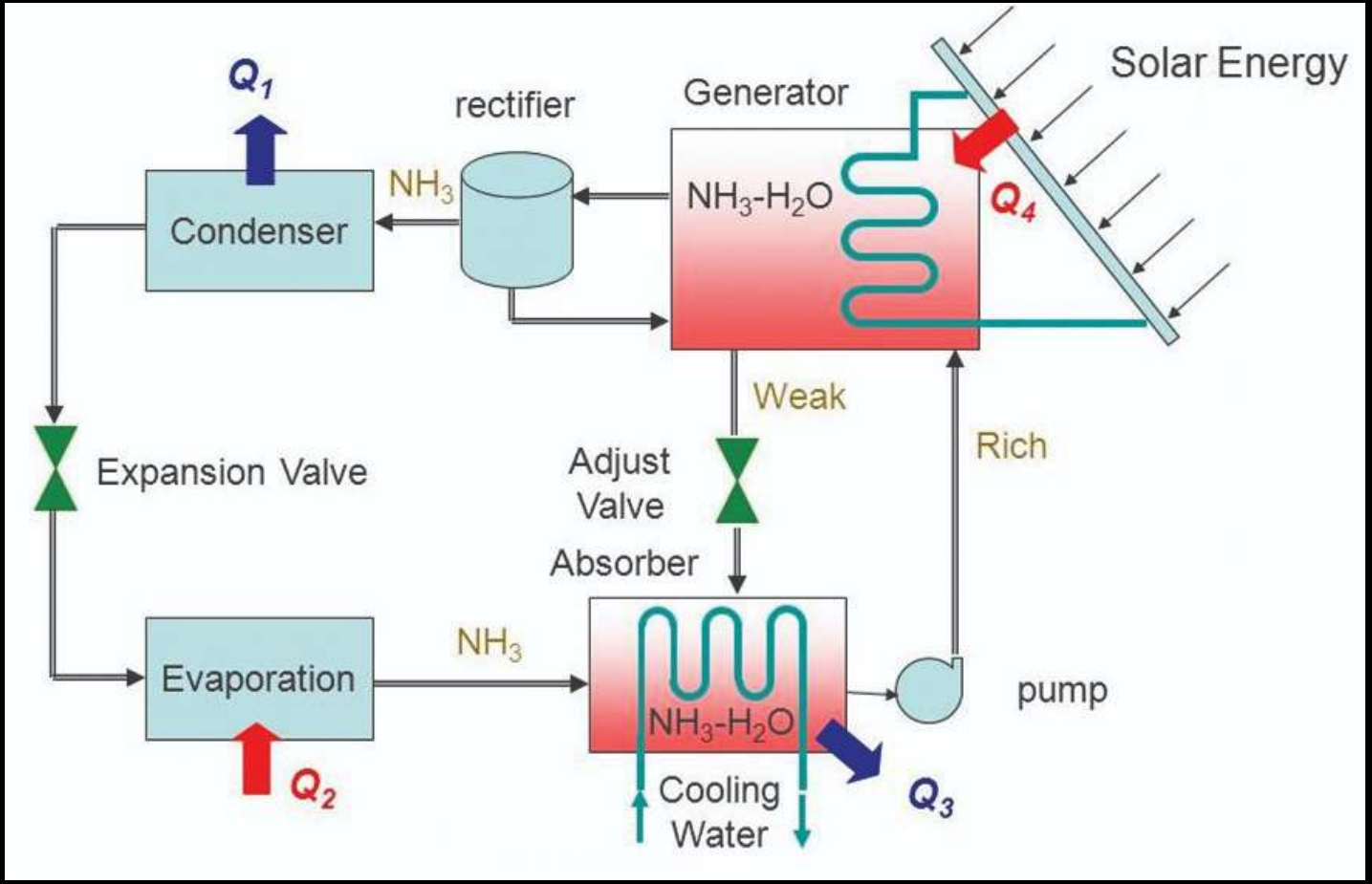
Comparison between Vapour Compression & Vapour Absorption Refrigeration Systems

S.No	Vapour Compression System	Vapour Absorption System

Solar Refrigeration System

- A **solar-powered refrigerator** is a refrigerator which runs on energy directly provided by sun, and may include photovoltaic or solar thermal energy.
- Solar powered refrigerators are characterized by thick insulation and the use of a DC (not AC) compressor. Traditionally solar-powered refrigerators and vaccine coolers use a combination of solar panels and lead batteries to store energy for cloudy days and at night in the absence of sunlight to keep their contents cool.
- **Types of Solar Refrigeration System**
- Solar refrigeration systems can be classified in three different categories. They are:
- **i.** Photovoltaic operated refrigeration system
- **ii.** Solar mechanical refrigeration
- **iii.** Absorption refrigeration.

Cont…


Solar Energy
Q_1
rectifier
Generator
NH_3
Condenser
NH_3-H_2O
Q_4
Weak
Rich
Expansion Valve
Adjust
Valve
Absorber
NH_3
Evaporation
NH_3-H_2O
pump
Q_2
Cooling
Water
Q_3

Advantages and disadvantages of Solar power refrigeration system over vapour compression system

Advantages of Solar Refrigeration

- Solar energy is the main source of energy that is utilized to run solar refrigerator. So, significant amount of electrical power is saved and it also causes less pollution that would have been added due to the use of power produced by the conventional power plants. The solar energy is available in every part of the world and unlike fossil fuels and nuclear power, it is a clean source of energy.
- Additional power from the solar collector can also be used for the other domestic purposes. The solar refrigerators can be very useful where there is no continuous supply of electricity or difficult to get conventional fuel. More importantly it is renewable in nature.

Cont..

- The Conventional refrigeration systems emit significant amount of gas which pollute the environment. This solar refrigeration system is also needed to lower the environmental impact caused due to conventional refrigeration systems.
- The maintenance cost of such system is considerably low compared to that of the conventional system. Those facts encourage to use solar refrigeration system whenever possible.

Cont..

Disadvantages of Solar Refrigeration

- Solar refrigeration systems also have some disadvantages. As solar radiation is not available throughout the day, power production is not uniform. Again it depends on the intensity of the beam radiation.
- Even in the hottest regions on earth, the average solar radiation flux rarely exceeds 1 kWh/m2 and the maximum radiation flux over a day is about 6 kWh/m2. These are low values from the point of view of technological utilization.

Cont..

- So, those refrigeration systems can be used in those places where those problems are not present. To produce sufficient energy from solar system, it needs bigger collector.
- So, there is a need of bigger space for the collector which is another major problem for using solar refrigeration system. Initial investment to develop such set up is also large.

Cont…

- **Challenges**

The variation in availability of solar radiation occurs daily because of the day-night cycle and also seasonally because of the earth's orbital motion around the sun. In addition, variation occurs at a specific location because of local weather conditions. Consequently, the energy collected when the sun is shining must be stored for use during periods when it is not available. The need for storage significantly adds to the cost of the system. Thus, the real challenge in utilizing solar energy as an energy alternative is to address these challenges. One has to strive for the development of cheaper methods of collection and storage so that the large initial investments required at present in most applications are reduced.

Chapter 5 Refrigeration Equipments

- **Introduction**

Refrigeration system consists of several equipments like compressor, condenser, evaporator, expansion devices etc. A refrigerant compressor is a machine used to compress the refrigerant from the evaporator and to raise its pressure so that the corresponding temperature is higher than that of the cooling medium.

The condenser is an important device used in the high pressure side of a refrigeration system. Its function is to remove heat of the hot vapour refrigerant discharged from the compressor. The evaporator is used in the low pressure side of a refrigeration system. The liquid refrigerant from the expansion device enters into the evaporator where it boils and changes into vapour.

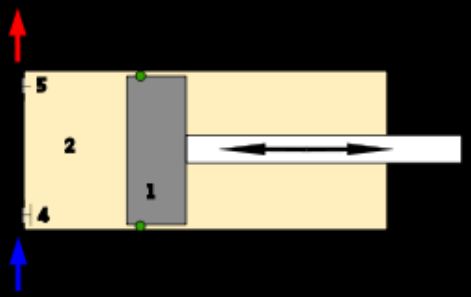
Cont..

- The function of an evaporator is to absorb heat from the surrounding location or medium which is to be cooled, by means of a refrigerant. The temperature of the boiling refrigerant in the evaporator must always be less than that of the surrounding medium so that the heat flows to the refrigerant.
- The expansion device which is also known as throttling device, divides the high pressure side and the low pressure side of a refrigeration system. It is connected between the receiver and the evaporator.

Classification of Compressor

- *Reciprocating compressor*
- Reciprocating compressors are piston-style, positive displacement compressors.
- Rotary screw compressors
  screw compressor
- *Rotary screw compressor*
- Rotary screw compressors are also positive displacement compressors. Two meshing screw-rotors rotate in opposite directions, trapping refrigerant vapor, and reducing the volume of the refrigerant along the rotors to the discharge point.
- Centrifugal compressors
- Centrifugal principle
- *Centrifugal compressor*
- Centrifugal compressors are dynamic compressors. These compressors raise the pressure of the refrigerant by imparting velocity or dynamic energy, using a rotating impeller, and converting it to pressure energy.
- Scroll compressors
- *Scroll compressor*
- Scroll compressors are also positive displacement compressors. The refrigerant is compressed when one spiral orbits around a second stationary spiral, creating smaller and smaller pockets and higher pressures. By the time the refrigerant is discharged, it is fully pressurized.

Reciprocating Compressor



- A **reciprocating compressor** or **piston compressor** is a positive-displacement compressor that uses pistons driven by a crankshaft to deliver gases at high pressure.
- The intake gas enters the suction manifold, then flows into the compression cylinder where it gets compressed by a piston driven in a reciprocating motion via a crankshaft, and is then discharged. Applications include oil refineries, gas pipelines, chemical plants, natural gas processing plants and refrigeration plants. One specialty application is the blowing of plastic bottles made of polyethylene terephthalate (PET).
- In the ionic liquid piston compressor many seals and bearings were removed in the design as the ionic liquid does not mix with the gas. Service life is about 10 times longer than a regular diaphragm compressor with reduced maintenance during use, energy costs are reduced by as much as 20%. The heat exchangers that are used in a normal piston compressor are removed as the heat is removed in the cylinder itself where it is generated. Almost 100% of the energy going into the process is being used with little energy wasted as reject heat.

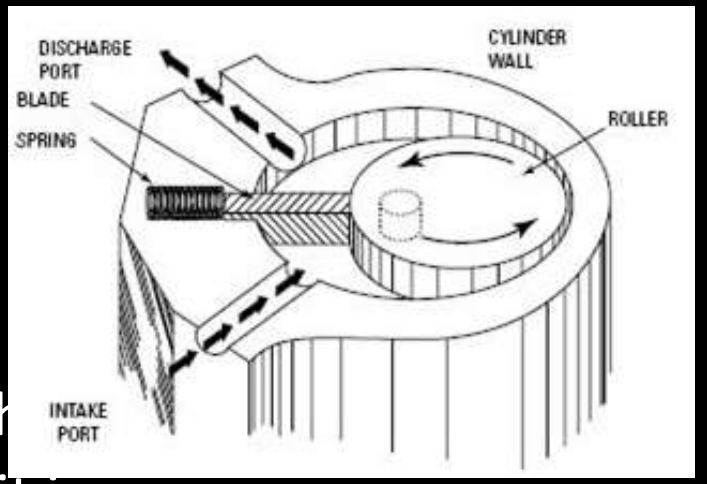
Rotary Compressors

- The rotary compressor used in HVAC applications

for air conditioning and heating systems offer some of the most efficient air conditioner and heat pump systems one can find on the market. Despite the rotary compressor being a key component of an air-source air conditioner or heat pump the efficiency offered by this compressor when used as a modulating compressor can exceed efficiency ratings of some geothermal systems.

When the compressor is coupled to an inverter and the proper inverter control system the efficiency of the air-source air conditioner or heat pump system spike to match those of some geothermal air conditioner or heat pump systems.

Cont..



- The rotary compressor is unique to high

efficiency refrigeration systems because it is

ideal for use with inverter type systems. Inverter type air conditioners and heat pumps offer higher efficiency ranges because it can be modulated or stepped up and down based on demand.

- The Rotary compressors used in HVAC applications are mostly either rotary vane compressors or rotary screw compressors with the rotary vane compressors being used in smaller HVAC applications such as residential split systems.
- The rotary screw being used in larger HVAC applications such as commercial chillers including process and industrial HVAC applications. Vibration issues are negligible for the rotary screw making it ideal for larger HVAC applications.

Difference between Rotary and Reciprocating

- The Rotary will endure higher discharge temperature and handle a presence of liquid refrigerant better.
- It is lighter and smaller and more efficient.
- It also controls oil better.
- Is it may a better compressor then reciprocating type? Perhaps. But it is important to remember that a properly handled recipe will happily work for 15 years or more. I know instances where they remain serviceable after 30 years.
- Rotaries haven't even being around for so long! However, I believe, the rotaries construction make them more resistant to small human errors and system's mischief.

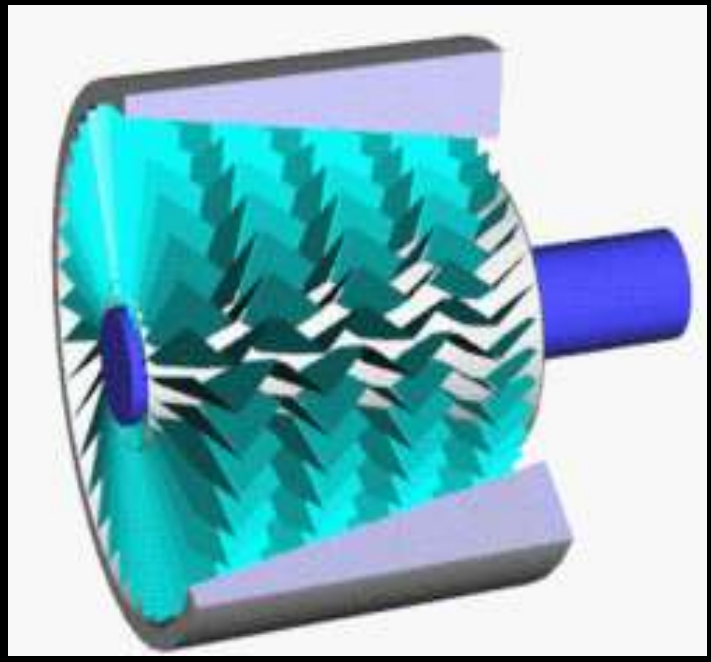
ROTARY SCREW COMPRESSORS

- Pulsation free air
- 100% continuous duty
- Quiet operation
- Energy efficient at full load
- Extended service intervals
- Reliable long life
- Improved air quality

Centrifugal Compressor

Compressor: For very big plants

Centrifugal compressors directly coupled with high speed rotating engines (gas turbine) are used.



Condenser

A **condenser** is a device or unit used to condense a substance from its gaseous to its liquid state, by cooling it. In so doing, the latent heat is given up by the substance and transferred to the surrounding environment. Condensers can be made according to numerous designs, and come in many sizes ranging from rather small (hand-held) to very large (industrial-scale units used in plant processes).
For example, a refrigerator uses a condenser to get rid of heat extracted from the interior of the unit to the outside air. Condensers are used in air conditioning, industrial chemical processes such as distillation, steam power plants and other heat-exchange systems. Use of cooling water or surrounding air as the coolant is common in many condensers.[1]

Classification of Condenser

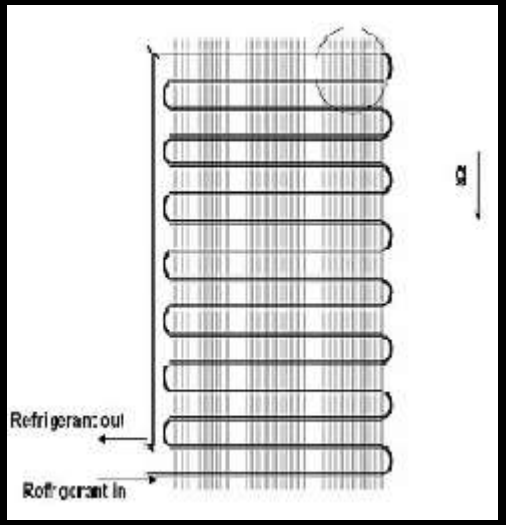
- There are three other condensers used in HVAC systems
- ***Water-cooled***
- ***Air-cooled***
- ***Evaporative***
- **Air cooled** – If the condenser is located on the outside of the unit, the air cooled condenser can provide the easiest arrangement. These types of condensers eject heat to the outdoors and are simple to install.
- **Water cooled** – Although a little more pricey to install, these condensers are the more efficient type. Commonly used for swimming pools and condensers piped for city water flow, these condensers require regular service and maintenance.
- **Evaporative** – While these remain the least popular choice, they are used when either water supply is inadequate to operate water cooled condenser or condensation temperature is lower that can achieved by air cooled condenser. Evaporative condensers can be used inside or outside of a building and under typical conditions, operate at a low condensing temperature.

Air-Cooled Condensers

- **Air-cooled condensers**: As the name implies, in air-cooled condensers air is the external fluid, i.e., the refrigerant rejects heat to air flowing over the condenser. Air-cooled condensers can be further classified into natural convection type or forced convection type.

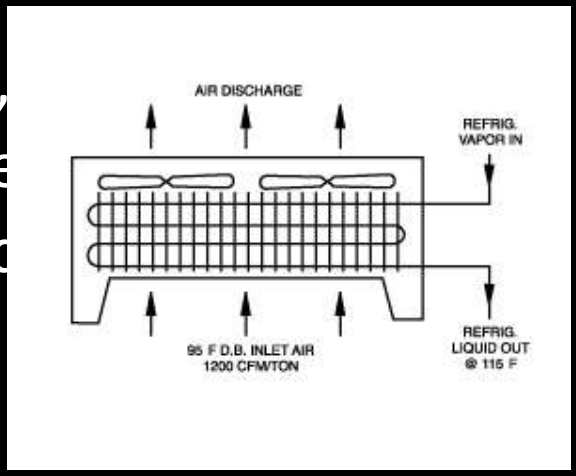
1) **Natural convection type**: In natural convection type, heat transfer from the condenser is by buoyancy induced natural convection and radiation. Since the flow rate of air is small and the radiation heat transfer is also not very high, the combined heat transfer coefficient in these condensers is small. As a result a relatively large condensing surface is required to reject a given amount of heat. Hence these condensers are used for small capacity refrigeration systems like household refrigerators and freezers.

--The natural convection type condensers are either plate surface type or finned tube type. In plate surface type condensers used in small refrigerators and freezers, the refrigerant carrying tubes are attached to the outer walls of the refrigerator.



Forced Convection type

- In forced convection type condensers, the circulation of air over the condenser surface is maintained by using a fan or a blower. These condensers normally use fins on air-side for good heat transfer. The fins can be either plate type or annular type.
- Forced convection type condensers are commonly used in window air conditioners, water coolers and packaged air conditioning plants. These are either chassis mounted or remote mounted.
- In chassis mounted type, the compressor, induction motor, condenser with condense fan, accumulator, HP/LP cut- out switch and pressure gauges are mounted on a single chassis.



Water-Cooled Condenser

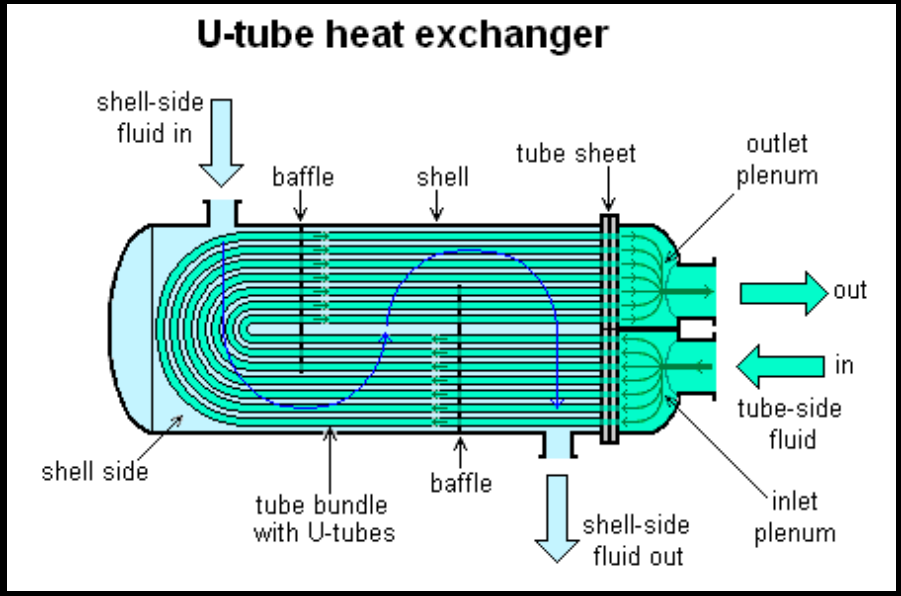
- A **water-cooled condenser** is a heat exchanger that removes heat from **refrigerant** vapor and transfers it to the **water** running through it. Having the **refrigerant** vapor condensed on the outside of a tube does this.
- In doing so, the vapor condenses and gives up heat to the **water** running inside the tube.

Cont..

- There are three types of Water cooled Condenser:
  - 1. Shell and Tube.
  - 2. Shell and Coil.
  - 3. Double pipe (Tube in tube).

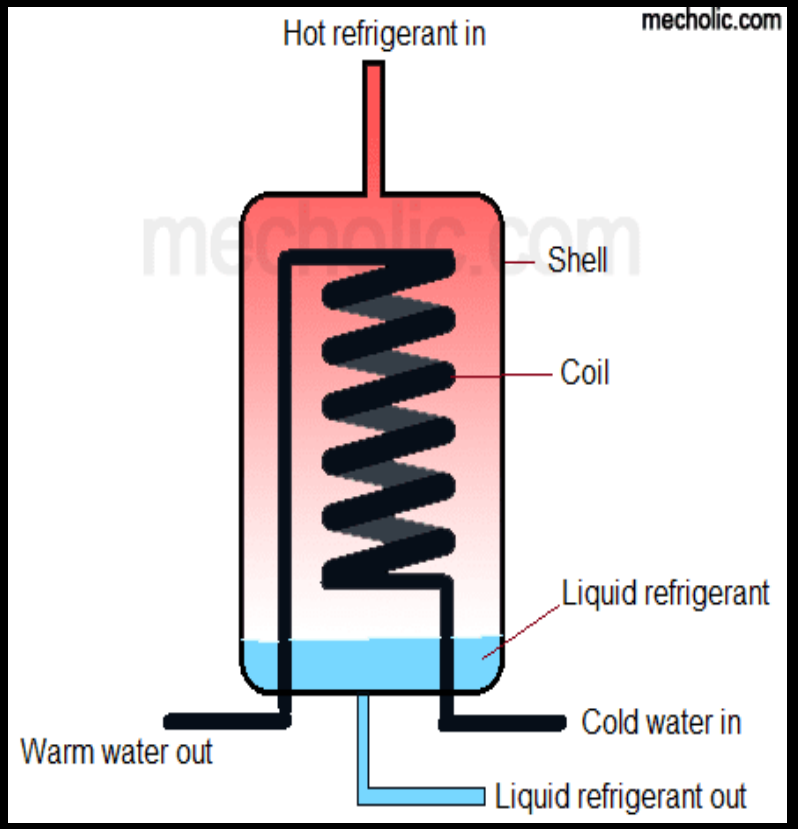
Shell and Tube Condenser

- It is the most common type of heat exchanger in oil refineries and other large chemical processes, and is suited for higher-pressure applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it.
- One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. The set of tubes is called a tube bundle, and may be composed of several types of tubes: plain, longitudinally finned, etc.



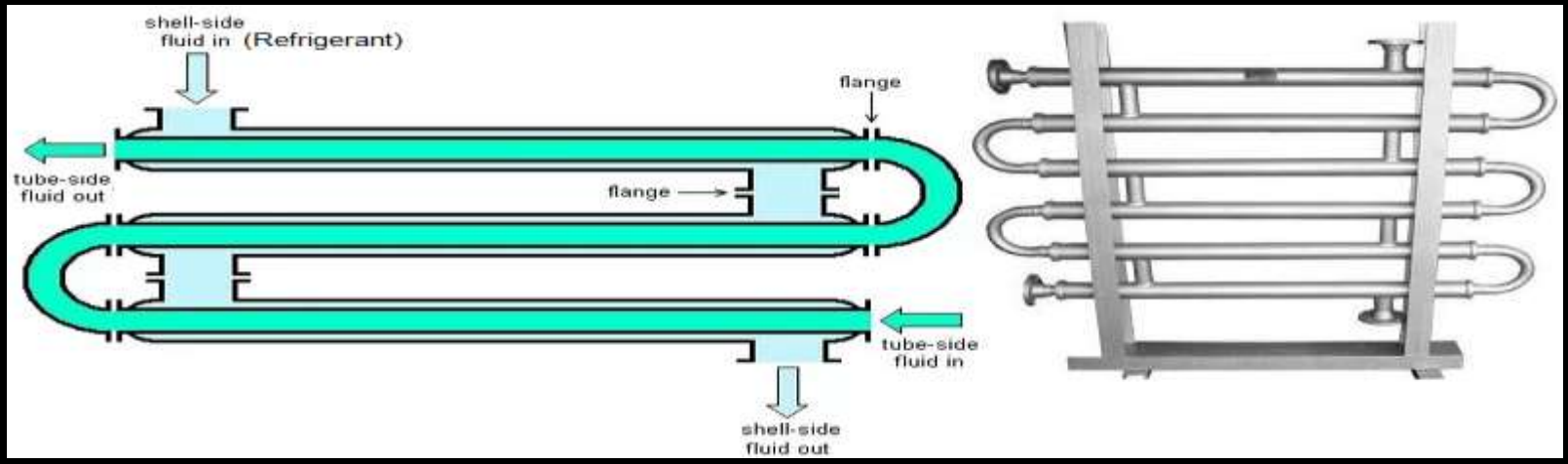
Shell and Coil Condenser

- Shell-and-Coils, capacitors have a welded or flanged outer shell with a coil inside are made of ribbed water tube. Coil inside the shell is continuous. Water flows through pipes of the coil, while the refrigerant flows above and beyond.
- The outer surface of the heat exchanger tubes and fins are in contact with the refrigerant. This is a vertical Shell-and-the condenser Coil. This can also be done in a horizontal position.



Tube in Tube Condenser

- Pipe-in-pipe water-cooled condenser popular because it is easy to do. Water passing through the inner tube is cooled by the refrigerant in the outer tube. The outside of the tube also cools the air in the room. Double cooling efficiency.
- There is a thin water film around the **condenser tubes** from which evaporative cooling takes place. The heat transfer coefficient for evaporative cooling is very large. Hence, the **refrigeration** system can be operated at low **condensing** temperatures



Evaporator

- Evaporator is an important component together with other major components in a refrigeration system such as compressor, condenser and expansion device. The reason for refrigeration is to remove heat from air, water or other substance.
- It is here that the liquid refrigerant is expanded and evaporated. It acts as a heat exchanger that transfers heat from the substance being cooled to a boiling temperature.

Cont..

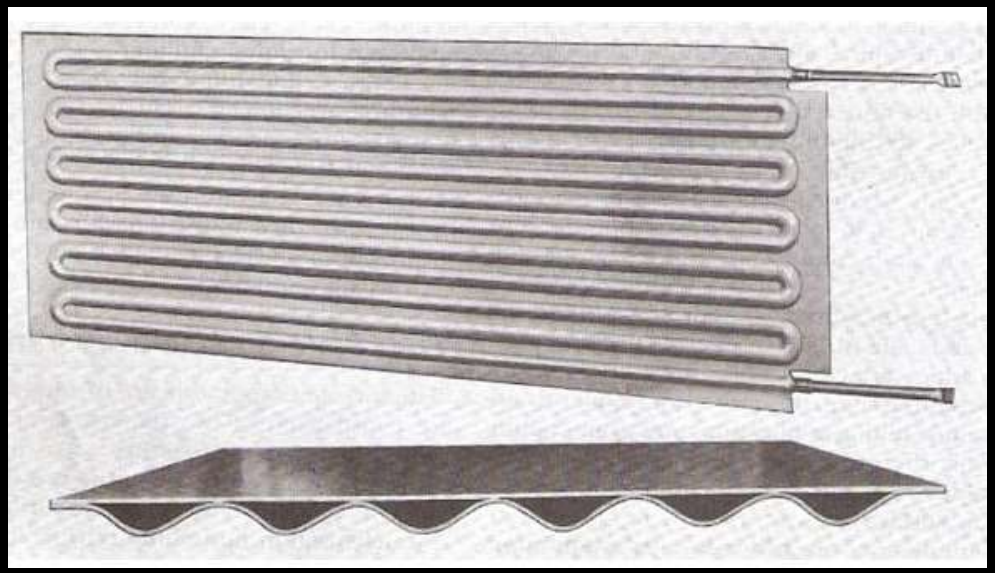
- The following types of evap. that are commonly being used:
- Direct expansion fin-and-tube type
- Plate Surface Evaporators.
- Bare-Tube and Plate.
- Double pipe type evaporator.
- Flooded type Evaporator .
- Dry Expansion type Evaporator.

Direct expansion fin-and-tube type

- These evaporators are used for cooling and dehumidifying the air directly by the refrigerant flowing in the tubes. Similar to fin-and-tube type condensers, these evaporator consists of coils placed in a number of rows with fins mounted on it to increase the heat transfer area. Various fin arrangements are used.
- Tubes with individual spiral straight fins or crimpled fins welded to it are used in some applications like ammonia. Plate fins accommodating a number of rows are used in air conditioning applications with ammonia as well as synthetic refrigerants such as fluorocarbon based refrigerants.

Plate Surface Evaporators

- These are also called bonded plate or roll-bond type evaporators. Two flat sheets of metal (usually aluminum) are embossed in such a manner that when these are welded together, the embossed portion of the two plates makes a passage for refrigerant to flow. This type is used in household refrigerators.



Bare Tube Evaporators

- The bare tube evaporators are made up of copper tubing or steel pipes. The copper tubing is used for small evaporators where the refrigerant other than ammonia is used, while the steel pipes are used with the large evaporators where ammonia is used as the refrigerant. The bare tube evaporator comprises of several turns of the tubing, though most commonly flat zigzag and oval trombone are the most common shapes.
- The bare tube evaporators are usually used fo

liquid chilling. In the blast cooling and the freez

operations the atmospheric air flows over the b

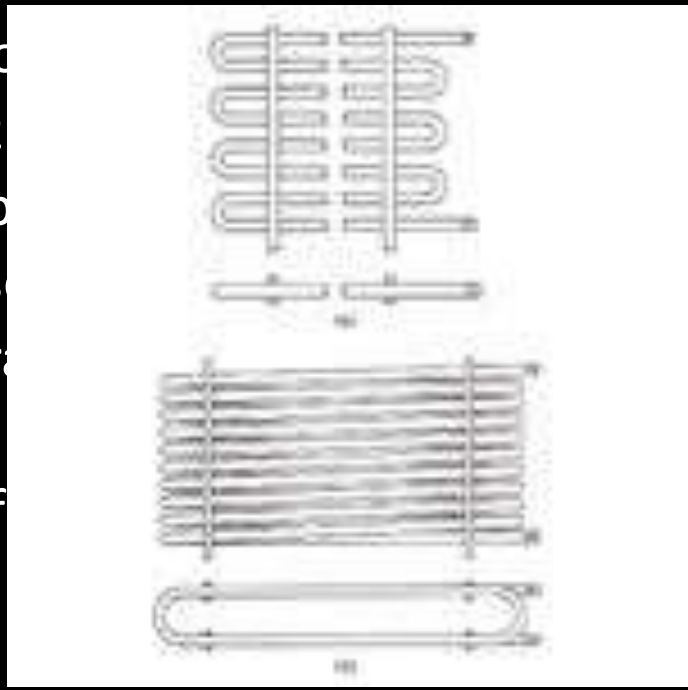
tube evaporator and the chilled air leaving it us

for the cooling purposes. The bare tube evapora

are used in very few applications, however the

tube evaporators fitted with the fins, called as f

evaporators are used very commonly.



Double pipe type evaporator

- This consists of two concentric tubes, the refrigerant flows through the annular passage while the liquid being chilled flows through the inner tube in counter flow. In which the outer horizontal tubes are welded to vertical header tubes on either side.
- The inner tubes pass through the headers and are connected together by 180o bends. The refrigerant side is welded hence there is minimum possibility of leakage of refrigerant.

Shell and Tube types of Evaporators

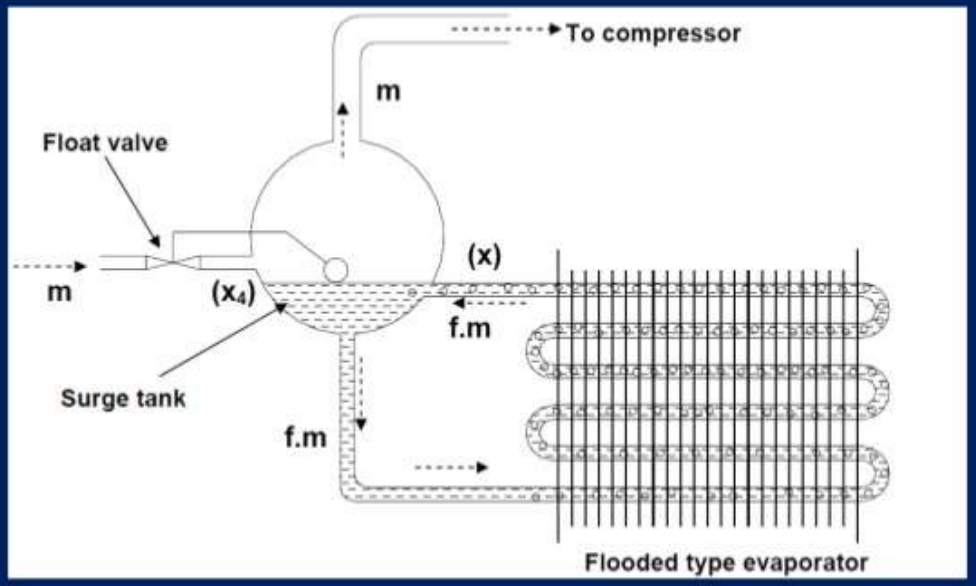
- The shell and tube types of evaporators are used in the large refrigeration and central air conditioning systems. The evaporators in these systems are commonly known as the chillers. The chillers comprise of large number of the tubes that are inserted inside the drum or the shell. Depending on the direction of the flow of the refrigerant in the shell and tube type of chillers they are classified into two types:
  - dry expansion type.
  - flooded type of chillers.

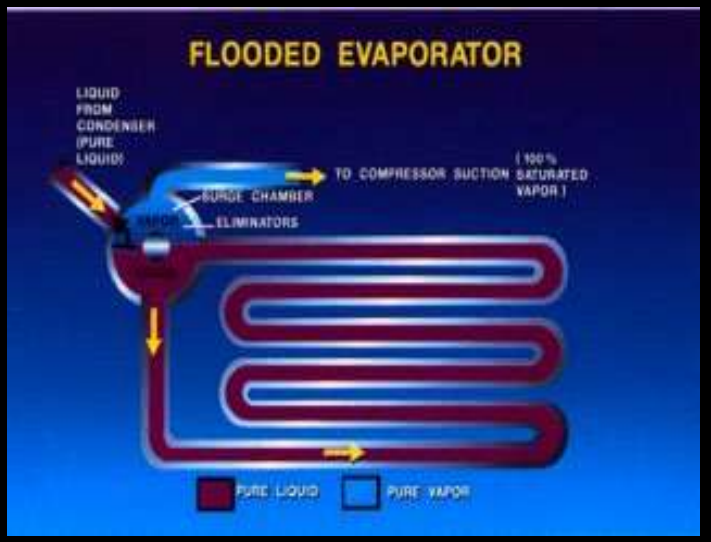
Flooded type of Evaporator (chillers)

- Evaporator is said to be flooded type if liquid refrigerant covers the entire heat transfer surface. This type of evaporator uses a float type of expansion valve.
- This is typically used in large ammonia systems. The refrigerant enters a surge drum through a float type expansion valve. The compressor directly draws the flash vapour formed during expansion. This vapour does not take part in refrigeration hence its removal makes the evaporator more compact and pressured drop due to this is also avoided.
- The liquid refrigerant enters the evaporator from the bottom of the surge drum. This boils inside the tubes as heat is absorbed. The mixture of liquid and vapour bubbles rises up along the evaporator tubes. The vapour is separated as it enters the surge drum. The remaining unevaporated liquid circulates again in the tubes along with the constant supply of liquid refrigerant from the expansion valve.

Cont..

Flooded type Evaporator





DRY EXPANSION EVAPORATORS

- Dry expansion evaporators are so called because liquid refrigerant enters the evaporator by an expansion valve and vaporizes by the time it reaches the end of the evaporator coil.
- There is always at least 20% vapor present within the evaporator pipe work.
- The amount of liquid present in dry expansion evaporators will depend upon the fixture load.
- At light load conditions, the amount of liquid will be small, and in high load conditions, the amount of liquid will be large.
- The larger the *wetted* surface, the greater the efficiency. (See Figure 3)

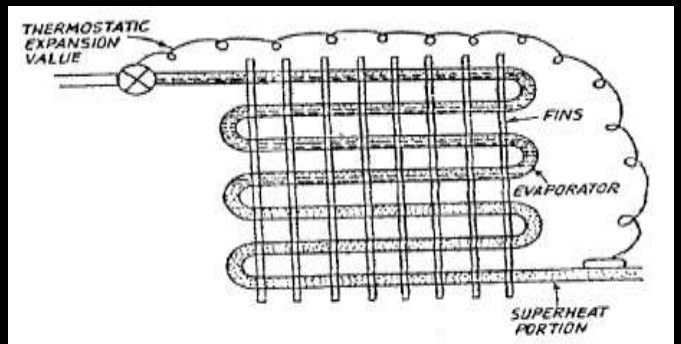


Fig. Direct Expansion Coil Evaporator

Expansion Devices

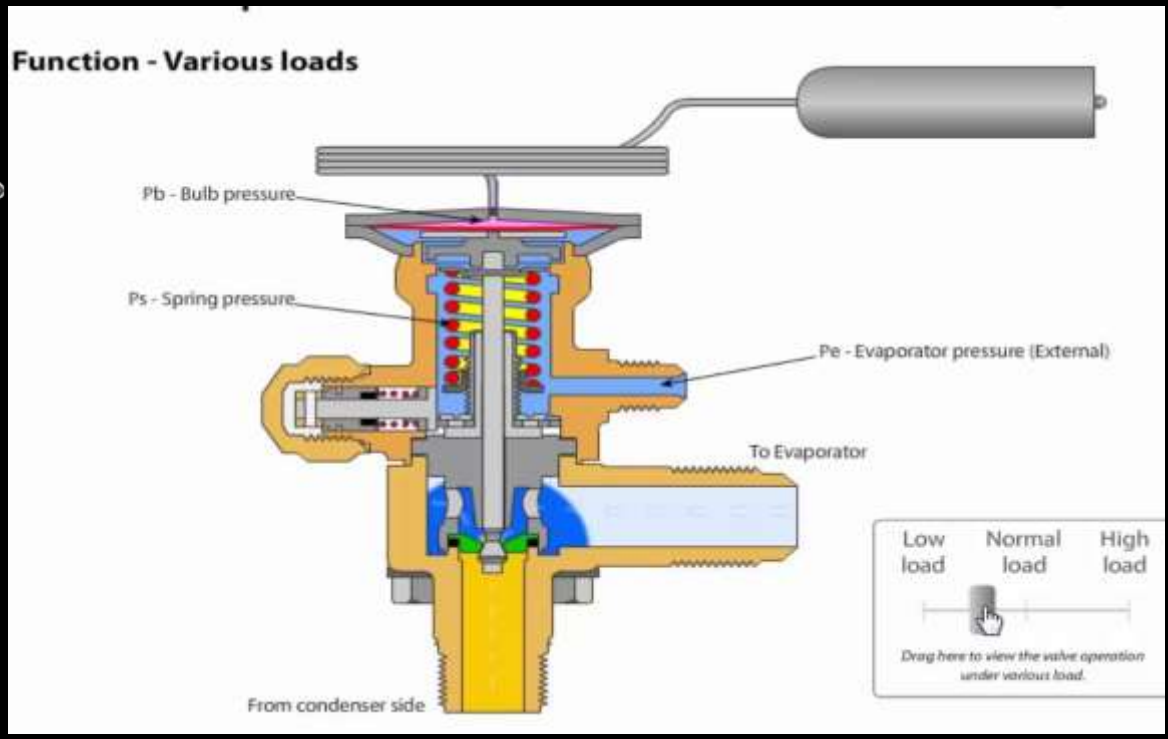
- The purpose of the expansion device is to rapidly reduce the pressure of the refrigerant in the refrigeration cycle. This allows the refrigerant to rapidly cool before entering the evaporator.
- The three most common expansion devices are:
  - **capillary tube**
  - **thermal expansion valve (TXV)**
  - **electronic expansion valve**

- A **capillary tube** is long, wound up copper tube with a tiny opening that receives hot, high pressure liquid refrigerant from the condenser.
- This small opening holds high pressure on one side of the tube and low pressure on the opposite side. The friction from the walls of the tube rapidly reduce the pressure of the refrigerant flowing through it.
- Think of a huge 5-lane highway that only has one lane open due to construction. Cars are packed closely together for miles, and everyone is slowly changing lanes and moving toward the opening. However, cars moving through the one open lane will pass through the construction and move on to a wide open highway. The cars interact with the construction exactly how high pressure refrigerant interacts with a capillary tube.
- Since it is a fixed hole it is very important that the system has the proper refrigerant charge — the device could break if there is excessive pressure due to additional refrigerant in the system.

Thermostatic Expansion Valve

- Thermostatic expansion valve or TEV is one of the most commonly used throttling devices in the refrigerator and air conditioning systems. The thermostatic expansion valve is the automatic valve that maintains proper flow of the refrigerant in the evaporator as per the load inside the evaporator. If the load inside the evaporator is higher it allows the increase in flow of the refrigerant and when the load reduces it allows the reduction in the flow of the refrigerant. This leads to highly efficient working of the compressor and the whole refrigeration and the air conditioning plant.
- The main function of this Valve are: **1) Reduce the pressure of the refrigerant. 2) Keep the evaporator active. 3) Allow the flow of the refrigerant as per the requirements**
- It is commonly used in the industrial refrigeration plants, high capacity split air conditioners, packaged air conditioners, central air conditioners and many other systems.

Cont..


Function - Various loads
Pb - Bulb pressure
Ps - Spring pressure
Pe - Evaporator pressure (External)
To Evaporator
From condenser side
Low load
Normal load
High load
Drag here to view the valve operation under various load.

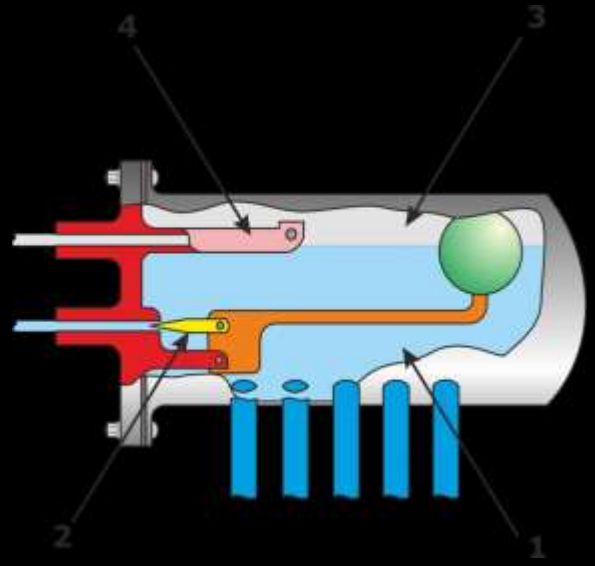
Low side float valves

- Low-side float valves are used for evaporators of the flooded-type system. In bigger capacity plants a small low-side float valve is used to pilot a liquid feed (and throttling) valve. According to the liquid level in the evaporator, the float valve transmits pressure signals to the main liquid feed valve to increase or decrease the extent of its opening.
- Thus the low-side float valve in

such a system is called a ‘pilot’ and

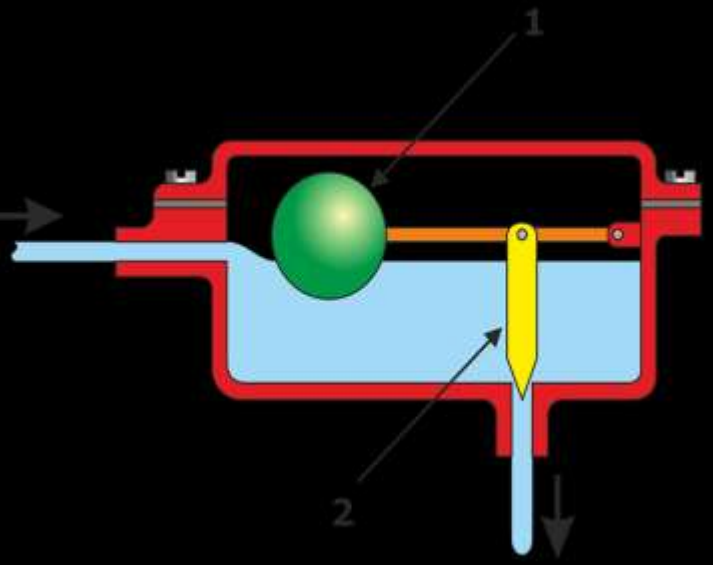
the liquid-feed valve is known as the

pilot-operated liquid-feed valve



High-side Float Valve

- The high-side float chamber is located between the condenser and evaporator. The liquid condensed in the condenser flows down to the float chamber.
- The high-side valve like the low-pressure float valve, is a liquid level sensing device and \maintains a constant liquid level in the chamber in which it is fixed.



Thermostat Switch

- A refrigerator thermostat has only one function -- controlling the refrigerator's cooling system by turning it on or off to ensure that the temperature inside the fridge stays in the correct range of 33 to 40 degrees Fahrenheit. In frost-free models, a separate thermostat with a timer controls the defrosting cycle.
- Thermostats typically are located inside the fridge behind the interior walls, with a sensor extending into the cooling compartment. There are three general types -- vapor pressure, bimetallic and solid state.

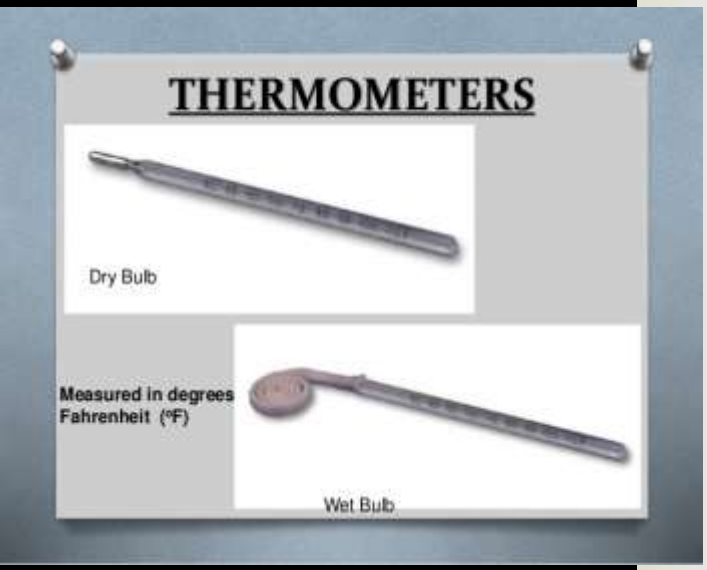
Chapter 6. Psychrometry

Humidity is the presence of moisture or water vapor in the air. Having high a Humidity level can be harmful.

1. Atmospheric air

- Atmospheric air is not completely dry but a mixture of dry air and water vapor.
- In atmospheric air, the content water vapor varies from 0 to 3% by mass.
- The processes of air-conditioning and food refrigeration often involve removing water from the air (dehumidifying), and adding water to the air (humidifying).

Cont..



2. The thermal parameters of moist air

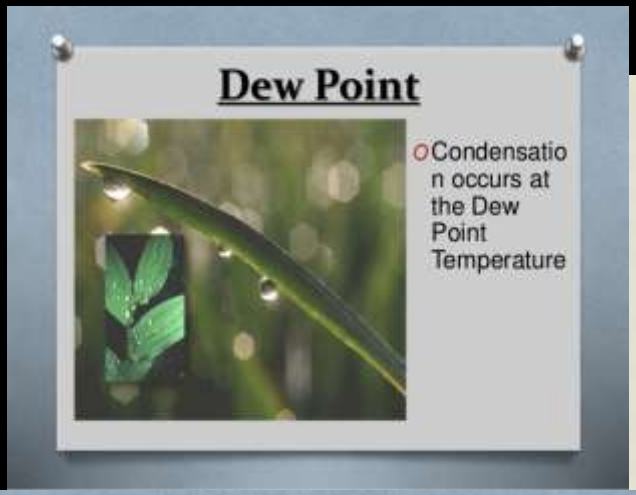
(1) Dry bulb temperature t

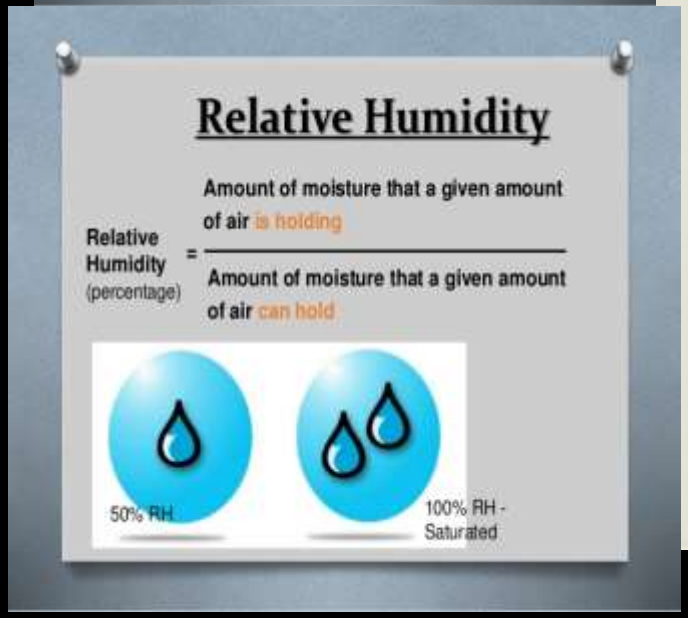
- Dry bulb temperature is the temperature of the air, as measured by an ordinary thermometer.
- The temperature of water vapor is the same as that of the dry air in moist air.
- Such a thermometer is called a dry-bulb thermometer in psychrometry, because its bulb is dry.

(2) Wet bulb temperature t_{WB}:

- Wet bulb temperature is thermodynamic adiabatic temperature in an adiabatic saturation process, and measured by a wet bulb thermometer.

Cont..





(3) Dew point temperature t_{DP}:

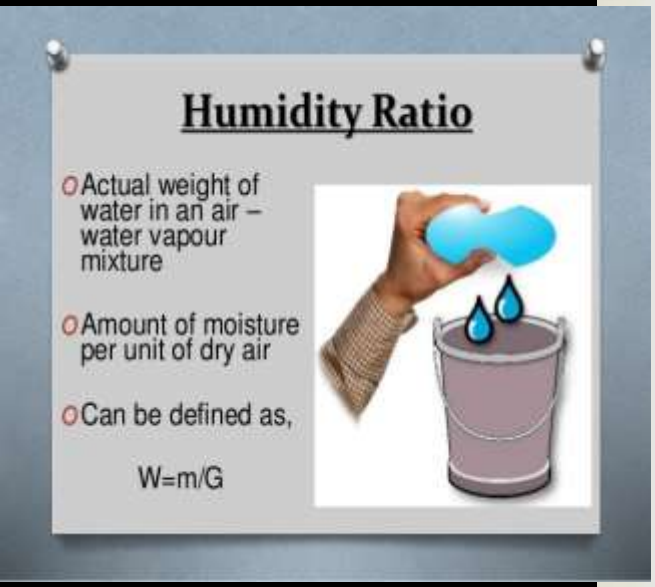
- When the unsaturated moist air is cooled at constant vapor pressure or at constant humidity ratio, to a temperature, the moist air becomes saturated and the condensation of moisture starts, this temperature is called dew point temperature of the moist air.

(4) Relative humidity Φ:

- Relative humidity is defined as the ratio of the mole fraction of the water vapor in a given moist air to the mole fraction of water vapor in a saturated moist air at the same temperature and the same atmospheric pressure.
- Relative humidity is usually expressed in percentage (%).
- From the ideal gas relations, relative humidity can be expressed as

$$\phi = \frac{x_w}{x_{w,sat}} = \frac{P_w}{P_{w,sat}}$$

Cont..



(5) Degree of Saturation μ:

- Degree of saturation is defined as the ratio of the humidity ratio of moist air w to the humidity ratio of saturated moist air w_{sat} at the same temperature and atmosheric pressure.

(6) Humidity ratio (Moisture Content) w:

- The humidity ratio is the mass kg of water vapor interspersed in each kg of dry air.
- It should be noted that the mass of water refers only to the moisture in actual vapor state, and not to any moisture in the liquid state, such as dew, frost, fog or rain.
- The humididy ratio, like other several properties to be studied- enthalpy and specific volume-is based on $1kg$ of dry air.

Cont..

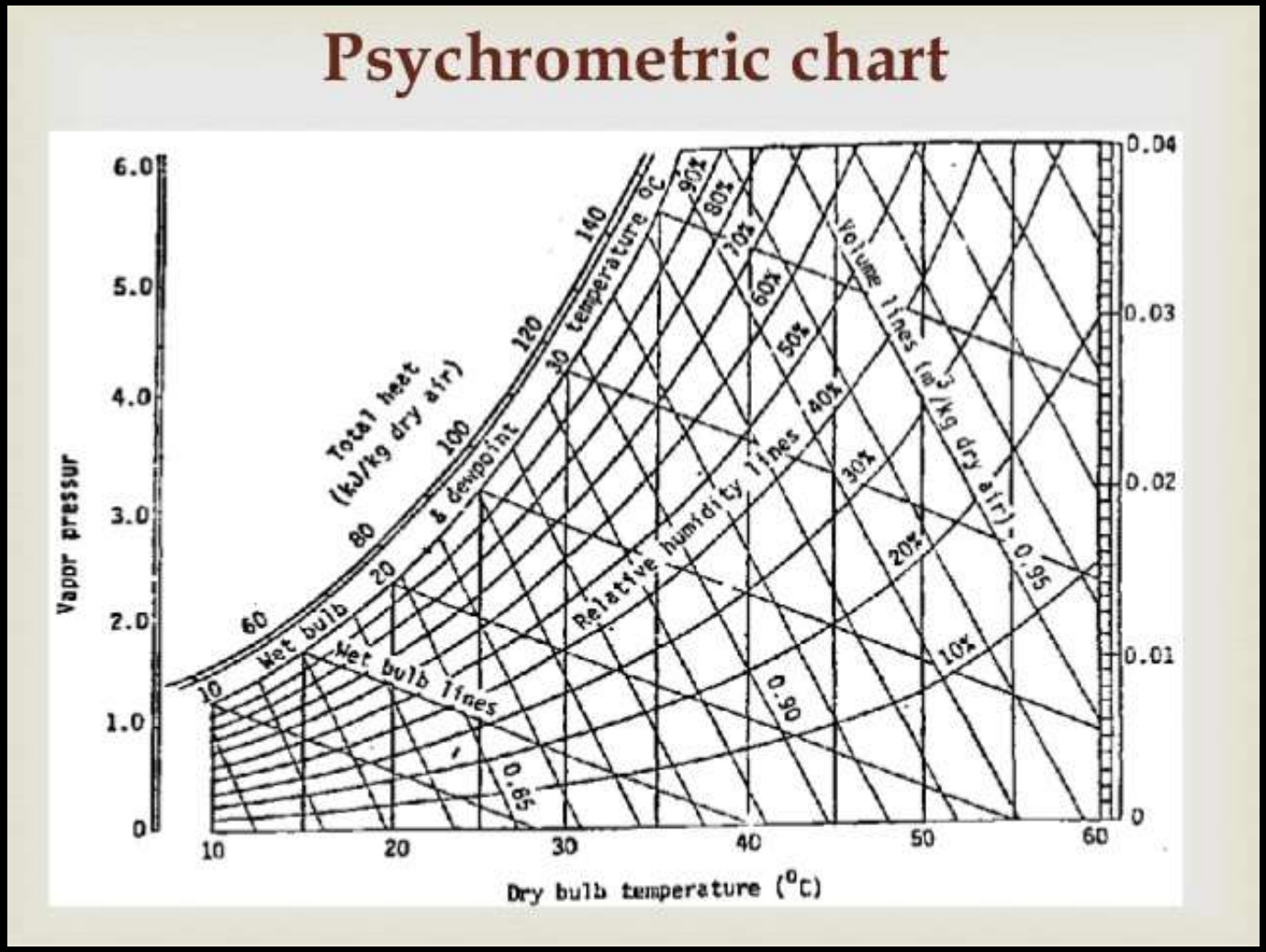
(7) Specific Volume/Moist Volume v:

- Specific volume of moist air v , m^3/kg_{dry} is defined as the total volume of the moist air (dry air and water vapor mixture) per kg of dry air.

(8) Specific Enthalpy:

- Specific enthalpy of moist air h (kJ/kg_{dry}) is defined as the total enthalpy of the dry air and water vapor mixture per kg of dry air.
- Enthalpy values are always based on some datum plane.
- Usually the zero value of the dry air is chosen as air at 0°C, and the zero value of the water vapor is the saturated liquid water at 0°C.

Cont..


Psychrometric chart
Vapor pressur
6.0
5.0
4.0
3.0
2.0
1.0
0
Total heat (kJ/kg dry air)
140
120
100
80
60
Wet bulb
& dewpoint
temperature °C
90%
80%
70%
60%
50%
40%
30%
20%
10%
Relative humidity lines
Volume lines (m³/kg dry air)
0.95
0.90
0.85
Wet bulb lines
10
20
30
40
50
60
0.04
0.03
0.02
0.01
0
Dry bulb temperature (°C)

Cont..

Psychrometric chart

- A psychrometric chart graphically represents the thermodynamic properties of moist air.
- It is very useful in presenting the air conditioning processes.
- The psychrometric chart is bounded by two perpendicular axes and a curved line:
  - 1) The horizontal ordinate axis represents the dry bulb temperature line t , in°C ;
  - 2) The vertical ordinate axis represents the humidity ratio line w , in $kg_w/kg_{dry.air}$
  - 3) The curved line shows the saturated air, it is corresponding to the relative humidity $\Phi=100\%$.

Cont..

- The psychrometric chart incorporates seven parameters and properties.
- They are dry bulb temperature t , relative humidity Φ , wet bulb temperature t_{WB}, dew point temperature t_{DP} , specific volume v, humidity ratio w and enthalpy h.

①Dry-bulb temperature t is shown along the bottom axis of the psychrometric chart.

The vertical lines extending upward from this axis are constant-temperature lines.

②Relative humidity lines Φ are shown on the chart as curved lines that move upward to the left in 10% increments.

The line representing saturated air ($\Phi = 100\%$) is the uppermost curved line on the chart.

And the line of $\Phi = 0\%$ is a horizontal ordinate axis itself.

Cont..

PSYCHROMETRIC PROCESSES

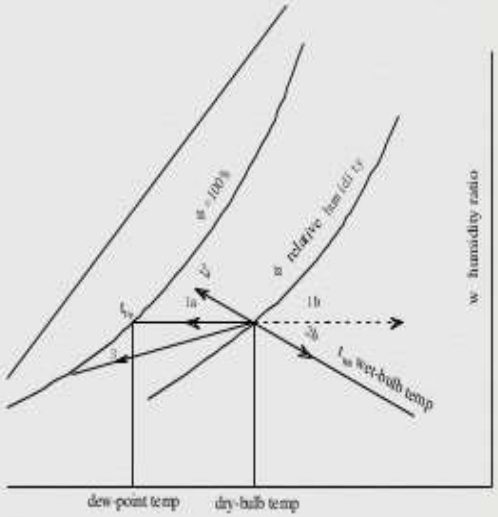
- SENSIBLE HEATING
- SENSIBLE COOLING
- DEHUMIDIFICATION
- HUMIDFIYING
- ADIABATIC COOLING
- ADIABATIC MIXING
  (MOIST AIR & WATER VAPOR)

Cont..

2. Main air handing processes and their variations in properties

(1) Sensible cooling along a cooling coil, or sensible heating along a heating coil

- The sensible cooling happens when the air is cooled without altering the specific humidity.
- During this process, the relative humidity of the air will increase.
- The sensible cooling can only take place under the condition when the temperature of the cooling coil is not below the dew point temperature of the air being processed.



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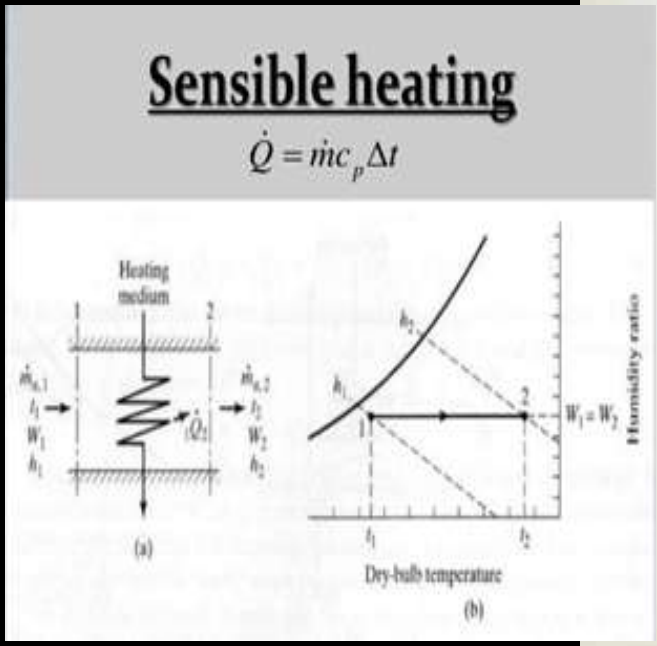
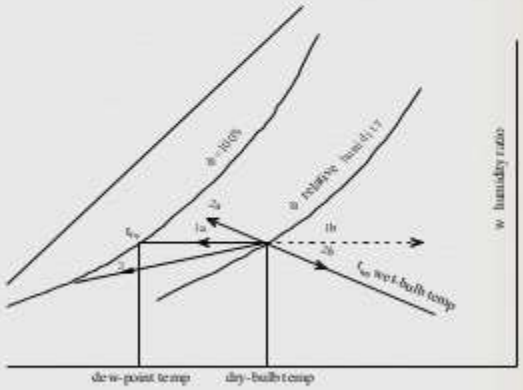


- The sensible heating is similar to sensible cooling, but with the dry bulb temperature increasing.
- It should be noted that there should be no water within the heating system because the evaporation of the water will increase the specific humidity of the air.



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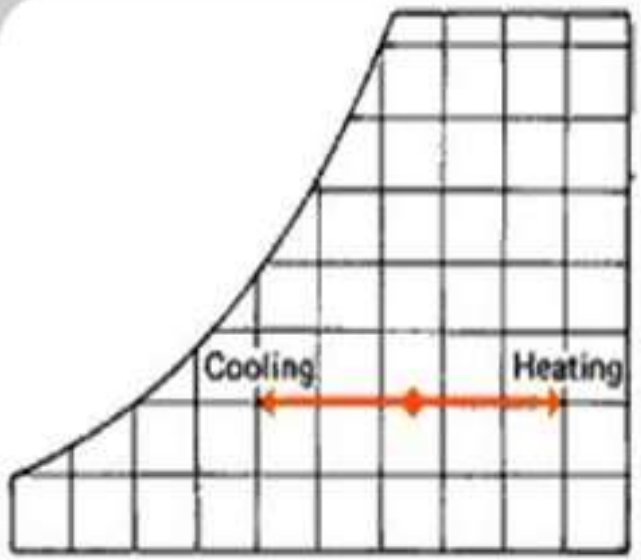
Sensible Heat & Cooling Processes

- **Heating & Cooling process – addition or removal of sensible heat without change in absolute moisture content.**
- **NOTE: RH changes as temperature changes.**

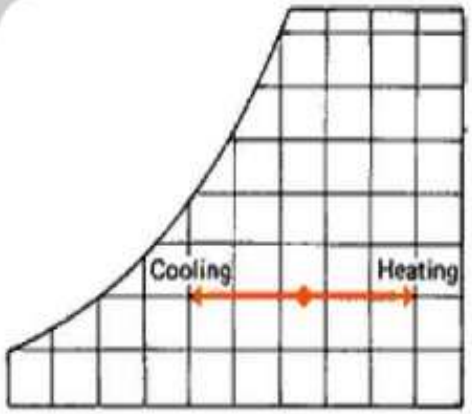


Sensible Heating & Cooling Process

Cont..

Sensible Heat & Cooling Processes

- Heating & Cooling process – addition or removal of sensible heat without change in absolute moisture content.
- NOTE: RH changes as temperature changes.

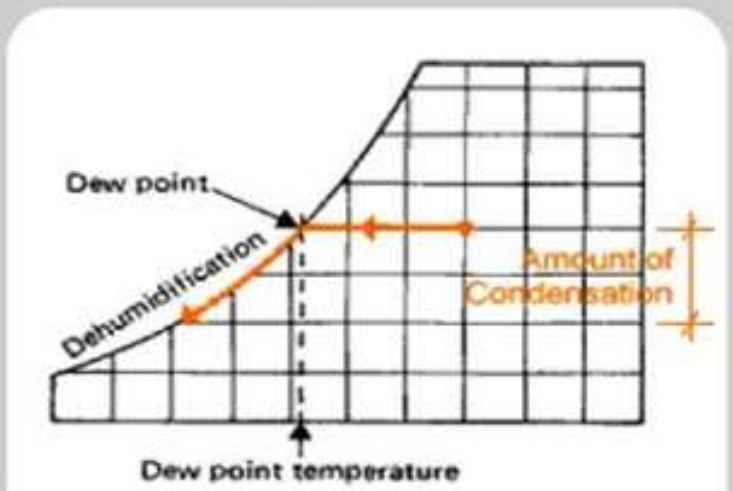


Sensible Heating & Cooling Process

Cont..

Psychrometry - Dehumidification

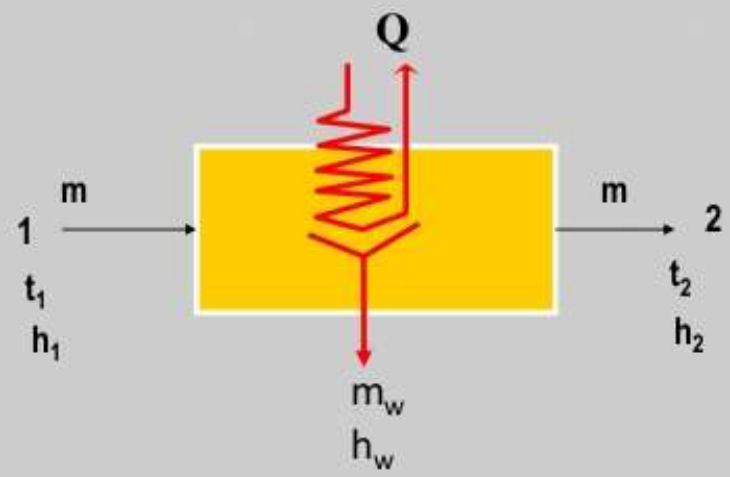
- **Dehumidification by cooling** – in cooling coils temp of air reduces and the saturation point (dew point) is reached.
- Further cooling results in reduction of absolute humidity.



Dehumidification By Cooling

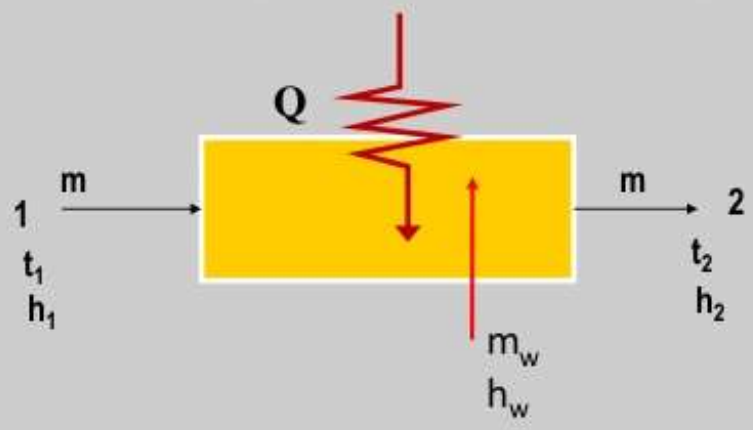
Cont..

3. **Cooling and Dehumidifying:** It is the removal of heat and moisture from moist air, it involves sensible and latent heat transfer.



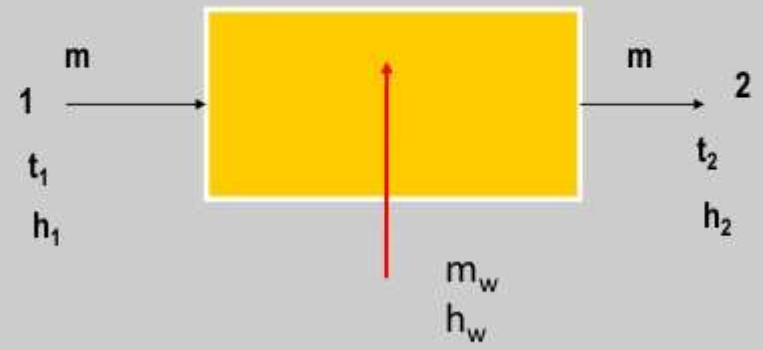
Cont..

4. **Heating and Humidifying:** It is the addition of heat and moisture to moist air, it also involves sensible and latent heat transfer.



Cont..

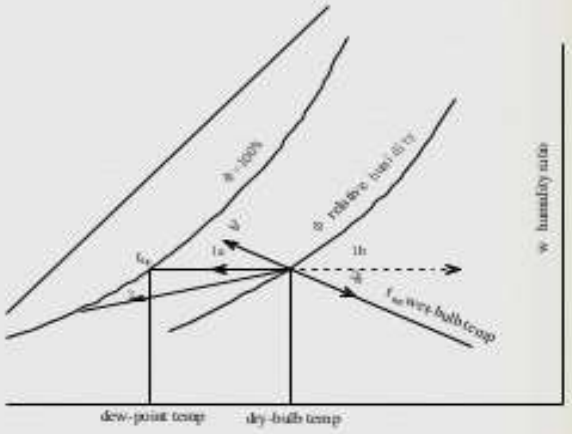
5. **HUMIDIFYING :** It is the addition of moisture to moist air without the addition of heat.



Cont..

(2) Adiabatic humidification and dehumidification using a humidifier or chemical dehumidifier

- The adiabatic humidification occurs when water vapor, of which temperature is near the wet bulb temperature of the moist air, is added to the air .
- A humidifier performs this function by supplying the water vapor.
- During the adiabatic humidification process along the constant wet bulb temperature line, the specific humidity of air will increase.
- Reduction in dry bulb temperature will happen as the evaporated water will absorb heat .



Chapter 7. Air Conditioners

- Purpose: maintain the atmosphere of an enclosed space at a required temp, humidity and purity
- Refrigeration system is at heart of AC system
- Types Used:
  - Self-contained
  - Refrigerant circulating
  - Chill water circulating

Cont..

Air conditioning

- Air conditioning is the science which deals with the supply and maintaining desirable internal atmospheric condition irrespective of external condition.
- Air conditioning may be defined as simultaneous control of temperature, humidity, motion of air and purity of air within the enclosed space.

Cont..

Classification of air conditioning

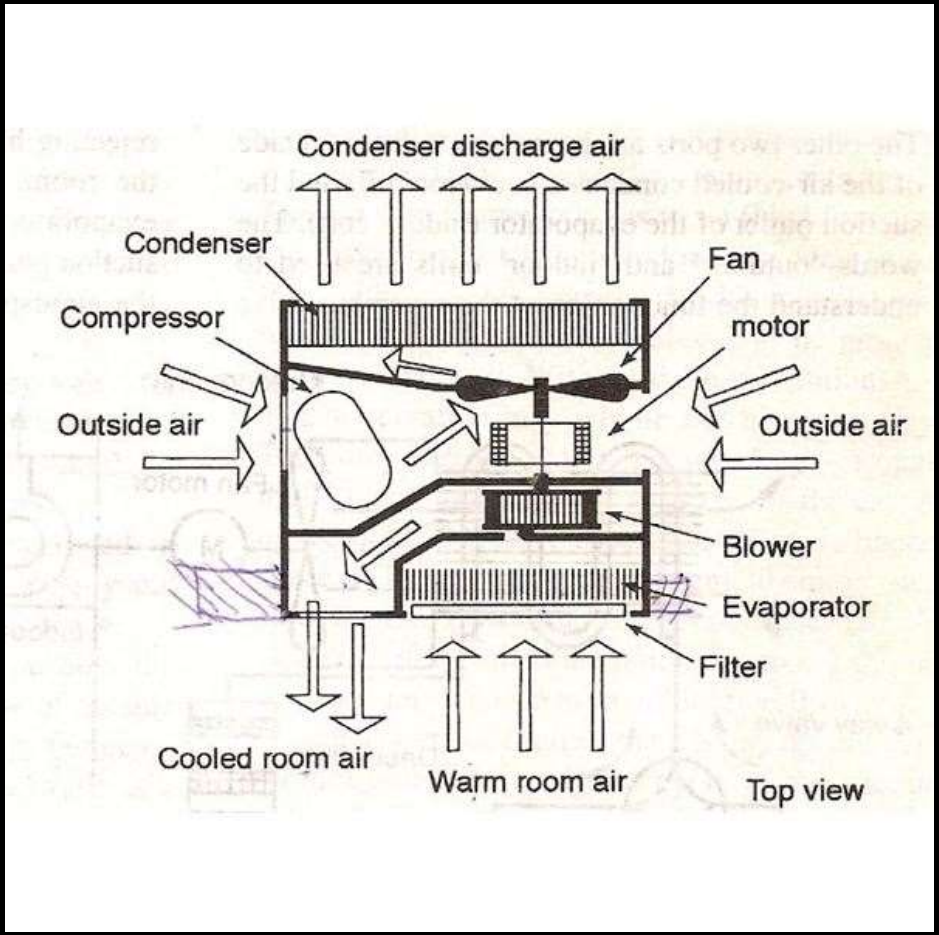
- a) According to purpose.
  - i) comfort air conditioning system
  - ii) Industrial air conditioning
- b) According season of year.
  - i) Winter air conditioning
  - ii) Summer air conditioning
  - iii) Year round (All weather air conditioning)

Cont..

Classification of air conditioning

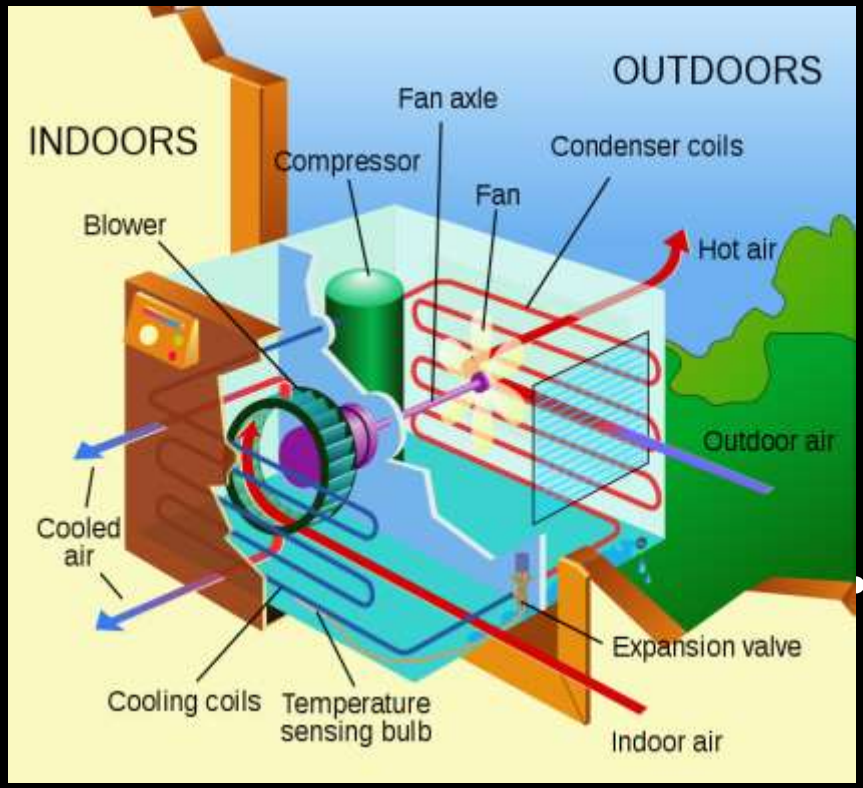
- c) According to equipment arrangement
  - i) central air conditioning
  - ii) unitary air conditioning
- d) According to working substance used.
  - i) All air system
  - ii) chilled water system
  - iii) Air water system

Window Air Conditioner



Air conditioning (often referred to as **AC**, **A/C**, or **air con**) is the process of removing heat and moisture from the interior of an occupied space, to improve the comfort of occupants. Air conditioning can be used in both domestic and commercial environments. This process is most commonly used to achieve a more comfortable interior environment, typically for humans and animals; however, air conditioning is also used to cool/dehumidify rooms filled with heat-producing electronic devices, such as computer servers, power amplifiers,

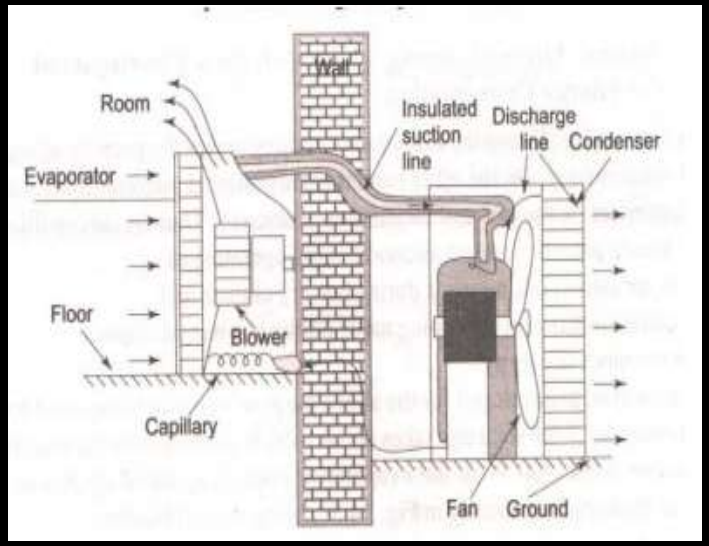
Cont..

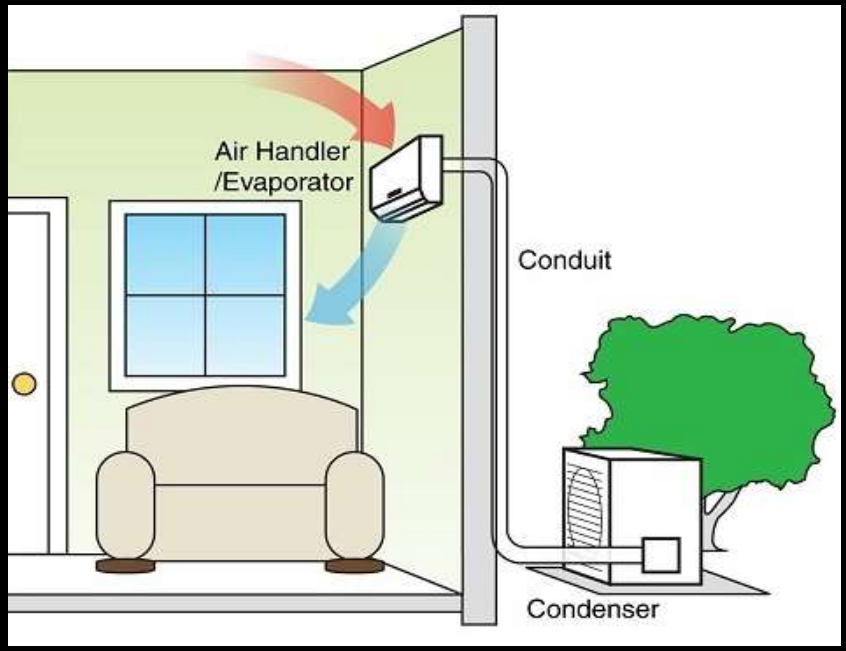


- Window unit air conditioners are installed in an open window. The interior air is cooled as a fan blows it over the evaporator. On the exterior the heat drawn from the interior is dissipated into the environment as a second fan blows outside air over the condenser.
- A large house or building may have several such units, allowing each room to be cooled separately.

Split Air Conditioner

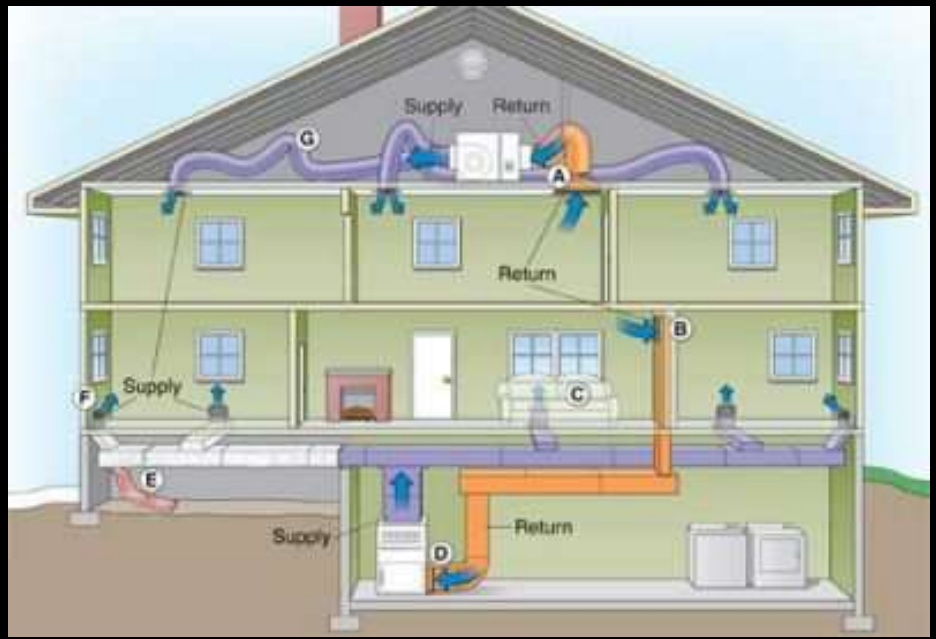
- Window unit air conditioners are installed in an open window. The interior air is cooled as a fan blows it over the evaporator. On the exterior the heat drawn from the interior is dissipated into the environment as a second fan blows outside air over the condenser. A large house or building may have several such units, allowing each room to be cooled separately.





Central Air-conditioning

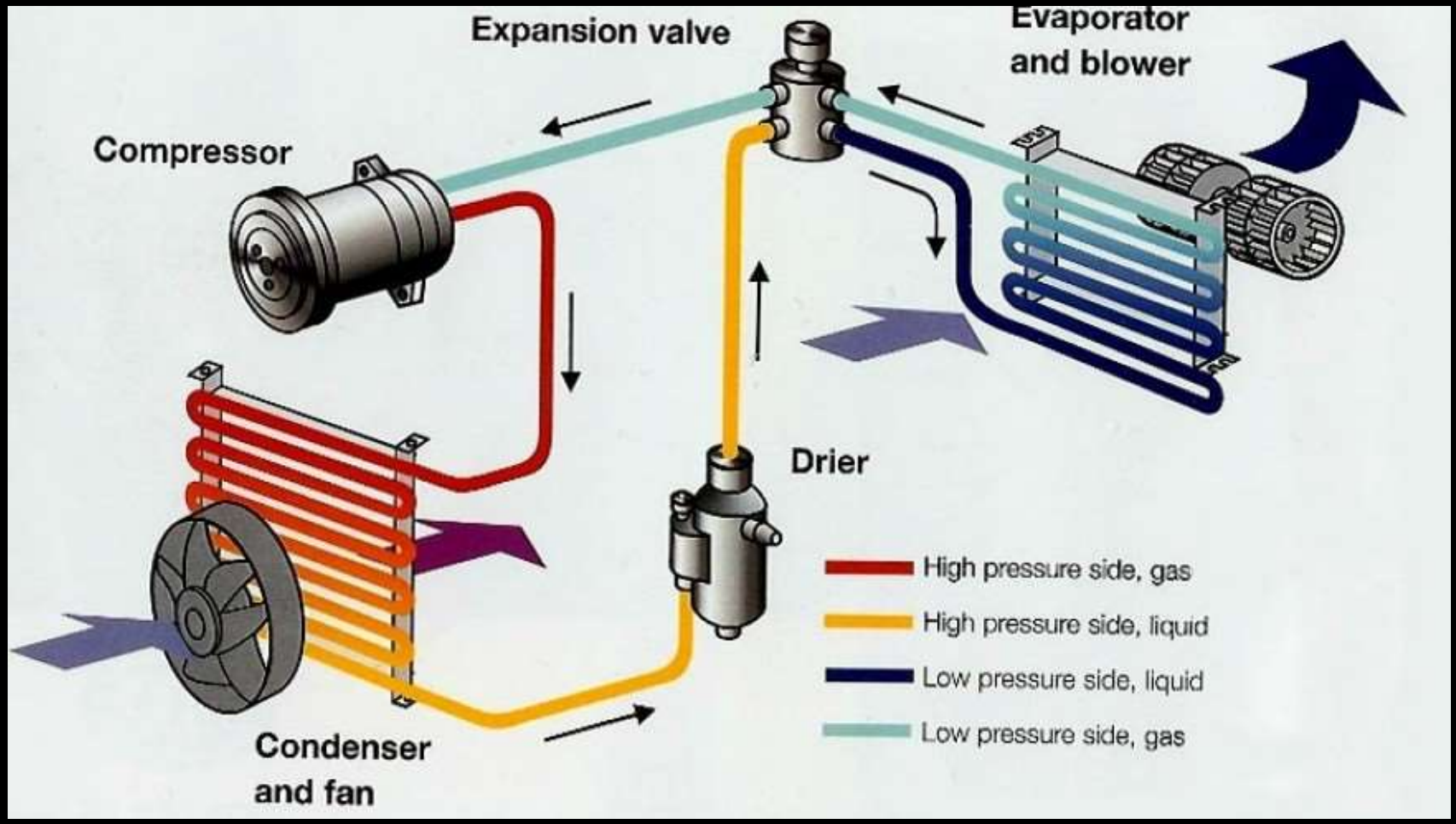
- Central (ducted) air conditioning offers whole-house or large-commercial-space cooling, and often offers moderate multi-zone temperature control capability by the addition of air-louver-control boxes.
- In central air conditioning, the inside heat-exchanger is typically placed inside the central furnace/AC unit of the forced air heating system which is then used in the summer to distribute chilled air throughout a residence or commercial building.



Automobile Air-Conditioning

- Air conditioning like it says 'conditions' the air. It not only cools it down, but also reduces the moisture content, or humidity. All air conditioners work the same way whether they are installed in a building, or in a car. The fridge or freezer is in a way an air conditioner as well. Air conditioning is a field in it's own right, but we'll stick to the main points or a car's air conditioning and the main parts used and a few hints to keep the air-con system running properly.
- Air conditioning's main principles are **Evaporation and Condensation**, then **Compression and Expansion**.

Cont..


Expansion valve
Evaporator
and blower
Compressor
Drier
Condenser
and fan
High pressure side, gas
High pressure side, liquid
Low pressure side, liquid
Low pressure side, gas

CHAPTER -8

LATEST DEVELOPMENT IN REFRIGERATION AND AIR CONDITIONING

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INVERTER TECHNOLOGY

- An inverter AC controls the speed of the compressor motor so as to regulate the temperature continuously. It is more effective and uses less power than a normal AC.
- It runs at full load until the fixed temperature achieved and runs at part load (generally half load) to maintain that temperature.
- An inverter Ac never turns off the motor or compressor.

Advantages of inverter AC

- Energy saving
- Less noisy
- Lower operational cost
- Requires no reset after a power cut
- Includes filtration process
- Comfortable

AUTO DEFROSTING

- It is the automatically defrosting the ice which may block the vents that allows air into the refrigerator compartment.

Advantages of Auto defrosting

- No need to manually defrost
- Most frozen food will not stick together
- Smells are limited because the air always circulate.
- Better temperature managements

Disadvantages of the Auto defrosting

- More expensive
- Thermal cut-out safety device is required to prevent overheating of the elements
- May cause freezer burn on articles placed in the freezer from partially defrosting then re-freezing.
- Increased electrical and mechanical complexity, making it more prone to component failure.

BLAST COOLING

- *Blast Cooling* (also *Blast Chilling*) is a precooling method where air is forced (blasted) out at relatively high velocities in order to cool food to a low temperature suitable for storage. Blast Cooling is also called forced-air cooling.
- Blast Cooling rapidly lowers the "pulp temperature" of product to preserve quality, extend shelf-life, and inhibit microbial growth.

BENEFITS OF BLAST COOLING

- Maintaining food quality
- Prevent food shrinkage
- Increase menu and service
- Achieve food safety standards

STAR RATING

- The **star rating** is a measure of energy efficiency of an appliance, it is a five-point scale where the higher the **rating**, the lower is the energy consumption and, hence, better savings. For each product, BEE decides a period of two to three years for which a **rating** table is valid.

BEE (**BUREAU OF ENERGY EFFICIENCY**)

- BEE is an agency of Government of India established in March 2002 under the Ministry of power. It is an autonomous Government agency which introduced conservation and efficient use of energy in certain electrical appliances in India. Bee star rating means the capacity of the appliance according to the volume, storage volume, and electricity it consumes per unit.

STAR RATING IN REFRIGERATORS

- The BEE star rating of the top refrigerators in India starts from a minimum of 1-star to a maximum of 5-star. The expense also increases with the stars and the quality of the Refrigerator as well. You must notice that these star ratings are only available for single door and frost-free refrigerators. These refrigerators are more expensive due to star ratings. But a 5-star refrigerator is more expensive than a 1-star. But in long run, it will save your money by saving your electricity bill.

POWER CONSUMPTION

- According to the calculation of annual electricity consumption, a no star Refrigerator consumes 1000 units per year. But a 3-star rating Refrigerator uses only 626 units of electricity consumption per year. A 3-star rated Refrigerator saves 44% of your electricity consumption and obviously your electricity bill.


THANK
YOU