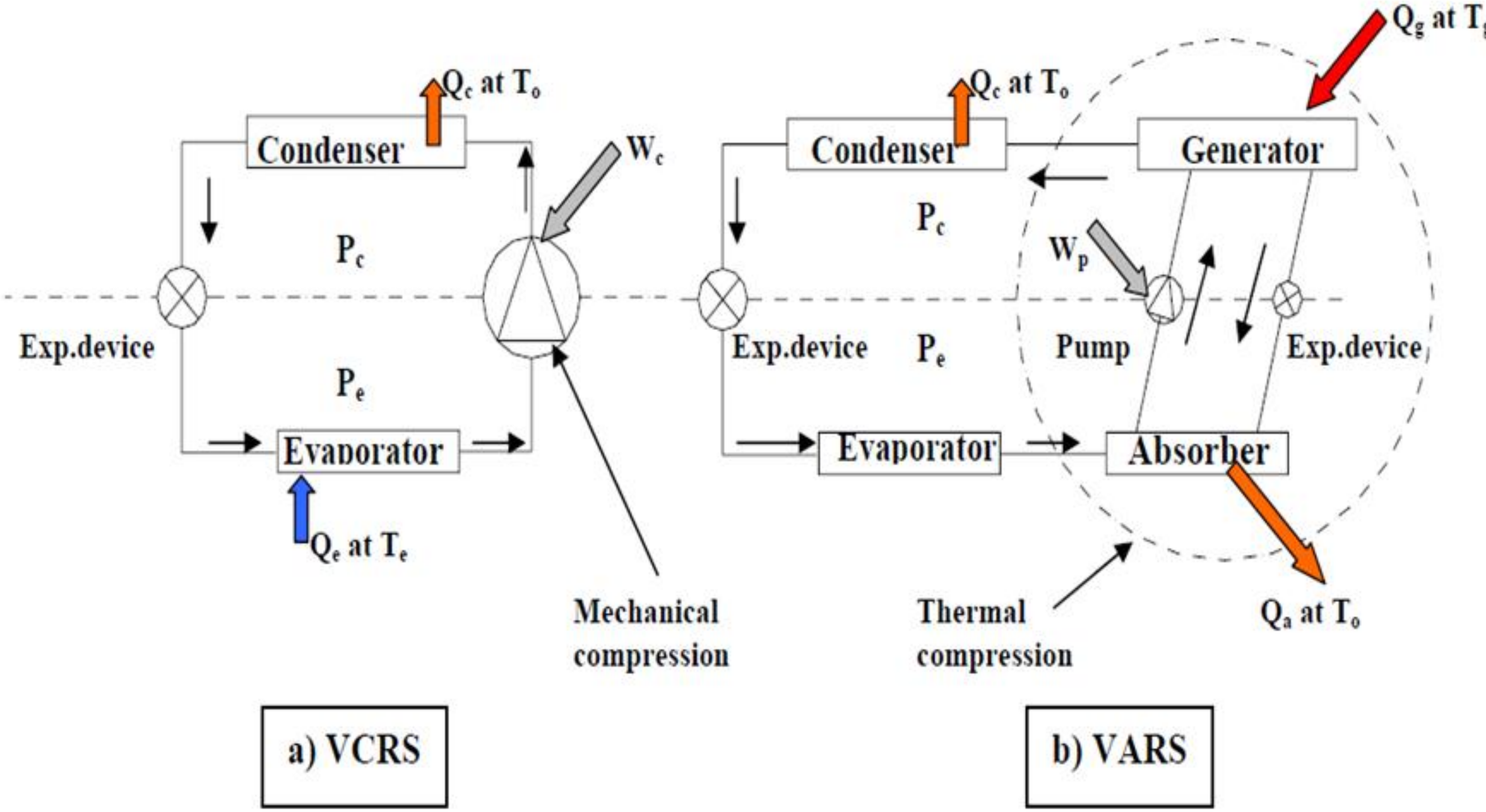
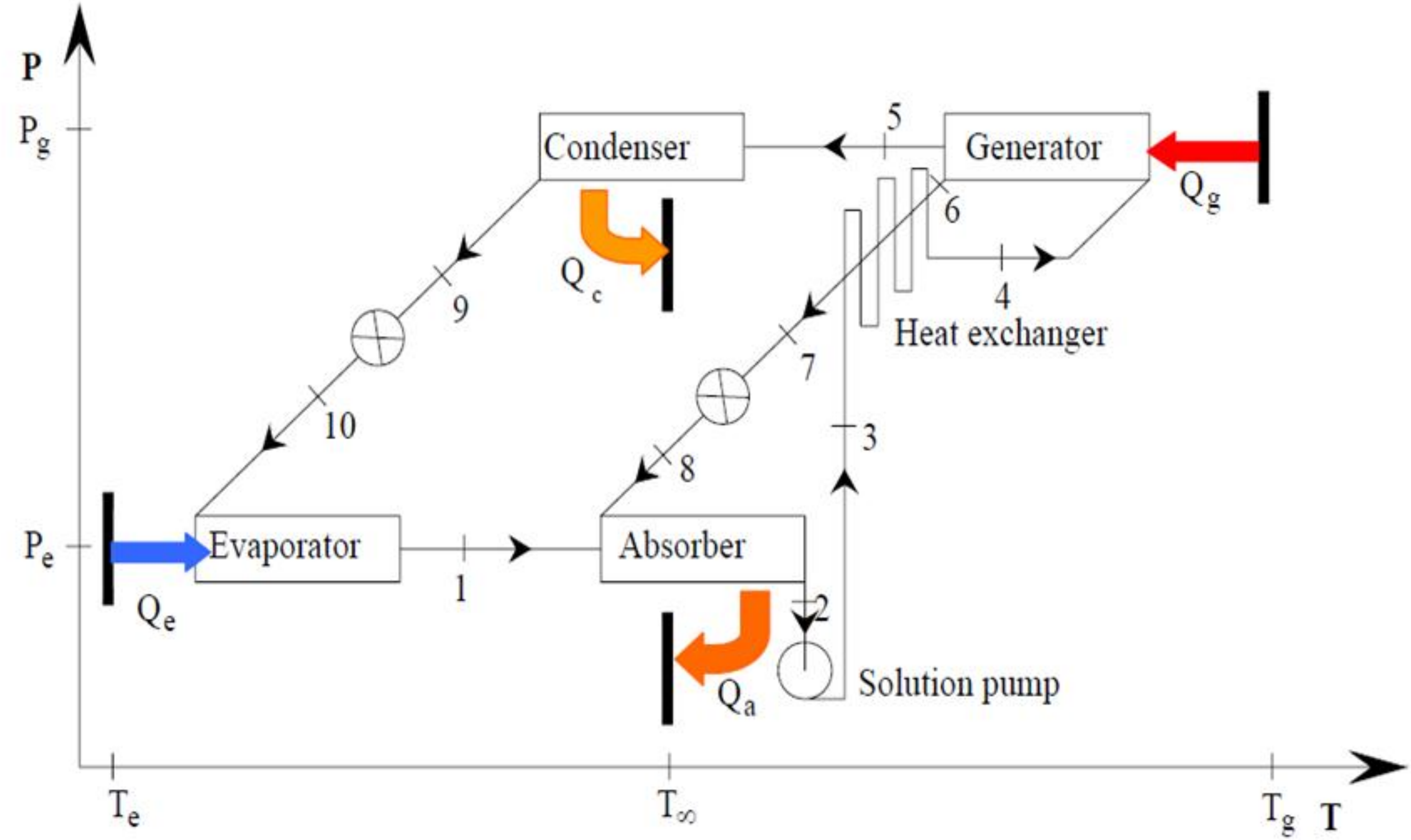
Vapour Absorption Refrigeration System

- Oldest Method of Producing Refrigeration Effect.
- Heat Energy is Used Instead of Mechanical Energy.
- The System Runs on Low – Grade Thermal Energy.
- The System is Preferred When Low – Grade Energy Such as Waste Heat or Solar Energy is Available.
- The System is Environment Friendly Since They uses Natural Refrigerants Such as Water or Ammonia.
- Compressor is Replaced By
  - Absorber
  - Generator
  - Pump
  - Pressure Reducing Valve

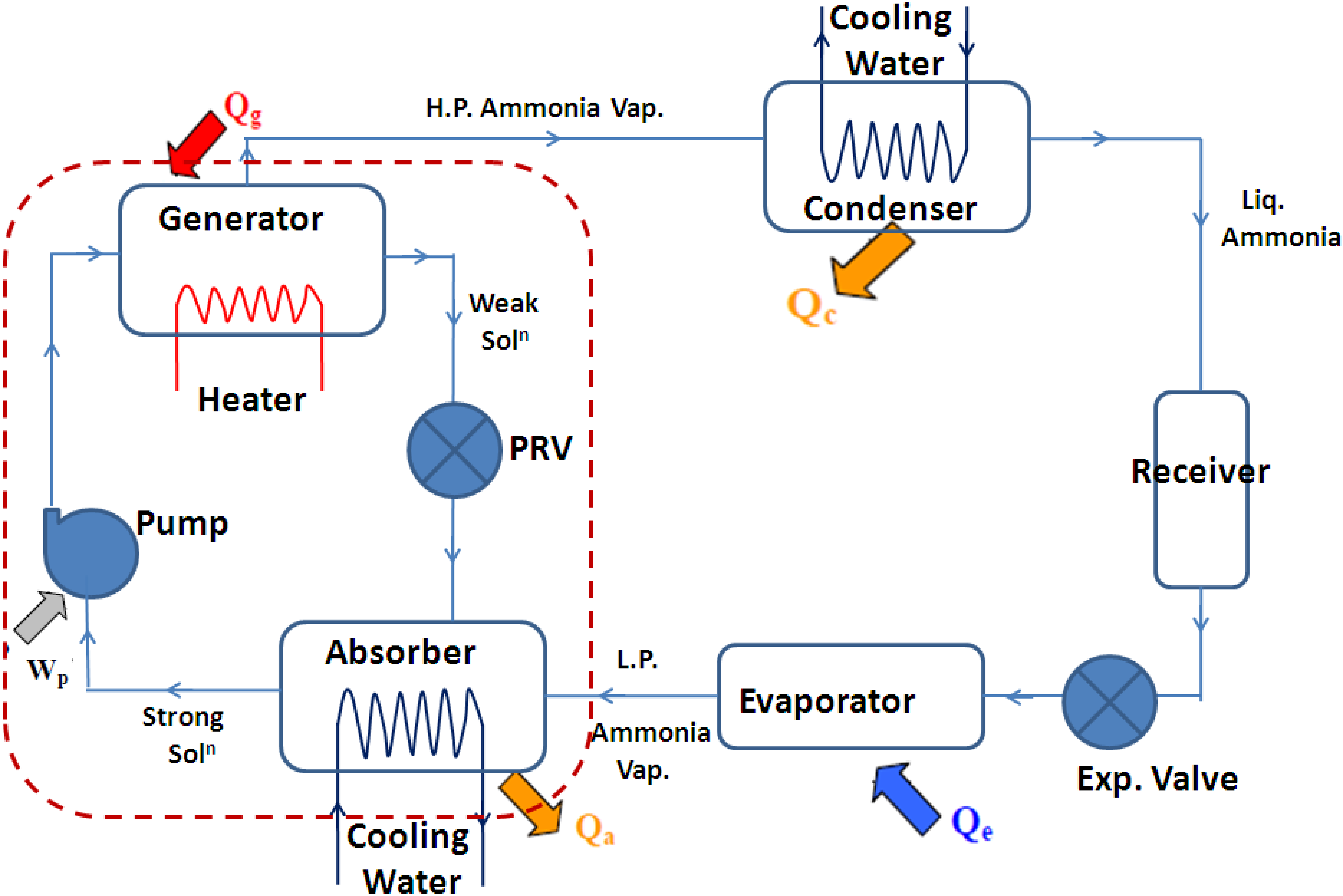
Vapour Absorption Refrigeration System



Vapour Absorption Refrigeration System



Simple Ammonia – Water Vapour Absorption System



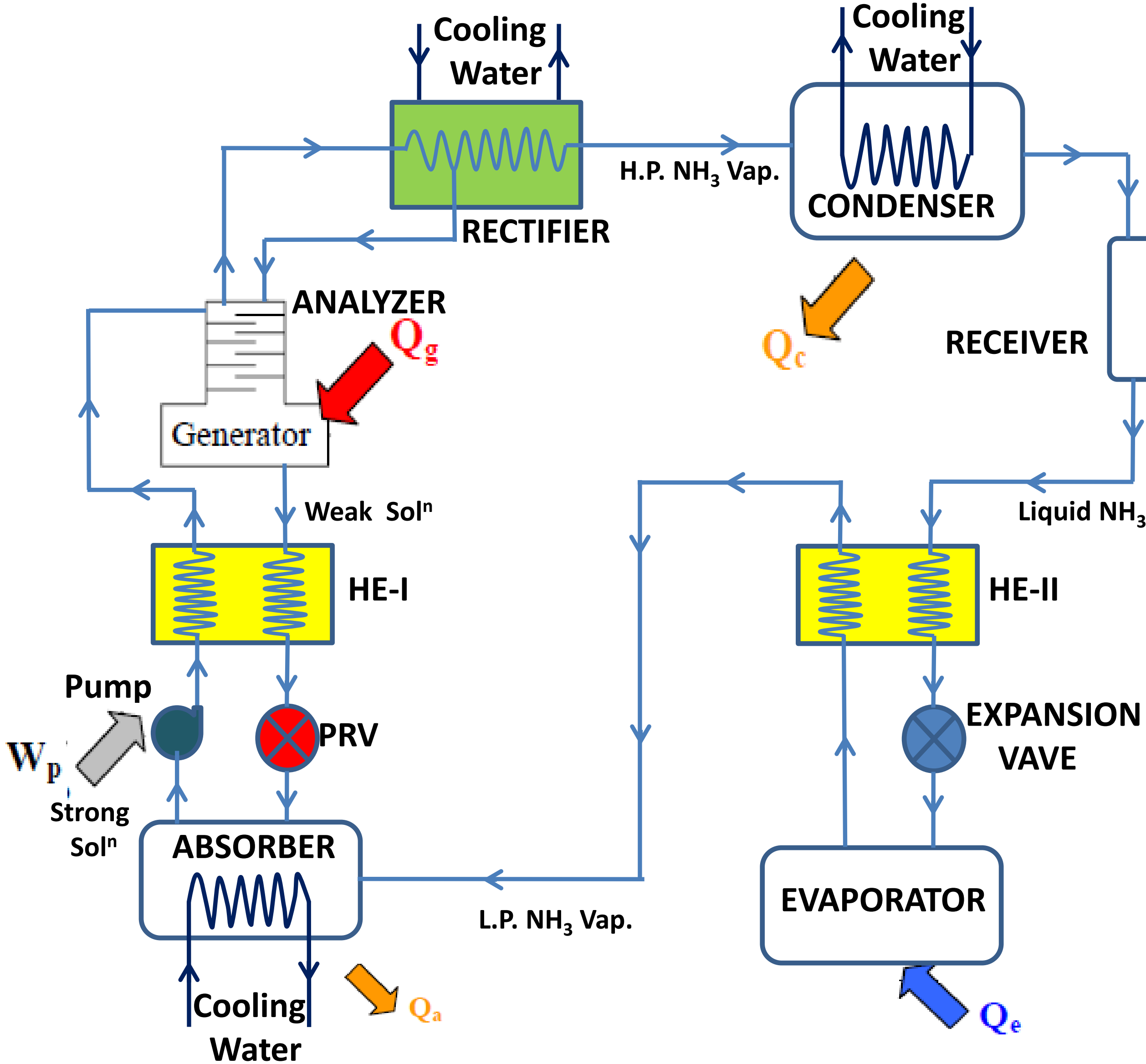
Simple Ammonia – Water Vapour Absorption System

- Water has ability to absorb large quantity of NH_3 vapours. Solution is known as Aqua-ammonia.
- L.P. NH_3 vapours are absorbed by cold water in the Absorber (Q_a Heat rejected to cooling water).
- Absorption of NH_3 Vapours in water lowers the pressure in absorber which draws more NH_3 vapours from Evaporator which raises temp. of solution.
- Water cooling arrangement is provided in the absorber to remove heat of solution, which increases absorption capacity of water.
- Strong solution from absorber is pumped to the Generator.
- The pump raises the pressure of solution to condenser pressure.
- The strong NH_3 solution is heated in the generator by steam or gas (Q_g Heat is supplied).

Simple Ammonia – Water Vapour Absorption System

- The ammonia vapours are driven off the solution at high pressure.
- The hot weak solution from generator flows back to absorber at low pressure after passing through pressure reducing valve.
- The H.P. NH_3 vapours are condensed in condenser to high pressure liquid NH_3 (Q_c Heat rejected to cooling water).
- The H.P. liquid ammonia through receiver is expanded to low pressure liquid ammonia in expansion valve.
- Low pressure liquid ammonia is evaporated in the evaporator to produce the required refrigeration effect (Qe Heat is absorbed).

Practical Ammonia – Water Vapour Absorption System



To Improve the performance and to make the system more **Practical** the Simple System is fitted with the following Components:

- Analyzer
- Rectifier
- Two Heat Exchangers (HE-I & HE-II).

Practical Ammonia – Water Vapour Absorption System

ANALYZER:-

- In Simple System In Generator some water is also vaporized with Ammonia.
- These water vapours flows into the condenser along with the NH_3 Vapours.
- If these unwanted water particles are not removed before entering into the condenser they will enter into the Expansion valve where they freeze & choke the pipe line.
- To remove these unwanted water particles ANALYZER is used.
- Analyzer is the integral part of Generator or made sometimes a separate piece of equipment.
- It consists of series of trays mounted above the Generator.
- The strong solution from Absorber is introduced at the top of Analyzer & flows downwards over trays into the Generator.

Practical Ammonia – Water Vapour Absorption System

- **The vapours from Generator are cooled and most of the water vapours are condensed and only Ammonia vapours leaves the top of Analyzer.**
- **Since strong solution is heated by vapours, less external heat is required in the Generator which enhance the Performance of the system.**

RECTIFIER:-

- **The water vapours are not completely removed from the Analyzer.**
- **A closed type vapour cooler called Rectifier or Dehydrator is used.**
- **The Rectifier is generally water cooled double pipe, Shell & Tube type.**
- **The function of rectifier is to cool further the ammonia vapours leaving the analyzer.**

Practical Ammonia – Water Vapour Absorption System

- **The remaining water vapours are condensed in the rectifier and only dry NH_3 vapours flows to the condenser.**
- **The condensate from rectifier returns to the top of analyzer by drip return pipe.**

HEAT EXCHANGER (HE-I):-

- **It is provided between Pump and Generator.**
- **It is used to cool the weak solution from Generator.**
- **The heat removed from the weak solution raises the temperature of strong solution.**
- **This operation reduces the heat supplied to Generator and amount of cooling required for the absorber which enhance the performance of the system.**

Practical Ammonia – Water Vapour Absorption System

HEAT EXCHANGER (HE-II):-

- **It is provided between Condenser and Evaporator.**
- **It is also called as liquid Sub-cooler.**
- **The liquid refrigerant leaving the condenser is subcooled by low temperature ammonia vapours from the evaporator.**

COP of the System:-

- **The net refrigerating effect (RE).**

  RE = Heat Absorbed by refrigerant in the Evaporator (Q_e).

- **The total energy Supplied**

  = Heat supplied in generator + Pump work

  = (Q_g + Q_p)

$$COP = \frac{\text{Heat Absorbed in the Evaporator } (Q_e)}{\text{Heat supplied in Generator } (Q_g) + \text{Pump work } (Q_p)}$$

$$COP = \frac{Q_e}{Q_g + Q_p}$$

Coefficient of Performance of an Ideal VAS

In an ideal Vapour Absorption System:-

- **Heat given to the refrigerant in Generator at Temp. T_g = Q_g**
- **Heat discharge to the Atmosphere or Cooling Water from Condenser & Absorber at Temp. T_c = Q_{c+a}**
- **Heat Absorbed by the refrigerant in Evaporator at Temp. T_e = Q_e**
- **Heat added to the refrigerant due to Pump work = Q_p**

Neglecting the Heat due to Pump Work Q_p

According to First Law of Thermodynamics:

$$Q_g + Q_e = Q_{c+a} \quad \text{--------- (1)}$$

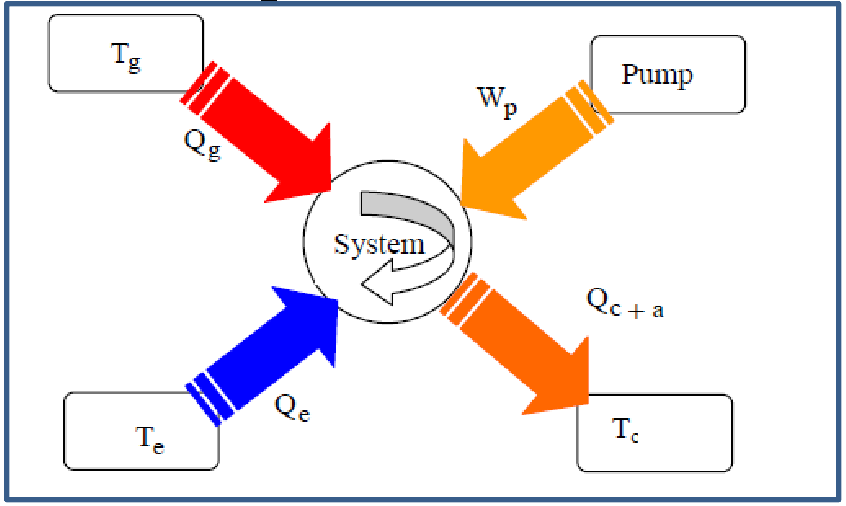


Fig.: Various energy transfers in a vapour absorption refrigeration system

Coefficient of Performance of an Ideal VAS

- An Ideal Vapour Absorption System is **Perfectly Reversible**.
- For completely reversible system the total **Entropy Change** (System + Surrounding) is **Zero**.

$$\therefore \quad \frac{Q_g}{T_g} + \frac{Q_e}{T_e} = \frac{Q_{c+a}}{T_c} \qquad \text{---------- (2)}$$

From Eq. (1) & (2)

$$\frac{Q_g}{T_g} + \frac{Q_e}{T_e} = \frac{Q_g + Q_e}{T_c}$$

$$\frac{Q_e}{T_e} - \frac{Q_e}{T_c} = \frac{Q_g}{T_c} - \frac{Q_g}{T_g}$$

$$Q_e\left(\frac{1}{T_e} - \frac{1}{T_c}\right) = Q_g\left(\frac{1}{T_c} - \frac{1}{T_g}\right)$$

Coefficient of Performance of an Ideal VAS

$$\frac{Q_e}{Q_g} = \left(\frac{T_e}{T_c - T_e}\right)\left(\frac{T_g - T_c}{T_g}\right) \quad \text{---------} \; (3)$$

Maximum Possible COP of the System is given by:

$$(COP)_{Max} = \left(\frac{Q_e}{Q_g}\right)$$

$\therefore$ **From Eq. (3)**

$$(COP)_{Max} = \left(\frac{T_e}{T_c - T_e}\right)\left(\frac{T_g - T_c}{T_g}\right) \quad \text{---------} \; (4)$$

Coefficient of Performance of an Ideal VAS

In Equation (4):

$$\left(\frac{T_e}{T_c - T_e}\right)$$ -- is the COP of Carnot Refrigerator working between T_c & T_e

$$\left(\frac{T_g - T_c}{T_g}\right)$$ -- is the Efficiency of Carnot Engine working between T_g & T_c

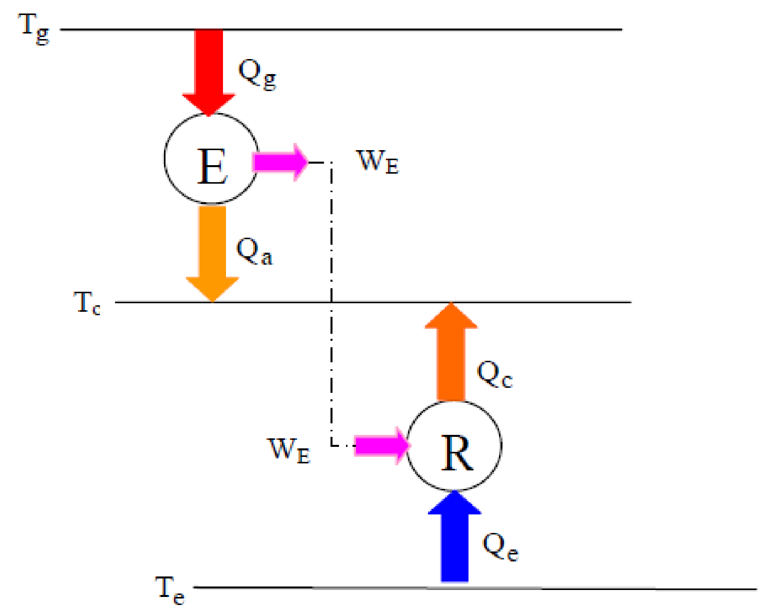


Fig.: Vapour absorption refrigeration system as a combination of a heat engine and a refrigerator

$$(COP)_{Max} = (COP)_{Carnot} \times \eta_{Carno}$$

- If in case the Heat is Discharge at ***Different Temperature*** in Condenser & Absorber then:

$$(COP)_{Max} = \left(\frac{T_e}{T_c - T_e}\right)\left(\frac{T_g - T_a}{T_g}\right)$$

Where T_a – Temp. at which Heat is Discharge in Absorber

Desirable Properties of Refrigerant-Absorbent Mixture

- **SOLUBILITY REQUIREMNT:- The refrigerant should exhibit high solubility with solution in Absorber, so that a strong solution highly rich in refrigerant is formed in the Absorber by absorption of refrigerant vapours.**
- **BOILING POINT REQUIREMENT:- There should be large difference in the boiling points of refrigerant and absorbent (Greater than 200^oC) so that only refrigerant is boiled-off in the Generator. This ensures that only pure refrigerant circulates through refrigerant circuit (Condenser-Exp.Valve-Evaporator) leading to isothermal heat transfer in Evaporator and Condenser .**
- **The Refrigerant-Absorbent mixture should have High Thermal Conductivity.**
- **It should have Low Viscosity to minimize Pump Work.**
- **It should have Low Freezing Point.**

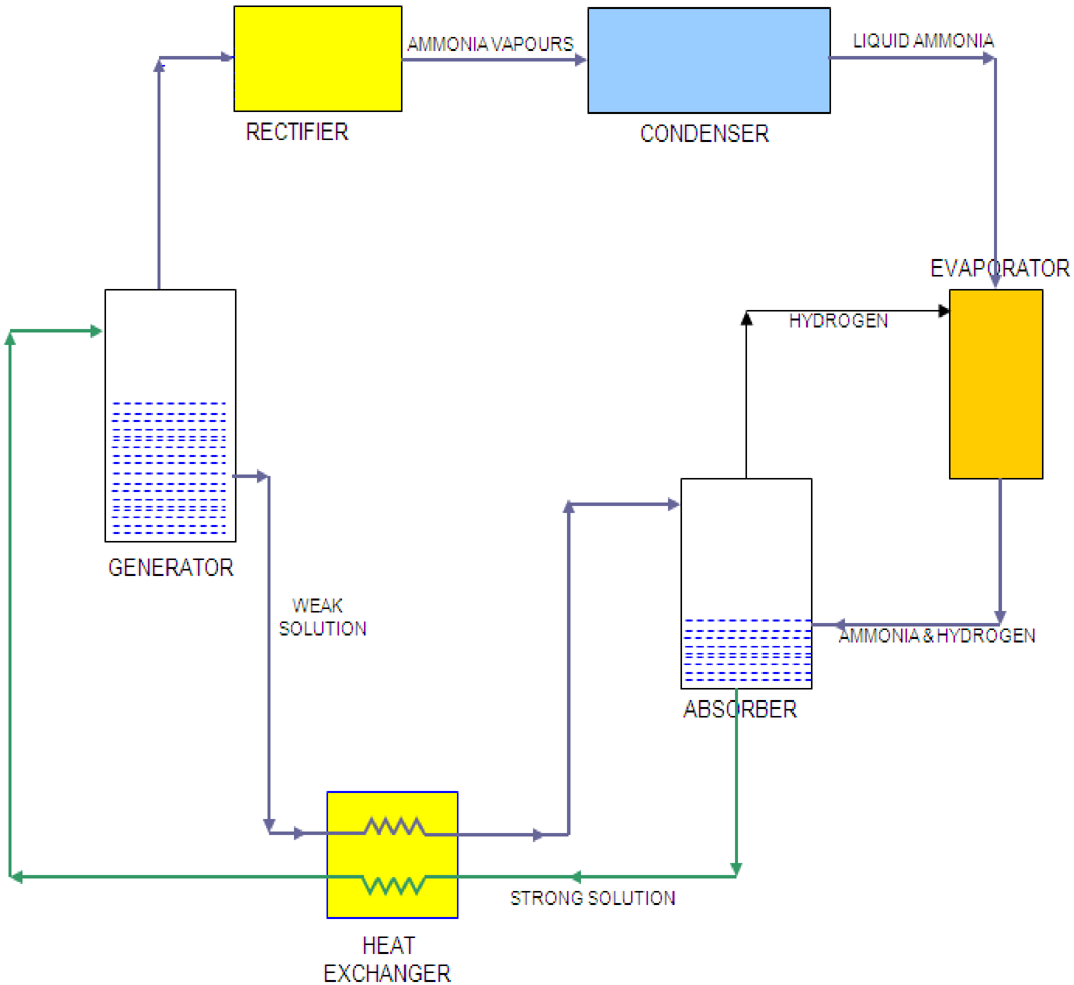
Desirable Properties of Refrigerant-Absorbent Mixture

- It should not undergo **Crystallization or Solidification** inside the system.
- The mixture should be **Safe, Chemically Stable, Non-Corrosive, Inexpensive** and should be **available easily**.

The most Commonly Used Refrigerant-Absorbent Pairs in Commercial Systems:

- **Water-Lithium Bromide (H_2O-LiBr)**
  - Refrigerant – Water
  - Absorbent – Lithium Bromide
  - Application – Above 0°C, A/C applications
- **Ammonia-Water (NH_3-H_2O)**
  - Refrigerant – Ammonia
  - Absorbent – Water
  - Application – Refrigeration applications

Domestic Electrolux Refrigerator



DOMESTIC ELECTROLUX (AMMONIA HYDROGEN) REFRIGERATOR (THREE-FLUIDS ABSORPTION SYSTEM)

Also Called as:

- Platen-Munters System
- Diffusion Absorption System
- Three Fluids Absorption System

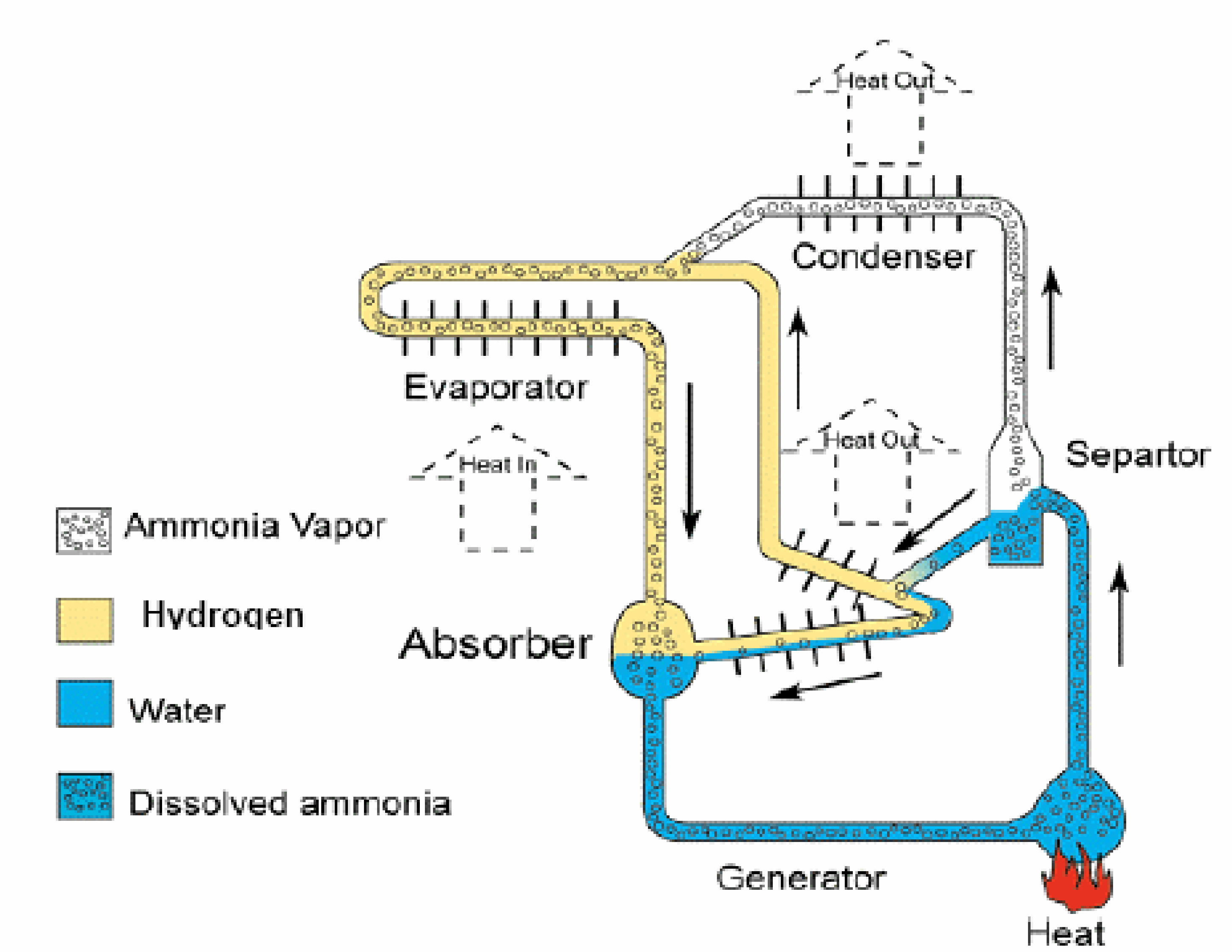
Three Fluids:

- Ammonia (Refrigerant)
- Water (Absorbent)
- Hydrogen (Inert Gas)

Operating Conditions:

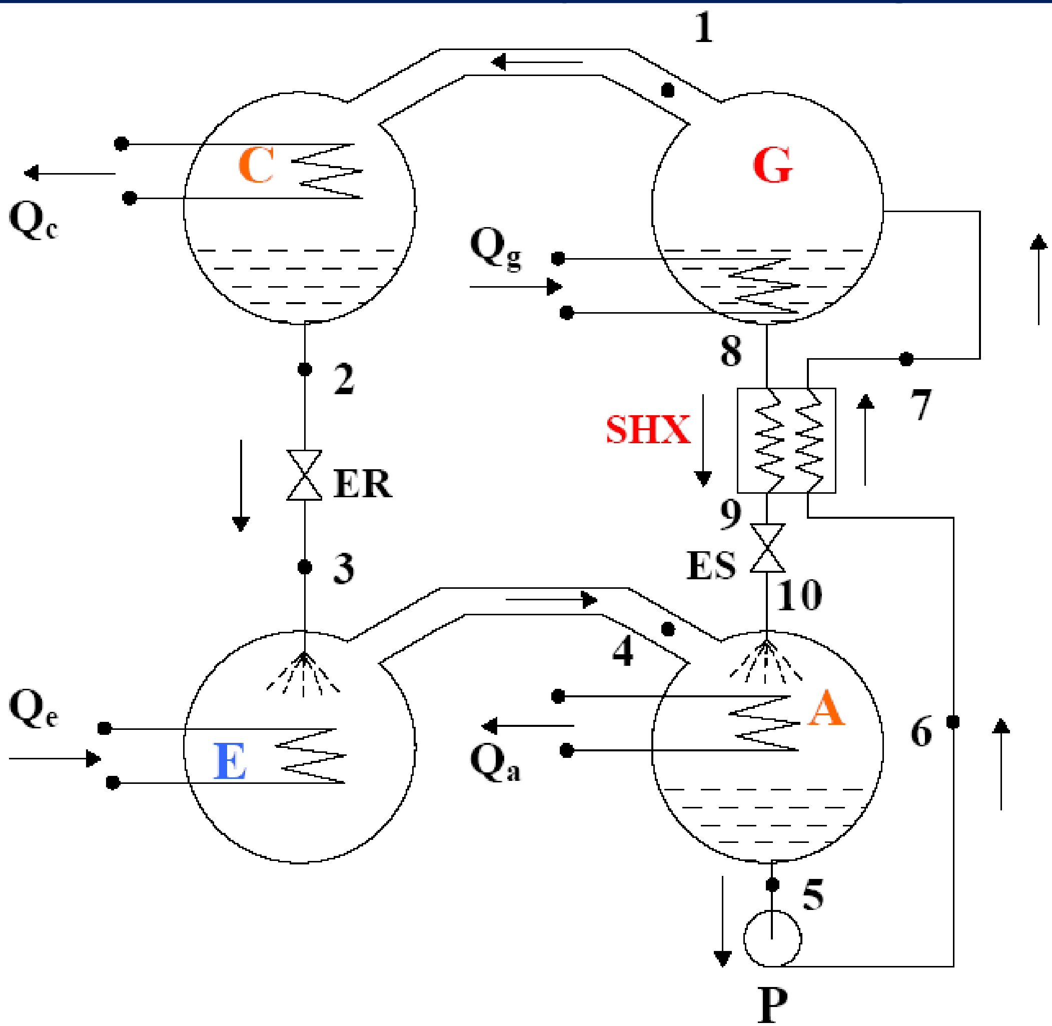
- Total Pressure Remains Constant Throughout the System.
- Circulation of Fluid due to Buoyancy Effect & Gravity.
- Pump less System

Platen – Munters System



Refrigeration circuit of a small diffusion-absorption (Platen-Munters) system

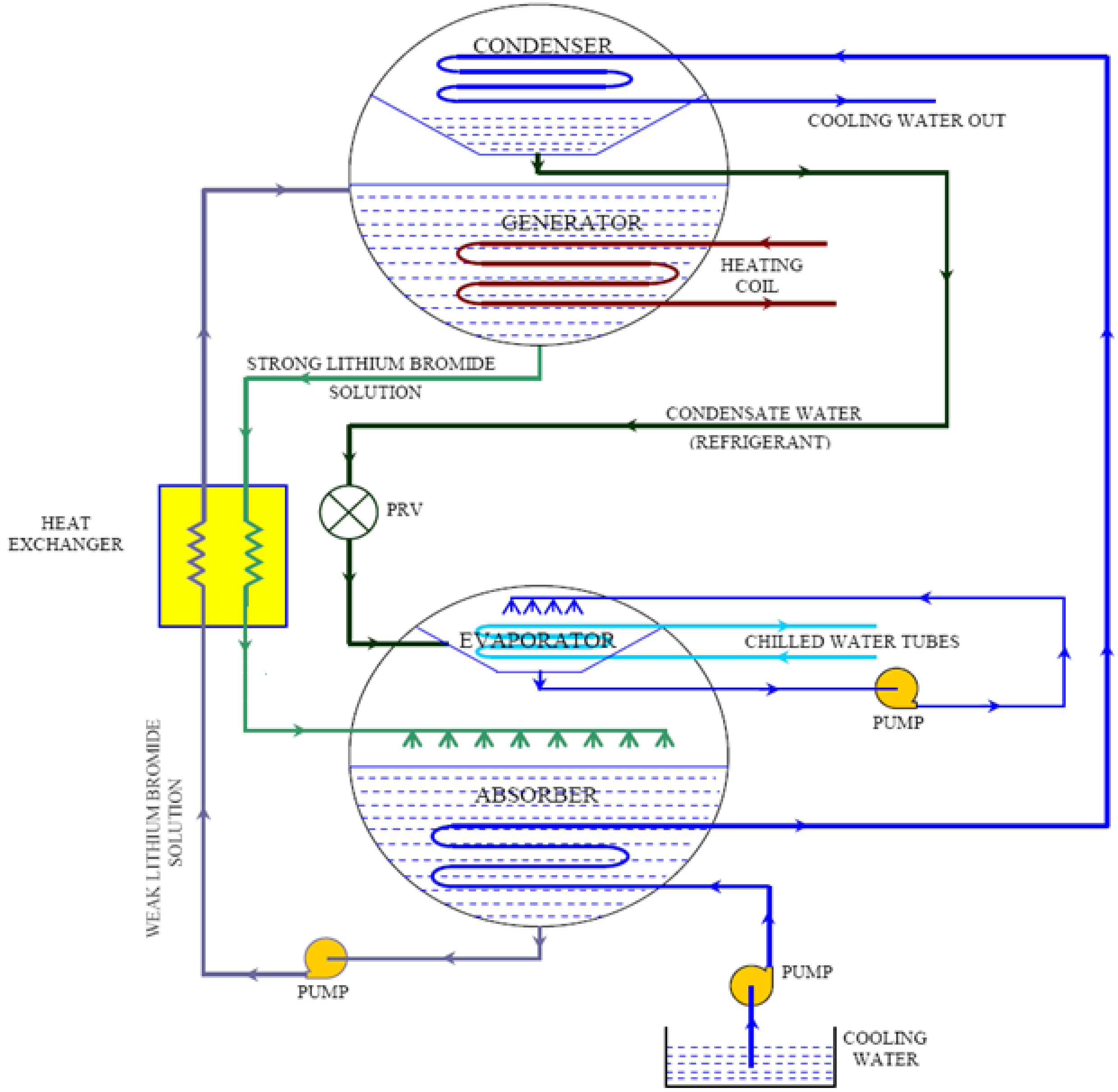
Lithium – Bromide Absorption Refrigeration System



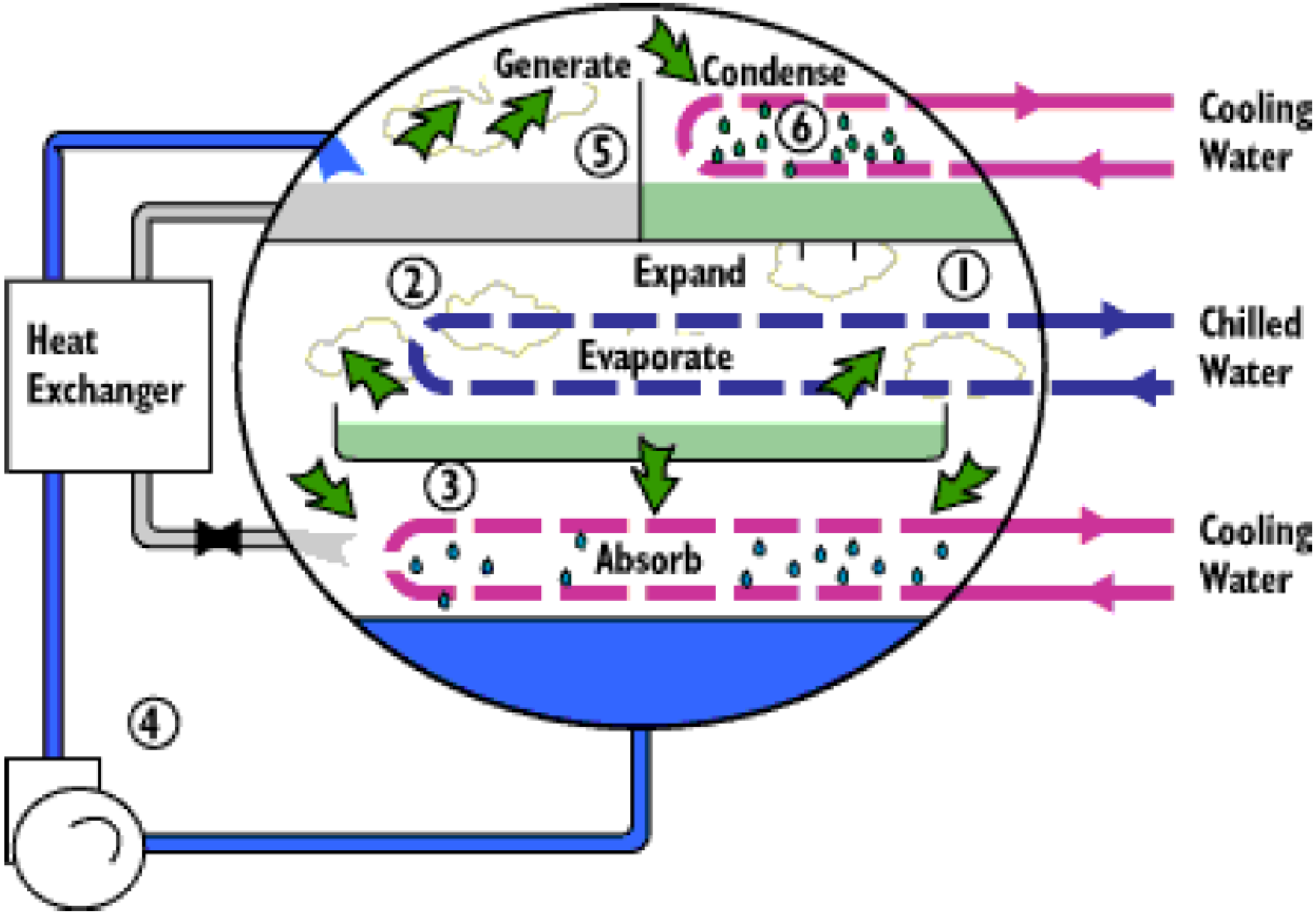
Schematic of a H2O-LiBr system

A: Absorber; C: Condenser; E: Evaporator; G: Generator; P: Solution Pump
SHX: Solution HX; ER: Refrigerant Expansion valve; ES: Solution Expansion valve

Single Effect Lithium – Bromide Absorption Refrigeration System

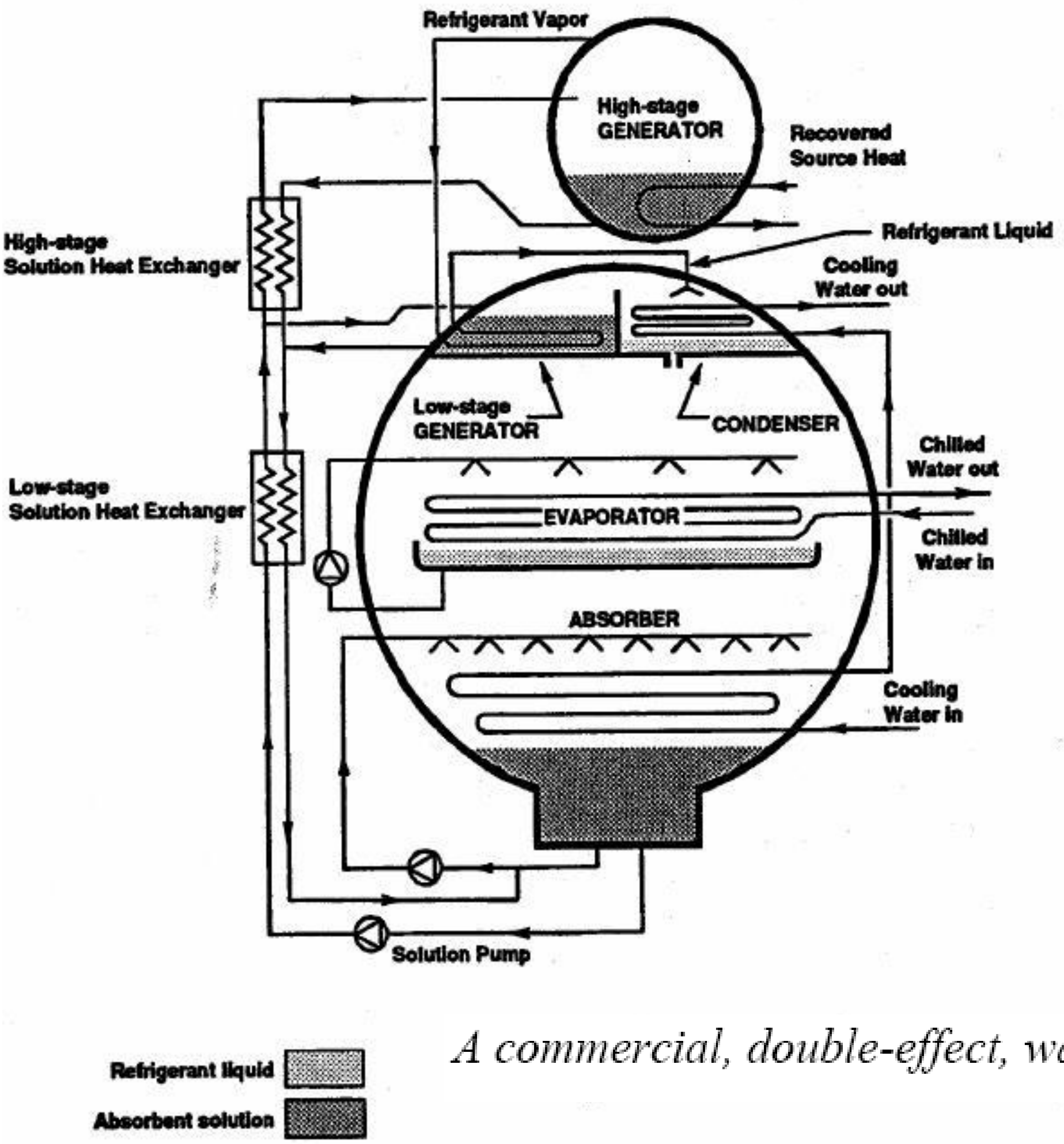


Lithium – Bromide Absorption Refrigeration System



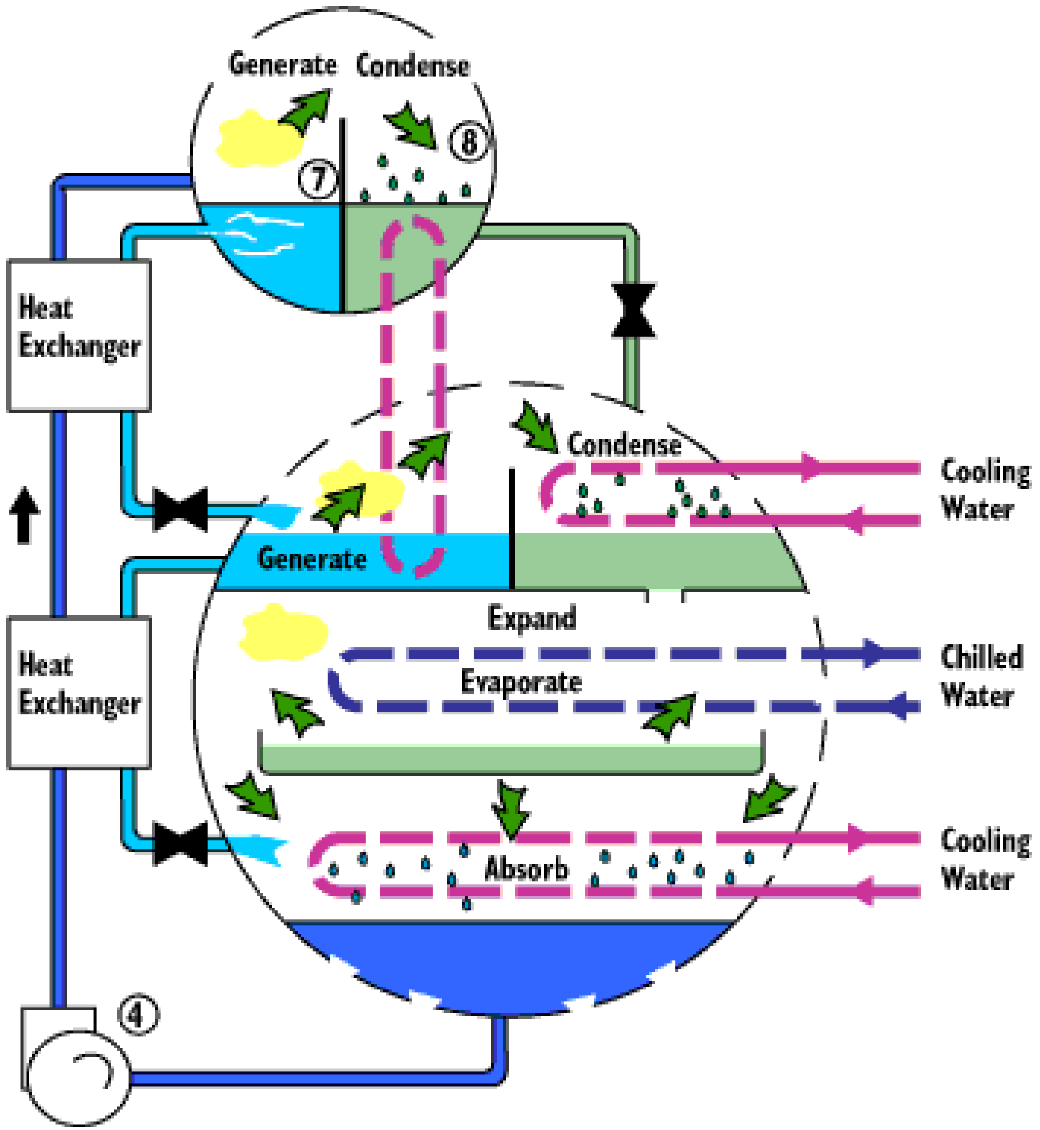
A commercial, single-drum type, water-lithium bromide system

Double Effect Lithium – Bromide Absorption Refrigeration System



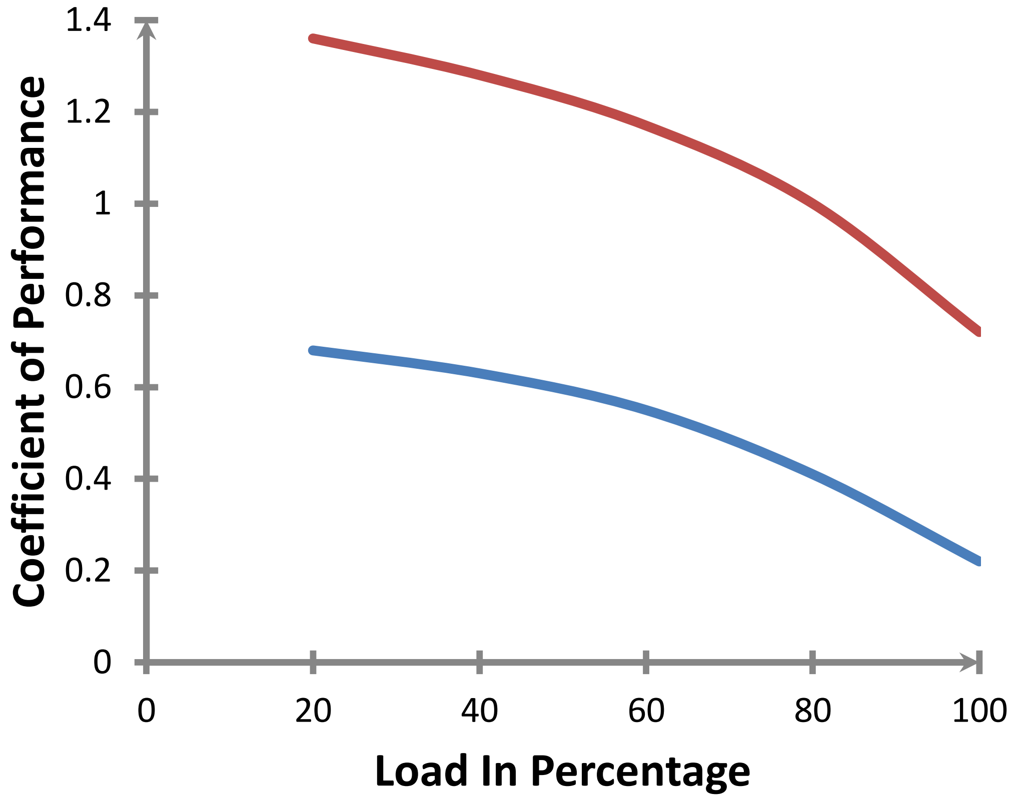
A commercial, double-effect, water-lithium bromide system

Double Effect Lithium – Bromide Absorption Refrigeration System



A commercial, double-effect, water-lithium bromide system

COP of Single & Double Effect Water – Lithium Bromide System



Comparison between compression and absorption refrigeration systems

Compression systems	Absorption systems
Work operated	Heat operated
High COP	Low COP (currently maximum ≈ 1.4)
Performance (COP and capacity) very sensitive to evaporator temperatures	Performance not very sensitive to evaporator temperatures
System COP reduces considerably at part loads	COP does not reduce significantly with load
Liquid at the exit of evaporator may damage compressor	Presence of liquid at evaporator exit is not a serious problem
Performance is sensitive to evaporator superheat	Evaporator superheat is not very important
Many moving parts	Very few moving parts
Regular maintenance required	Very low maintenance required
Higher noise and vibration	Less noise and vibration
Small systems are compact and large systems are bulky	Small systems are bulky and large systems are compact
Economical when electricity is available	Economical where low-cost fuels or waste heat is available