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① Describe the processes involved in the Vapor Compression Refrigeration Cycle with Sub-cooling and Super-heating by specifying respective schematic P-h and T-s diagrams.

Solution:

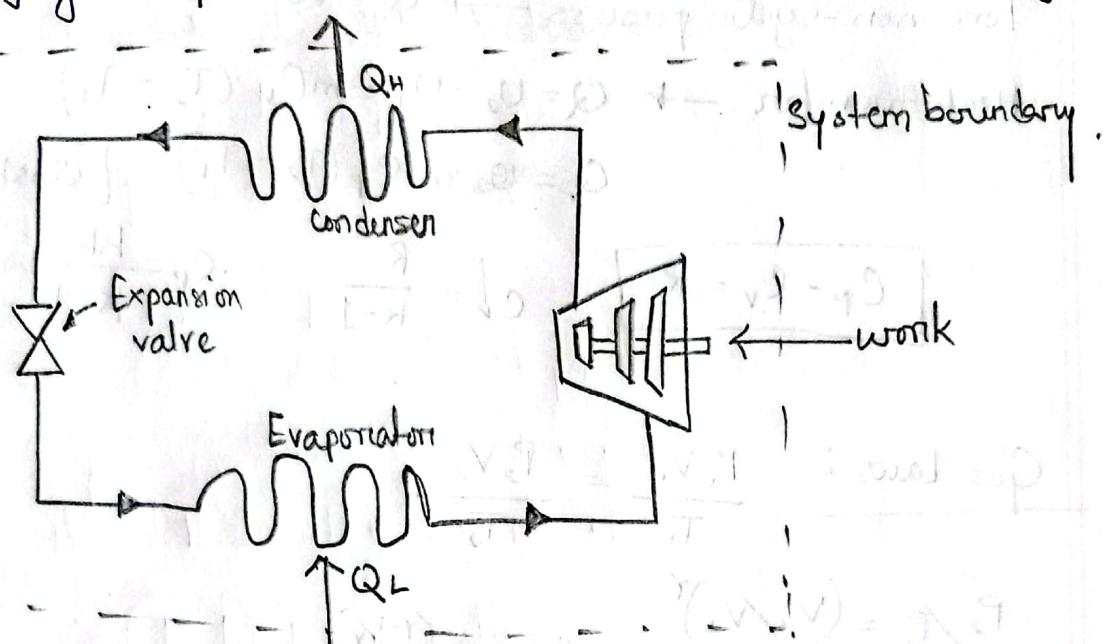
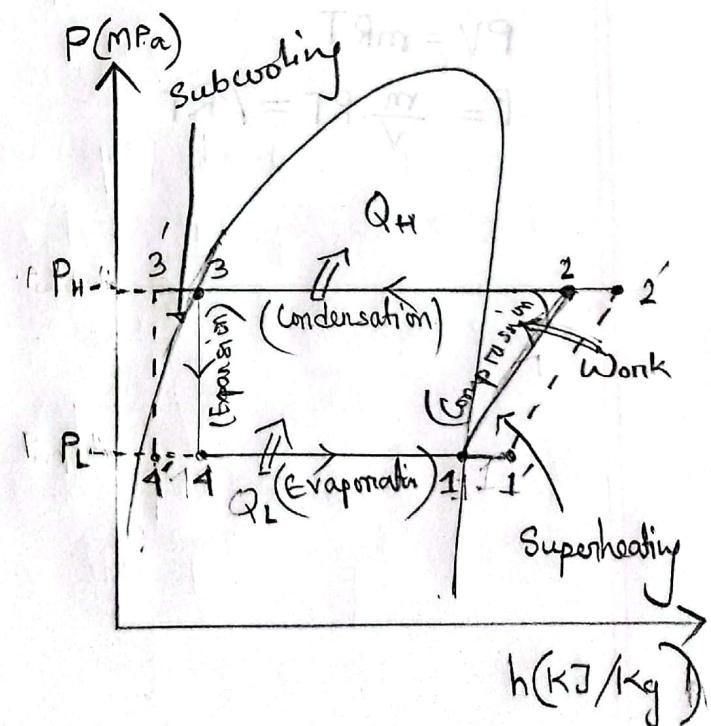
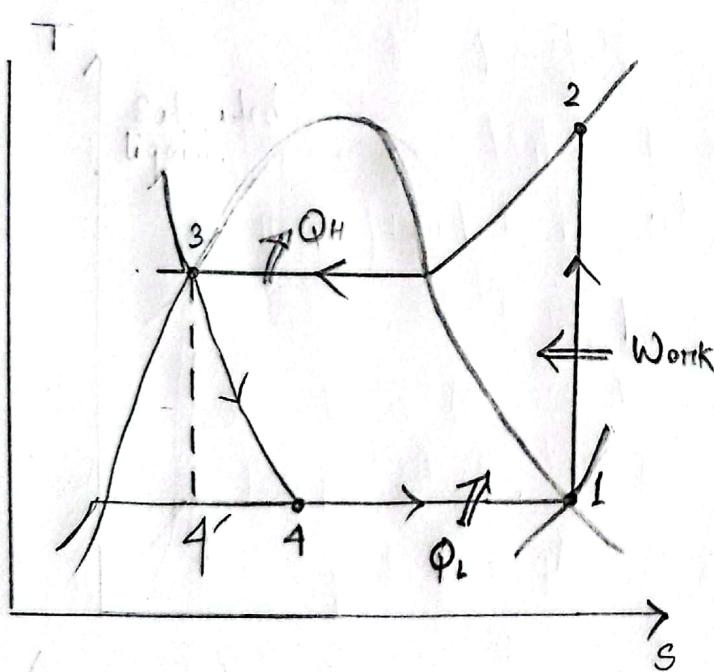


Fig: Refrigeration Cycle.



Isentropic Process (1-2). Compression:

① Refrigerant enters compressor under low pressure and having low temperature.

② Refrigerant is compressed adiabatically.

③ Then it leaves under the compressor

under high pressure and having high

(1-2) temperature.

~~(2-3)~~ → ④ Here, the superheating is done.

Isobaric Process (2-3) Condensation:

① Refrigerant enters condenser with high temperature under high pressure and gets condensed.

② It releases heat energy into the hot reservoir that is connected with the condenser.

③ The hot reservoir collects heat energy that is released because of the external work added to the gas.

④ Refrigerant leaves the condenser as high pressured liquid.

Isoenthalpic Process (3-4) Throttling :

- ① Refrigerant enters an expansion valve, also known as throttling valve, and the valve reduces the pressure causing the fluid to expand.
- ② The fluid passes through the valve and enters the next part with low pressure and low temperature.
- ③ Here, the subcooling is done.

Isobaric Process (5-6) Evaporation:

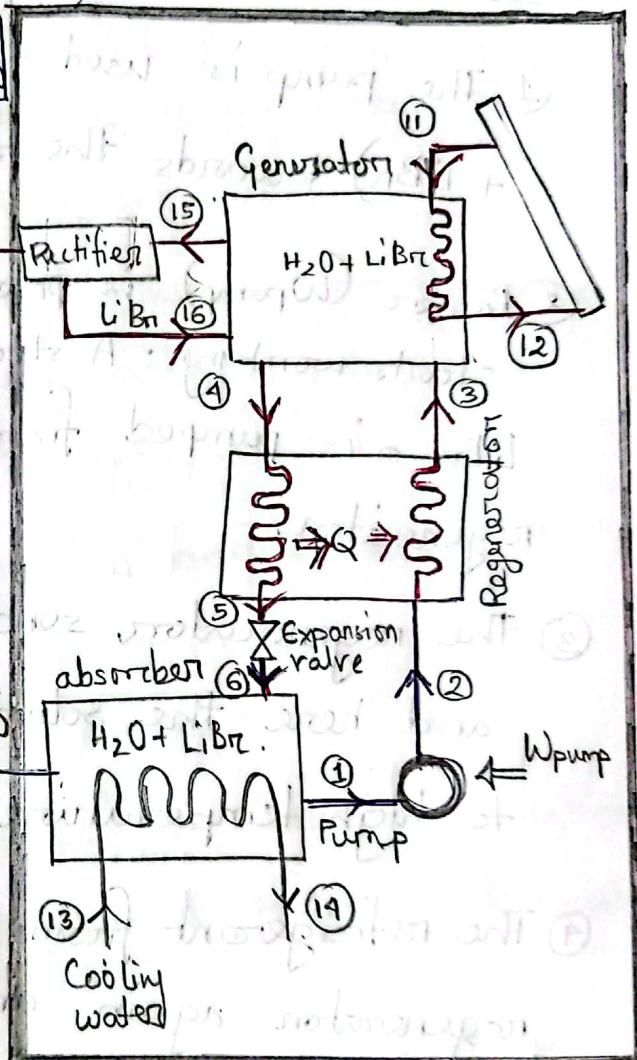
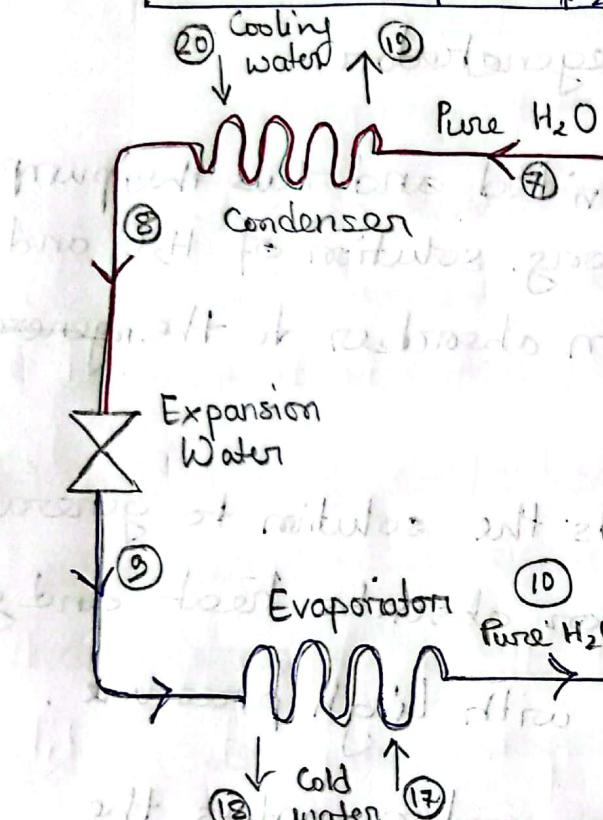
- ① Refrigerant enters the evaporator and absorbs heat from a cold reservoir that is connected to the evaporator.
- ② The fluid boils at a low temperature due to constant low pressure maintenance.
- ③ It then leaves the evaporator with a low temperature under low pressure and enters the compressor. As a result, the cycle starts again.

② Describe the Vapour Absorption Refrigeration process with a schematic diagram.

Answer:

Red arrows indicate high temperature H_2O

Blue ink and arrows indicate low temperature H_2O



In case of vapor absorption refrigeration the absorber and the generator does the compression instead of a compressor.

Steps of

(P.T.O)

1. $LiBr$ is first mixed with H_2O and then heated.

2. $LiBr + H_2O$ is heated.

Steps of the vapor absorption refrigeration process are cited below:

- ① The pump is used to send the refrigerant ($H_2O + LiBr$) towards the regenerator.
- ② Power (W_{pump}) is provided and thus the pump starts working. A strong solution of H_2O and $LiBr$ is pumped from absorber to the ~~regenerator~~.
- ③ The regenerator sends the solution to generator and here the solution absorbs heat and goes to high temperature with high pressure.
- ④ The refrigerant from generation enters the regenerator again and this time releases heat and leaves the regenerator slowly.
- ⑤ Then enters the Expansion valve and ~~gets~~ gets expanded as due to reduction of pressure.
- ⑥ The expand refrigerant enters the absorber and the pump does the same thing as in step.1 is repeated.

⑦ The generator sends the high temperature solution not only to the regenerator but also to the rectifier which separates LiBr and H_2O . Pure water is sent to the condenser.

⑧ Condenser condenses the H_2O and sends it to the Expansion valve.

⑨ Expand fluid leaves the expansion or throttling valve with high low temperature under low pressure and enters the evaporator.

⑩ Pure water gets evaporated and enters the absorber where exists the high temperature refrigerant (H_2O and LiBr). Now the pure water with low temperature weakens the solution ($\text{H}_2\text{O} + \text{LiBr}$), cools it down and step-1 is repeated thus.

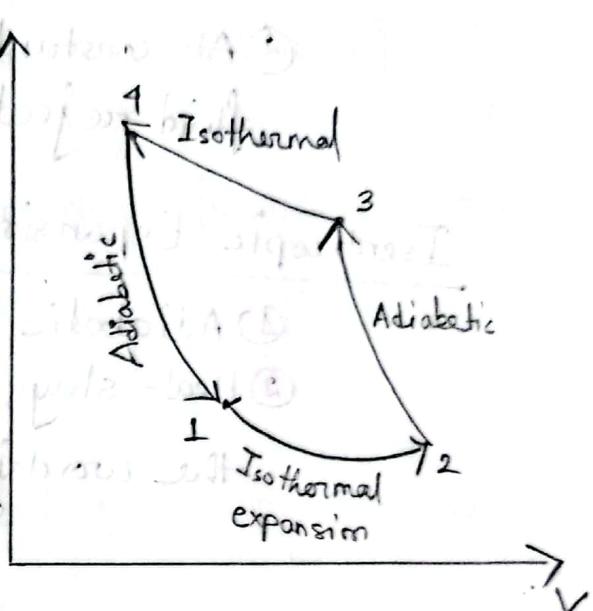
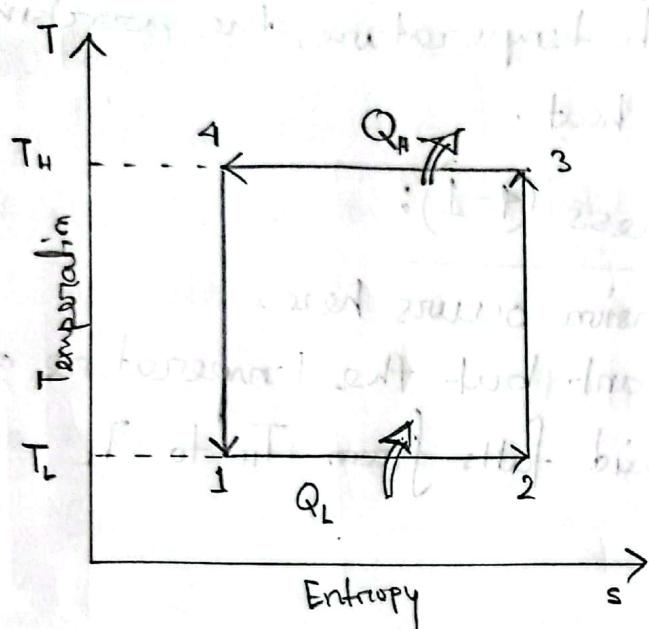
~~Here, heat from ORC waste enters the absorber and generator :-~~
Some minor steps are done inside the coils; and absorber and generator :-

⑪ Heat from ORC waste enters the generator and mixes with the refrigerant ($\text{H}_2\text{O} + \text{LiBr}$).

- (12) Some heated liquid leaves the generator and step - 11 is repeated once ORC waste heat is absorbed again.
- (13) This step is done inside the absorber, cooling water is provided ~~in the~~ into the absorber which help weakening the solution.
- (14) Water leaves the absorber.
- (15) This step is between the generator and rectifier where H_2O and LiBr enters the rectifier and is separated. Rectifier sends pure water out towards condenser.
- (16) The separated LiBr inside the rectifier enters the Generator again. This is the step where LiBr is avoided from going outside the compression process.
- (17) It happens in the evaporator. ~~Cold water~~ enters. Heat is low pressured vapour will enter.
- (18) Low pressured vapour leaves the Evaporator.
- (19) Cooling water leaves condenser.
- (20) Cooling water enters the condenser.

③ Explain Reversed Carnot Cycle with P-V and T-s diagram.

Answer:



Isothermal Process (1-2)

- ① Isothermal expansion is done.
- ② At constant low temperature, heat is absorbed from the fluid.

Isothermal Compression (2-3)

- ① With the aid of external work, temperature of the fluid rises from T_L to T_H .

- ② Heat remains constant

- ③ Adiabatic compression takes place here.

Isothermal Process (3-4)

- ① Isothermal Compression takes place here.
- ② At constant high temperature, the working fluid rejects the heat.

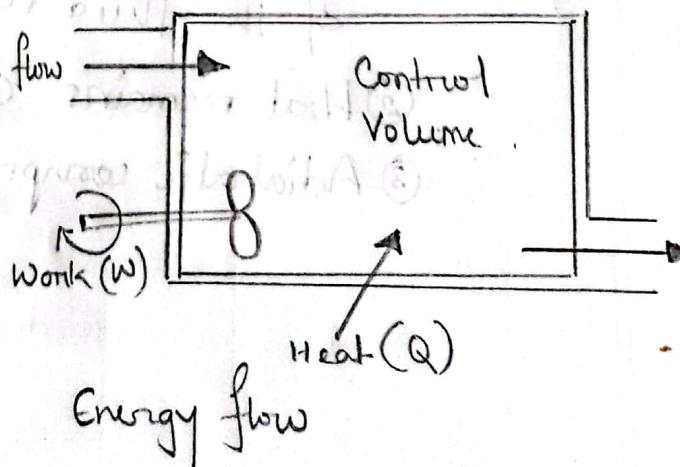
Isoentropic Expansion Process (4-1):

- ① Adiabatic expansion occurs here.
- ② Heat stays constant but the temperature of the working fluid falls from T_H to T_L .

- 7 With the neat sketches and proper assumptions, derive the steady flow Energy Equation. Simplify the equation for Rotary Compression, Diffusion, Throttling Process and Heat Exchanger.

Answer: Assumptions of Steady Flow Process:

- ① The mass flow rate at the inlet is constant with respect to time and equal to the mass flow rate at the outlet.



② The properties at any point within the open system do not vary with time.

③ Properties are constant over the cross section of the flow at inlet and outlet.

④ Heat or work crossing the boundary is done at a uniform rate

We know,

Energy entering the system = Energy leaving the system.

$$\text{So, } PE_1 + KE_1 + P_1 V_1 + U_1 + Q = PE_2 + KE_2 + P_2 V_2 + U_2 + W.$$

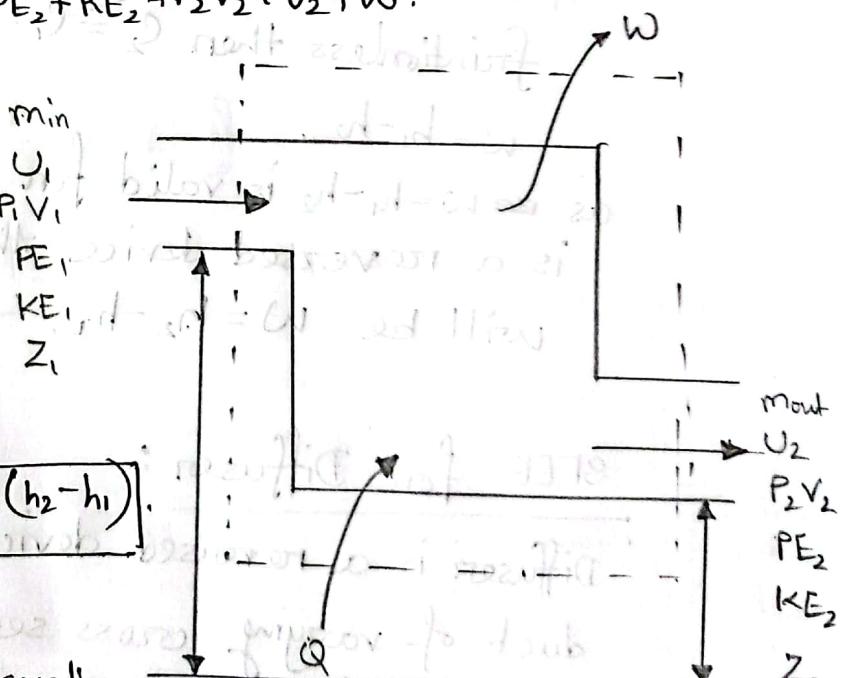
$$\Rightarrow Q = \Delta PE + \Delta KE + [(P_2 V_2 + U_2) -$$

$$(P_1 V_1 + U_1)] + W$$

$$= \Delta PE + \Delta KE + \Delta H + W$$

$$\Rightarrow Q - W = mg(z_2 - z_1) + \frac{1}{2}m(c_2^2 - c_1^2) + m(h_2 - h_1).$$

$$\Rightarrow q - w = g(z_2 - z_1) + \frac{1}{2}(c_2^2 - c_1^2) + (h_2 - h_1).$$



Steady Flow Energy Equation (SFEE).

SFEE for Rotary Compressor:

A rotary compressor is a reversed turbine and a turbine is a device which produces work by expanding high pressurized fluid to a low pressurized fluid.

We know,

$$\text{SFEE} \rightarrow q - w = g(z_2 - z_1) + \frac{1}{2}(c_2^2 - c_1^2) + (h_2 - h_1)$$

For turbines,

$$\text{Here, } q = 0; z_1 = z_2$$

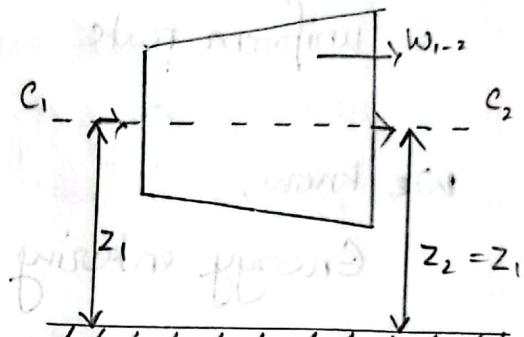
$$\text{SFEE} \rightarrow 0 = w + \frac{1}{2}(c_2^2 - c_1^2) + (h_2 - h_1)$$

$$\Rightarrow h_2 - h_1 = w + \frac{1}{2}(c_2^2 - c_1^2)$$

If we consider the system is
frictionless then $c_2 \approx c_1$.

$$w = h_1 - h_2$$

As $w = h_1 - h_2$ is valid for turbine and rotary compressor
is a reversed device the SFEE for compressor
will be $w = h_2 - h_1$.



SFEE for Diffuser:

Diffuser is a reversed device of a nozzle which is a duct of varying cross sectional area where velocity increases with a corresponding drop in pressure.

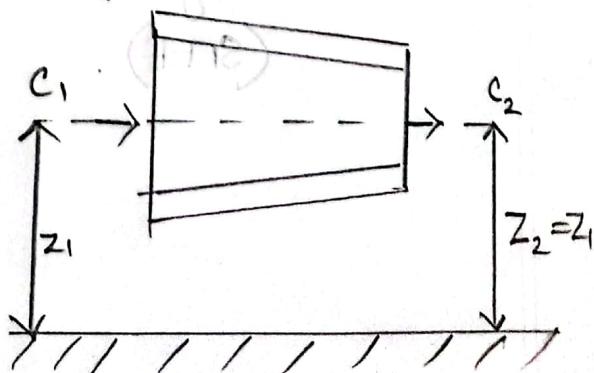
$$\text{SFEE} \rightarrow q - w = g(z_2 - z_1) + \frac{1}{2}(c_2^2 - c_1^2) + (h_2 - h_1)$$

$$\text{Here, } z_2 = z_1; q = 0; w = 0$$

$$\text{So, } 0 = \frac{1}{2}(c_2^2 - c_1^2) + (h_2 - h_1)$$

$$\Rightarrow h_1 + \frac{c_1^2}{2} = h_2 + \frac{c_2^2}{2}$$

It is valid for diffuser too.



SFEE for Throttling process:

When fluid steadily flows through a restricted passage like a partially closed valve, orifice, porous plug etc., pressure of the fluid drops substantially and the process is called throttling.

$$\text{we know, SFEE} \rightarrow q - w = g(z_2 - z_1) + \frac{1}{2}(c_2^2 - c_1^2) + (h_2 - h_1)$$

Here, $q = w = 0$; $z_1 = z_2$ and $c_2 \approx c_1$

$$\text{so, } 0 = (h_2 - h_1)$$

$\Rightarrow h_2 = h_1$ [here, enthalpy remains constant]

SFEE for Heat Exchanger:

A heat-engine exchanger transfers heat from one fluid to another and there is no work done during heat exchange

$$\text{So, } w = 0; z_1 = z_2; c_2 \approx c_1$$

Thus putting them in the SFEE, we get,

$$\therefore q = (h_2 - h_1)$$

