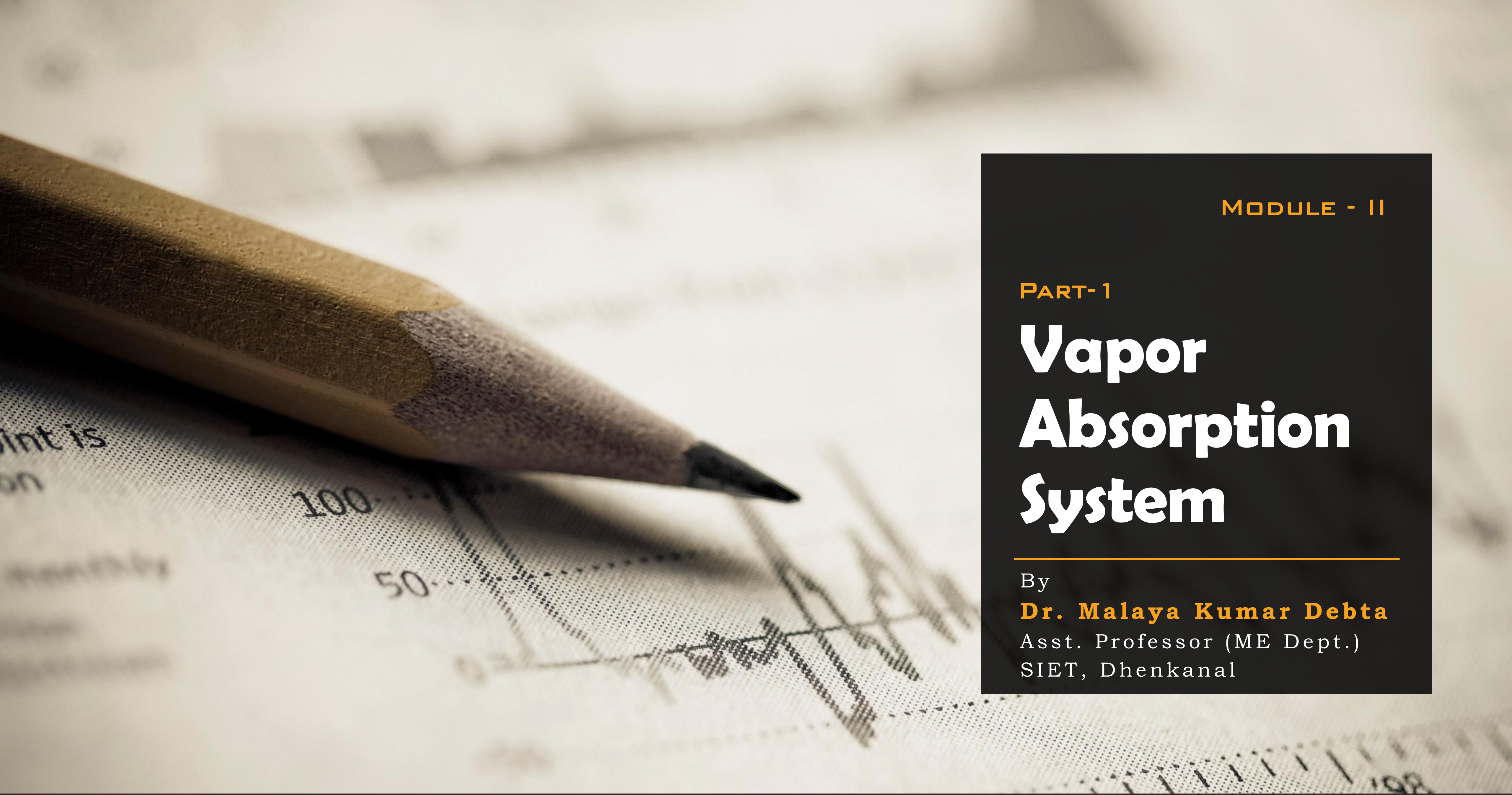

Module - II

Part- 1

Vapor Absorption System

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INTRODUCTION

- The vapour absorption refrigeration system is one of the method of producing refrigerating effect.
- Uses heat energy instead of mechanical energy as in vapour compression system.
- In the vapour absorption system the compressor is replaced by an absorber, a pump, a generator, and a pressure reducing valve.
- These component in vapour absorption system perform the same function as that of a compressor in vapour compression system.

REFRIGERATION

- The term ‘refrigeration’may be defined as the process of removing heat from a substance under controlled condition.
- In other words the refrigeration means a continued extraction of heat from a body whose temperature is already below the temperature of its surrounding.
- UNITS OF REFRIGERATION-
- The practical unit of refrigertion is expressed in terms of “tonne of refrigeration.
- REFRIGERANT-
- Refrigerant is a heat carrying medium in the refrigeration system, which absorb heat from the low temp system and discard heat so absorb to a higher temperature system.
- In the vapour absorption refrigeration system we use ammonia as the refrigernt.

WORKING PRINCIPLE

- The vapour absorption refrigeration system is one of the method of producing refrigerating effect.
- Uses heat energy instead of mechanical energy as in vapour compression system.
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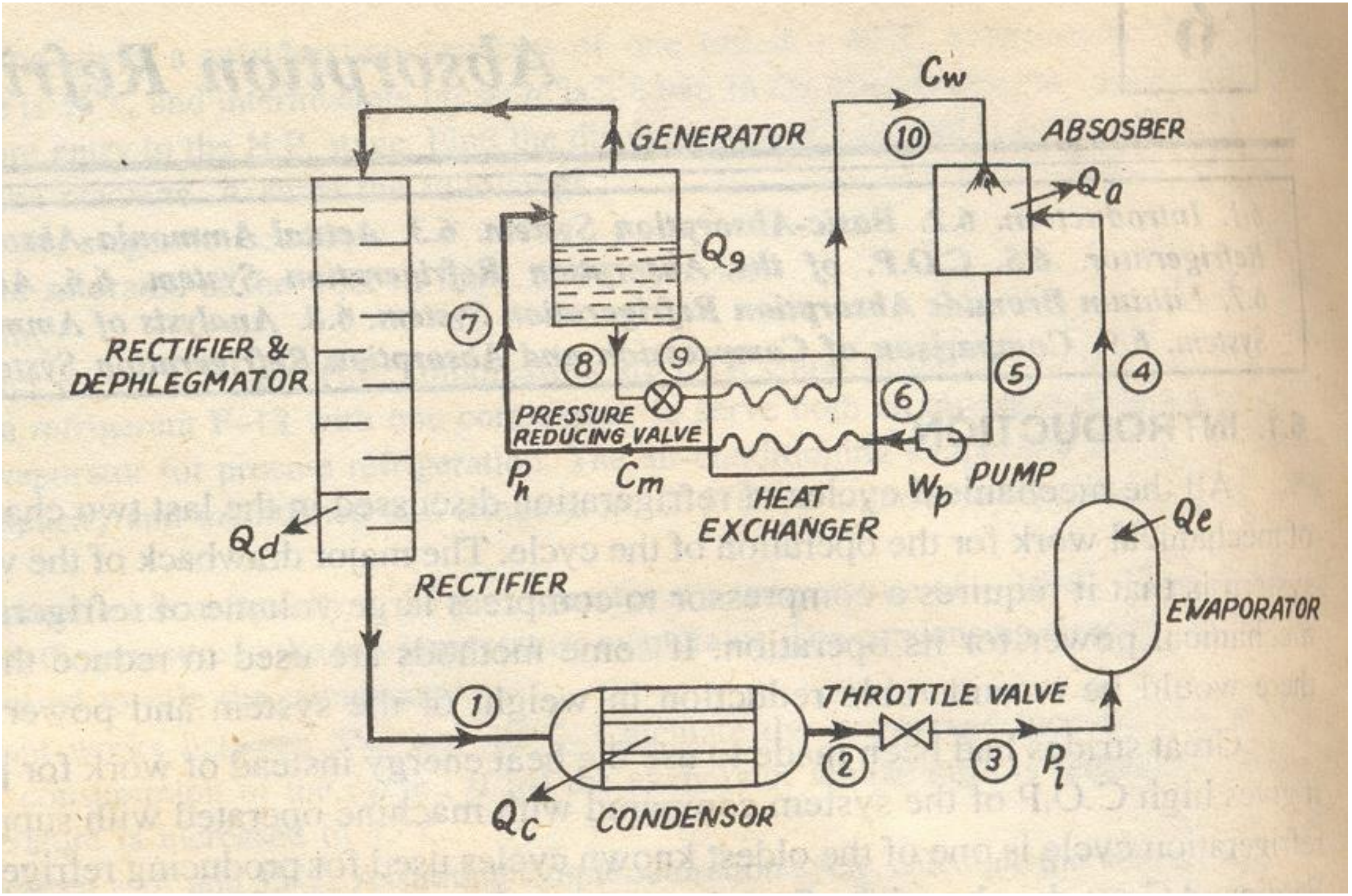


A) Absorber:

- Its primary function is to assimilate low-pressure refrigerant vapours into a mixture of refrigerant and absorbent.
- The absorber receives the weaker solution from the generator and the low-pressure refrigerant vapours from the evaporator. The refrigerant vapours are absorbed within the absorber, resulting in a more concentrated solution.
- During this absorption process, the refrigerant vapours release **latent heat**, causing a **rise in temperature** within the absorber. This increase in temperature can reduce the absorbent's absorption capacity. To mitigate this effect, cooling water is employed to lower the solution's temperature.

B) Pump:

The pump plays a crucial role in drawing the concentrated solution from the absorber and delivering it to the generator at an **elevated pressure**.

C) Generator:

- Its primary purpose is to **elevate the temperature** of the concentrated solution, achieved through heating coils, solar energy, or waste heat utilisation. Since the refrigerant has a lower boiling point than the absorbent, the refrigerant within the solution vaporises, leaving the solution weaker.
- To prevent potential system damage, the weak solution from the generator is not directed to the condenser but returns to the absorber through a pressure reducing valve (PRV).

D) Condenser:

High-pressure refrigerant vapours from the generator enter the condenser. Within the condenser, **a cooling medium** is utilised to **lower the temperature of the hot refrigerant vapours**. This process results in the **transformation** of the refrigerant vapours into high-pressure saturated liquid refrigerant.

E) Pressure Reducing Valve (PRV):

The pressure reducing valve is strategically positioned between the high-pressure generator and the low-pressure absorber. It reduces the pressure of the weak solution exiting the generator before it is directed back to the absorber.

F) Expansion Valve:

Located between the condenser and evaporator, the expansion valve serves a critical role. After exiting the condenser, the high-pressure liquid refrigerant enters the expansion valve. Here, the high-pressure liquid refrigerant undergoes a transition into a mixture of low-pressure refrigerant, comprising both liquid and vapour components.

G) Evaporator:

The evaporator is situated within an enclosed space where the cooling process occurs. The low-pressure liquid refrigerant absorbs heat from the surrounding environment within the evaporator, providing a cooling effect. As a result of this heat absorption, the liquid refrigerant transforms into low-pressure refrigerant vapours.

Difference between VC and VA systems:

	VC	VA
1.	It uses high grade energy/work energy	It uses low grade energy/heat energy
2.	Compressor is used	Compressor is replaced by absorber, pump and generator
3.	Large wear &tear due to compressor	Less wear and tear
4.	Large possibilities of refrigerant leakage	Less possibilities of leakage
5.	High COP due to i/p as high grade energy	Less COP due to i/p as low grade energy
6.	Moisture may damage the compressor	No such problem is occure

Types of Vapour Absorption Refrigeration System:

- Absorption Refrigeration Systems can be categorized based on the **working fluids** they use.
- The most common types include **water-lithium bromide (LiBr)** and **ammonia-water (NH_3-H_2O)** systems.

A. Based on the Working Fluids:

1) **Aqua Ammonia:**

In this VARS configuration, water is the absorbent, while ammonia is the refrigerant. This system has the capability to generate temperatures below 0°C, making it well-suited for refrigeration purposes.

2) **LiBr–H_2O:**

The LiBr–H_2O VARS system employs lithium bromide (LiBr) as the absorbent and water as the refrigerant. Since water freezes at 0°C, this system is predominantly used for air conditioning and chilling applications.

B. Based on the Number of Stages:

1) **Single Effect VARS System:**

The single-effect VARS system relies on a solitary generator, resulting in the regeneration process occurring in a single stage. However, it tends to exhibit a lower Coefficient of Performance (COP) when compared to the double-effect VARS system.

2) **Double Effect VARS System:**

Contrasting with the single-effect counterpart, the double-effect VARS system integrates two generators, facilitating regeneration in two distinct stages. As a consequence, it typically boasts a higher COP than the single-effect system.

COP of Vapour Absorption Refrigeration System

Advantages of VARS:

The **advantages** include:

- Energy-efficient using waste heat.
- Environmentally friendly, no CFCs.
- Quieter operation.
- Lower electricity consumption.
- Suitable for remote areas.
- Longer component lifespan.
- Effective for high-temperature applications.

Disadvantages of VARS:

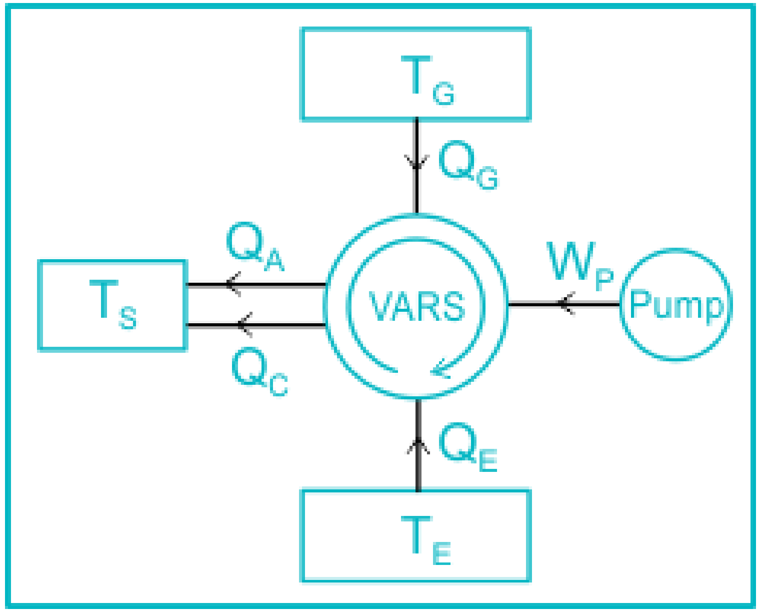
The **limitations** are:

- Larger and bulkier compared to vapour compression systems.
- Limited cooling capacity.
- Higher initial cost.
- Requires a heat source for operation.
- Lower coefficient of performance (COP) in some cases.
- More complex maintenance.

Application of VARS:

The **applications** of VARS are:

- Industrial cooling and refrigeration.
- Air conditioning in large buildings.
- Power plants for waste heat utilisation.
- Remote and off-grid refrigeration.
- Ammonia-water systems for low-temperature applications.



$$COP_{VARS} = \left[\frac{T_G - T_o}{T_G}\right] \times \left[\frac{T_R}{T_o - T_R}\right]$$

T_G = Temperature at generator
T_E = Temperature at evaporator
T_S = Surrounding temperature

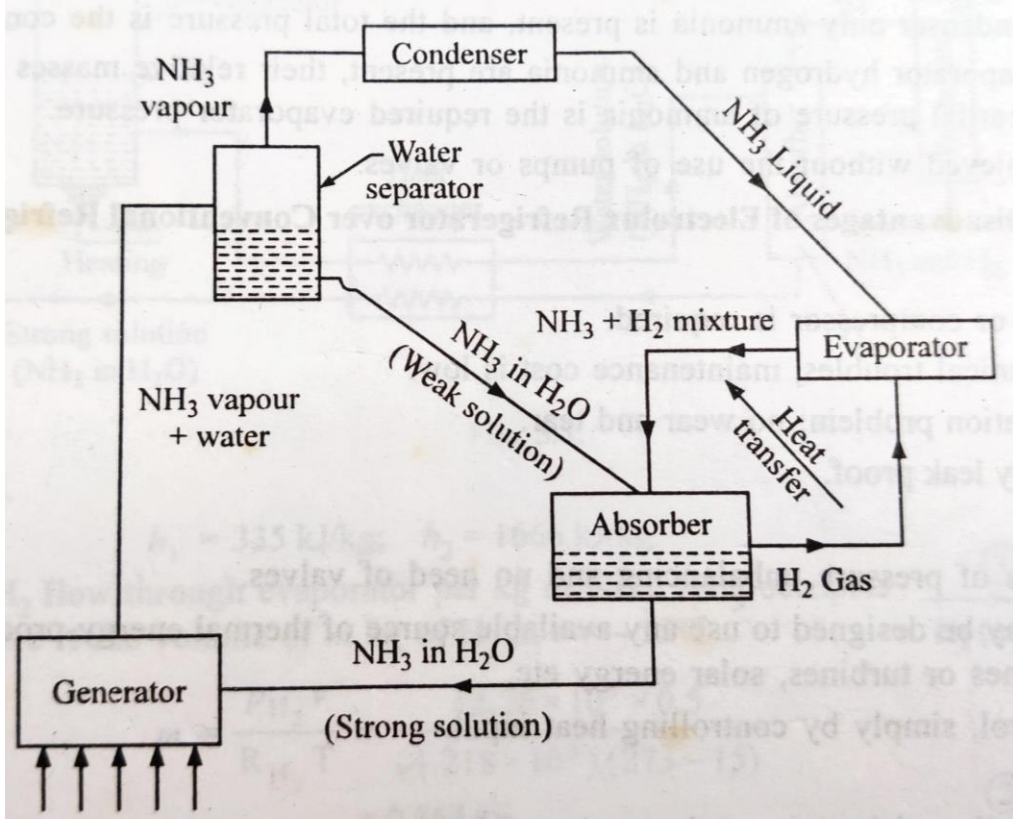
Electroflux Refrigeration System:

- It is also called as ‘**Munters Platen System**”as developed by **Carl Munters.**
- It is a **three fluid absorption system**. (NH_3 , H_2O , H_2)
- **NH_3** is used as refrigerants, **H_2O** as absorbent and **H_2** is used to create low pressure in the evaporator.
- There is **no pump required** in Electroflux system.

- **NH_3 :** It is used as refrigerant because it possesses most of the desirable properties. Though it is toxic, and not otherwise preferred in domestic appliances, it is very safe in this system due to absence of any moving parts in the system. This leads to very less chance of any leakage.
- **H_2:** It is the lightest gas, and used to **increase the rate of evaporation** of the liquid ammonia passing through the evaporator. It is also **non-corrosive** and **insoluble in water**. This is used in the low-pressure side of the system.
- **H_2O:** It is used as a solvent because it has **strong affinity/ability to absorb ammonia** readily.

Principle of Electroflux Refrigeration System:

Electrolux refrigerator makes the use of properties of gas-vapour mixtures (i .e. mixture of hydrogen gas and vapour refrigerant). If a liquid (here, liquid refrigerant ammonia) is exposed to an inert atmosphere (here, Hydrogen gas), then the liquid will evaporate. This evaporation requires heat, which is taken from the surroundings (here, space or substance to be cooled), in which, the evaporation takes place. A cooling effect is thus produced. The partial pressures of vapour refrigerant (here, Ammonia) must be low in the evaporator and high in condenser. The total pressure throughout the circuit must be constant, so that, the movement of the working fluid (here, ammonia as refrigerant) is purely by means of convection currents. Therefore, no pump is required for circulation and pressure increase. Partial pressure of working fluid (here, ammonia as refrigerant) is kept low in requisite parts of the circuit by concentrating hydrogen in those parts.



Working:

Working. The ammonia liquid leaving the *condenser* enters the *evaporator* and evaporates into the hydrogen at the low temperature corresponding to its low partial pressure. The mixture of ammonia and hydrogen passes to the absorber into which is also admitted water from the *separator*. The water absorbs the ammonia and the hydrogen returns to the evaporator. In the absorber the ammonia therefore passes from the ammonia circuit into water circuit as ammonia in water solution. This strong solution passes to the *generator* where it is heated and the vapour given off rises to the separator. The water with the vapour is separated out and a weak solution of ammonia is passed back to the absorber, thus completing the water circuit. The ammonia vapour rises from the separator to the condenser where it is condensed and then returned to the evaporator.

The actual plant includes refinements and practical modifications (which are not included here).

The following *points are worth noting*:

- The complete cycle is carried out entirely by gravity flow of the refrigerant.
- The hydrogen gas circulates only from the absorber to the evaporator and back.
- With this type of machine efficiency is not important since the energy input is small.
- It has not been used for industrial applications as the C.O.P. of the system is very low.

Strong aqua ammonia solution present in the absorber flows in to the generator. It is heated in the generator by using an external source like gas burner. During this heating process, the ammonia dissolved in the strong solution gets vapourized. This ammonia vapour refrigerant coming out from the generator is passed through a rectifier or water separator provided between the generator and the condenser. Sometimes, water vapours (in small quantity) may be formed in generator. These water vapours may pass on to condenser and then to evaporator along with ammonia vapours, where they may freeze at low temperature and further, may choke the tubes. The function of rectifier or water separator is to prevent the entry of these water vapours into condenser and then to the evaporator. After passing through rectifier, the dehydrated ammonia vapour is liquefied in the condenser. After condenser, a U-tube gas seal is provided to prevent backflow of ammonia as well as entry Of hydrogen in to the condenser. Now, liquid ammonia enters the evaporator, where it meets the hydrogen gas. Please note that, the whole system is charged to a pressure of 14 bar and the evaporator contains hydrogen at a pressure of 12 bar.

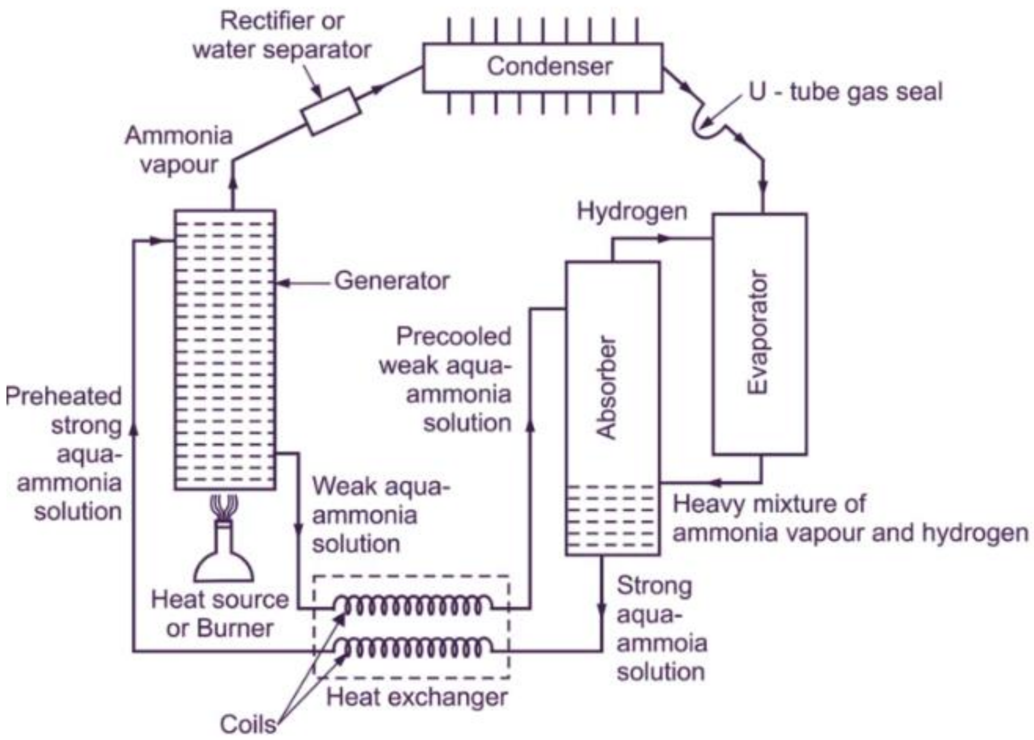


Fig. 1: Electrolux refrigerator

Role of Hydrogen:

Hydrogen is non-corrosive and insoluble in water. Role of Hydrogen as

1. It reduces the partial pressure of refrigerant in the evaporator.
2. It permits the refrigerant to evaporate at low temperature in the evaporator corresponding to its partial pressure.
3. Being the lightest gas, it is used to increase evaporation rate of liquid ammonia refrigerant passing through the evaporator.
4. By presence of hydrogen, it is possible to maintain uniform total pressure throughout the system.
5. To improve COP.
6. To circulate the refrigerant.
7. To provide a vapour seal.
8. By presence of Hydrogen, the condenser and evaporator pressures of the refrigerant are maintained in the following way.

- In condenser, only ammonia is present and tota pressure is the condensing pressure.
- In evaporator, hydrogen and ammonia are present. Their relative masses are adjusted in such a way that, the partial pressure of ammonia is equal to required evaporator pressure.

These conditions of pressures are achieved without use of pumps or valves.

Advantages of Electroflux Refrigerator:

- No need of pump.
- Due to absence of any moving part, the operation is noise free.
- Hydrogen gas required is much cheaper.
- Leak proof system.
- No lubrication problem.
- Low maintenance cost due to absence of moving parts.
- Easy control (simp y by control ing heat input)
- No chance of pressure unbalancing.
- No need of valves.

Disadvantages of Electroflux Refrigerator:

- More complicated in construction and working.
- Low cop.
- The major disadvantage is that, if the system is spoiled once, it cannot be repaired and therefore, system has to be replaced fully.
- It cannot be used for industrial purposes or applications due to low COP, i.e. poor performance.

Sample Numericals:

Module - II

Part-2

Thermoelectric Refrigeration

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Thermoelectric Refrigeration:

- Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials.
- This effect is commonly used in camping and portable coolers and for cooling electronic components and small instruments.
- Applying a DC voltage difference across the thermoelectric module, an electric current will pass through the module and heat will be absorbed from one side and released at the opposite side. One module face, therefore, will be cooled while the opposite face simultaneously is heated.
- On the other hand, maintaining a temperature difference between the two junctions of the module, a voltage difference will be generated across the module and an electrical power is delivered.

Basic principles of thermoelectric modules:

Thermoelectricity is based upon following basic principles:

1. **Seebeck effect**
2. **Peltier effect**
3. **Thomson effect**
4. **Joule effect**
5. **Fourier effect**

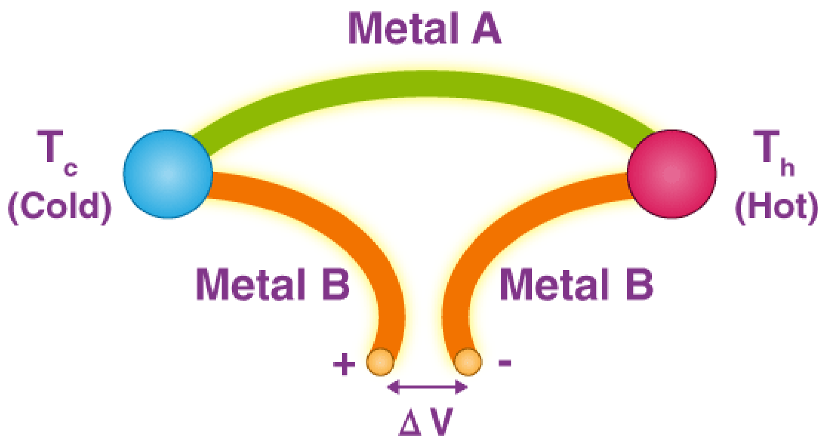
SeeBeck Effect:

- In 1821, Thomas Seebeck found that an electric current would flow continuously in a **closed circuit** made up of **two dissimilar metals**, if the junctions of the metals were maintained at **two different temperatures**.
- **Thermoelectric power supply generators** are based on the Seebeck effect which is based on voltage generation along a conductor subjected to a **gradient of temperature**.
- When a temperature gradient is applied to a conductor, an **electromotive force** is produced. The voltage difference generated is proportional to the temperature difference across the thermoelectric module between the two junctions, the hot and the cold one. i.e. **ΔV α ΔT**

SeeBeck Coefficient

- The Seebeck coefficient is defined as the ratio of the voltage difference to the temperature gradient.
- If the temperature difference ΔT between the two ends of a material is small, then the Seebeck coefficient of a material is defined as:

$$\alpha_{ab} = \Delta V / \Delta T$$



Where, $\alpha_{ab} = \alpha_a - \alpha_b$, and α_a & α_b is the Seebeck Coefficient having units **Volts per Kelvin** for metals A & B

Peltier Effect:

- In 1834, a French watchmaker and part time physicist, Jean Peltier found that an electrical current would produce a temperature gradient at the junction of two dissimilar metals.
- The Peltier effect is the main contributor to all thermoelectric cooling applications. It is responsible for heat removal and heat absorbance.
- It states that when an electric current flows across two dissimilar conductors, the junction of the conductors will either absorb or emit heat depending on the flow of the electric current.

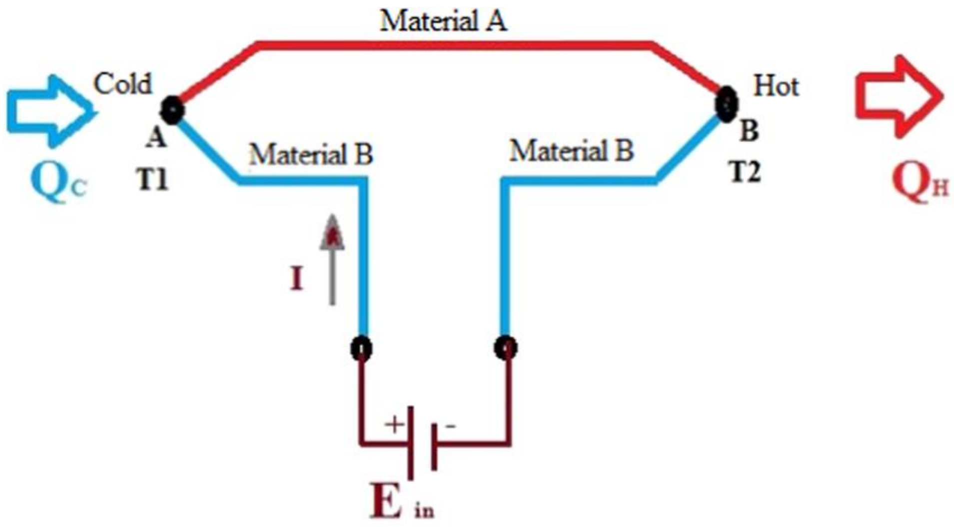
Peltier Coefficient

- When a current is made to flow through a junction between two conductors A and B, heat may be **generated (or released)** at the junction.
- The **Peltier heat** generated/released at the junction per unit time, **Q** , is **proportional to the input electric current**. The constant of proportionality is called the **Peltier coefficient.**

$$Q \propto I \Rightarrow Q = \pi_{ab} I$$

Where, $\pi_{ab} = \pi_a - \pi_b$, and π_a & π_b are the Peltier coefficient of conductor A & B,

I is the electric current (from A to B)



Thompson Effect:

- The Thompson effect governs the cooling and the heating of a material carrying a current and subjected to a temperature gradient.
- It states when an electric current is passed through a conductor having a temperature gradient over its length, heat will be either absorbed by or expelled from the conductor.

$$\frac{dQ}{dx} = \tau I \left[\frac{dT}{dx}\right]$$

  - Whether heat is absorbed or expelled depends upon the direction of both the electric current and temperature gradient

Peltier Coefficient