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COURSE NAME : ME

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SECTION : A

SEMESTER : 2

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DEPT. : CSE .

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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:

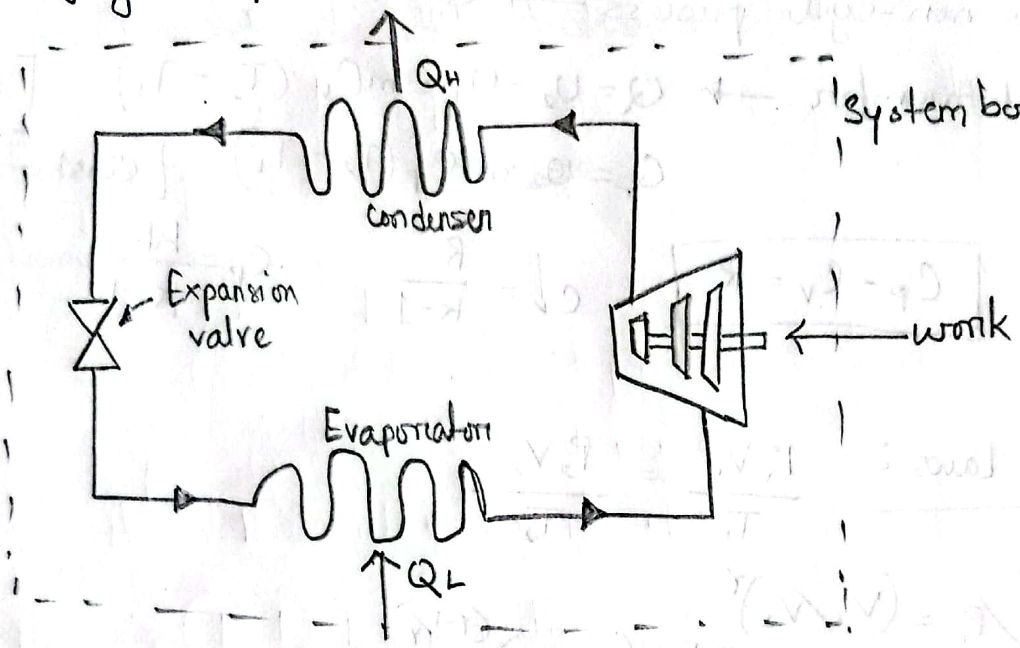
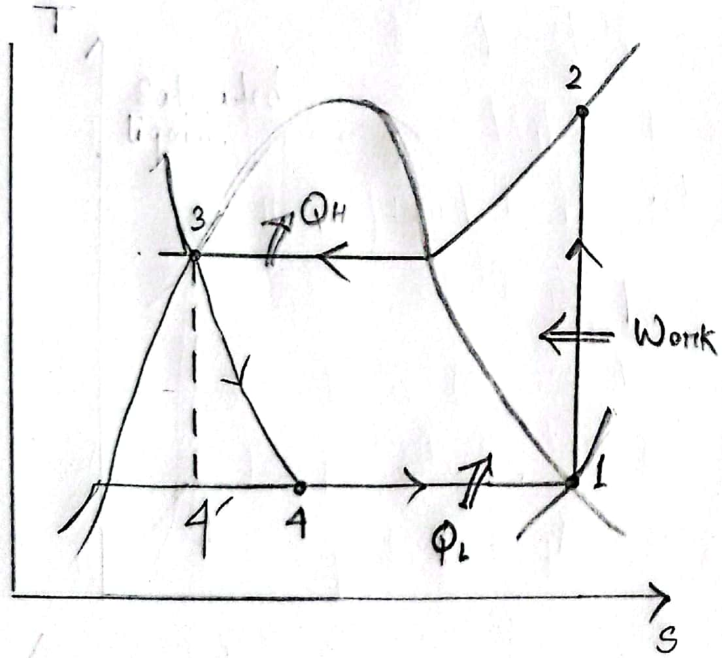
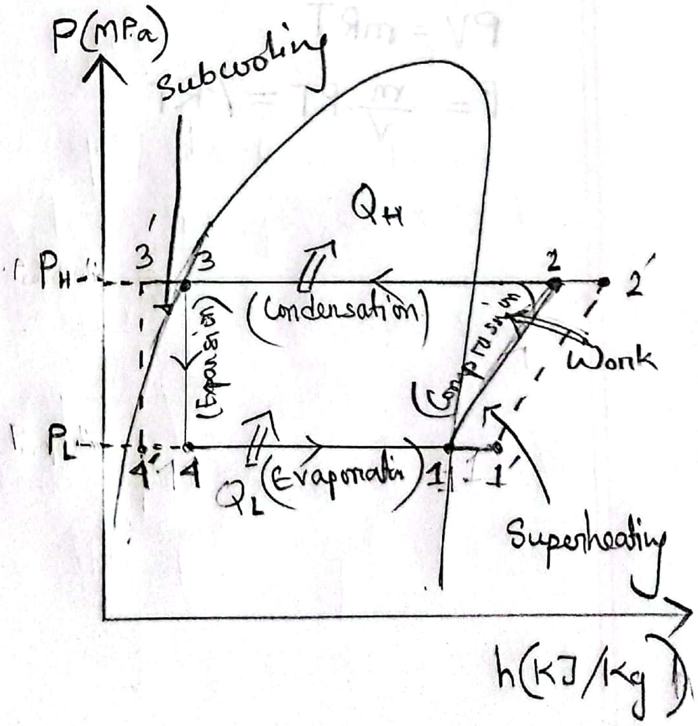


Fig: Refrigeration Cycle





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 temperature.

④ Here, the superheating is done.

Isobaric Process (2-3) Condensation:

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

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.

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Isenthalpic Process (3–4) Throttling :

① Refrigerant enters an expansion valve, also know 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 ~~pla~~ part with Low pressure and low temperature.

③ Here, the subcooling is done.

Isobaric Process (4–1) Evaporation :

① Refrigerant enters the evaporator and absorbs heat from a cold reservior that is connected to the evaporator.

② The fluid boils at a low temperature due to constant low pressure maintainance.

③ It then leaves the evaporator with a low temperature under low pressure and enters the compressor. As a result, the cycle starts again.

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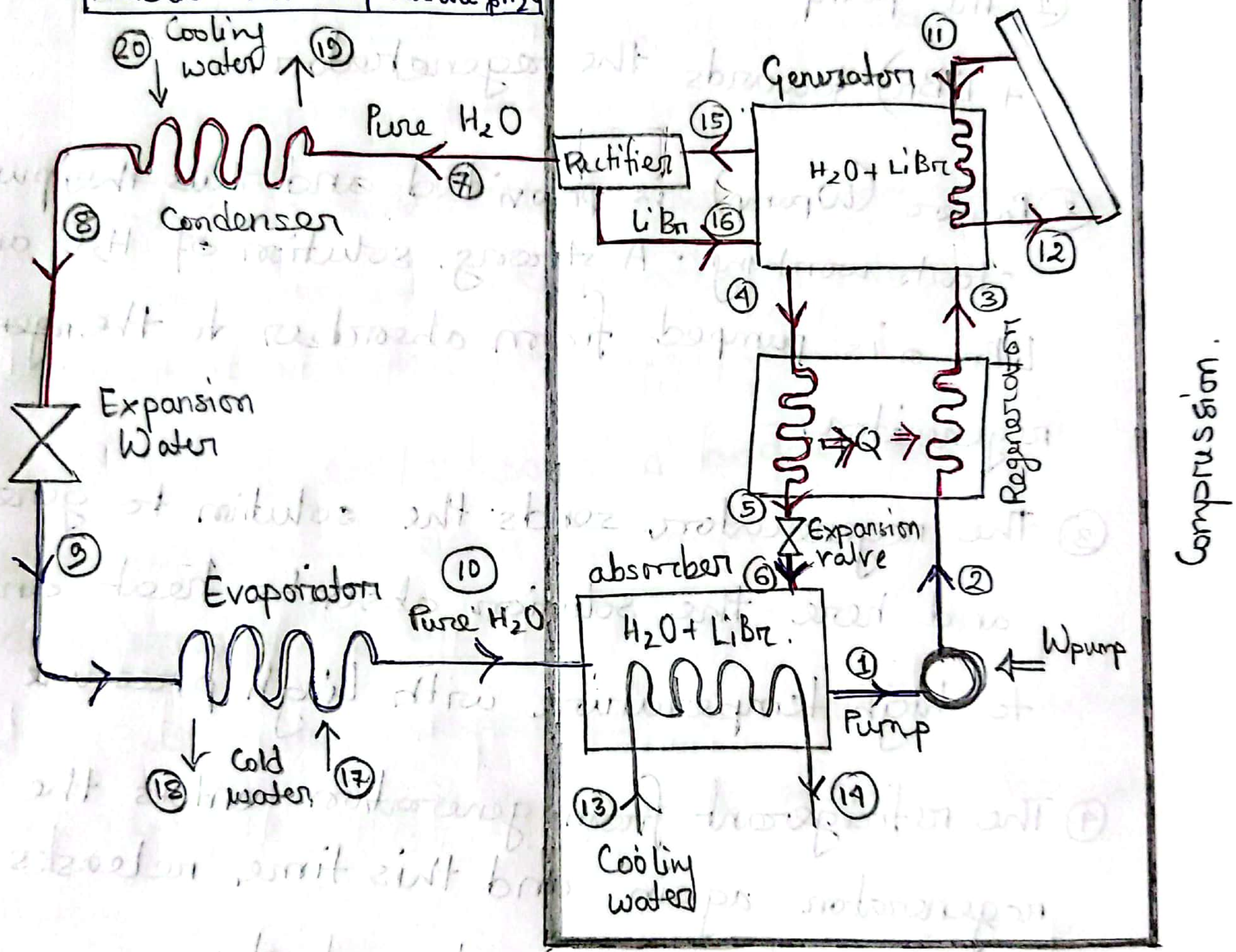
② Describe the Vapour Absorption Refrigeration process with a shematic diagram.

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)

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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~~ 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 ~~goes~~ 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.

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(7) The generator sends the high temperature, solution not only to the regenerator but also to the rectifier which seperates LiBr and H_2O. Pure water is send to the condenser.

(8) Condenser condenses ~~the~~ H_2O and sends it to the Expansionsion valve.

(9) Expand fluid leaves the expansion or throttling valve with ~~hig~~ 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 (H_2O+ LiBr), Cools it down and step-1 is repeated thus.

~~(11) Here, heat from ORC water enters the~~

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 (H_2O + LiBr).

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(12) ~~The~~ 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 a~~ into the absorber which help weakening the solution. ~~and~~

(14) Water leaves the absorber.

(15) This step is between the generator and rectifier where H_2O and LiBr enters the rectifier and is seperated. Rectifier sends pure water out towards condenser.

(16) The seperated 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.

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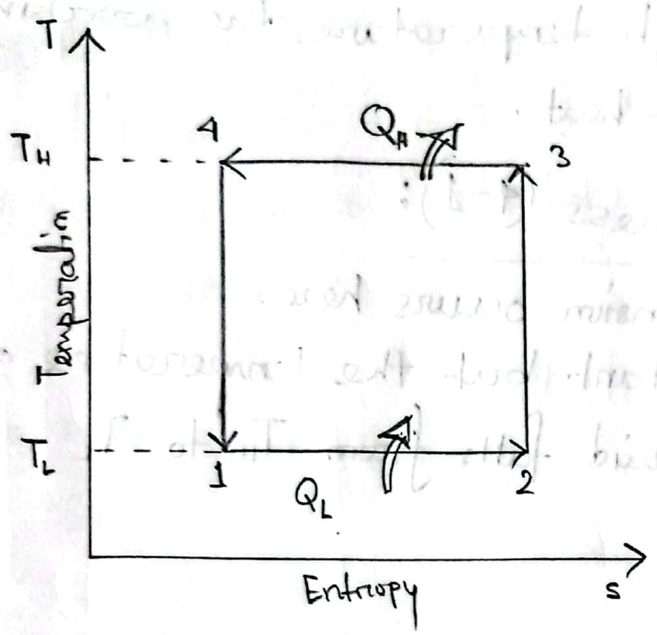
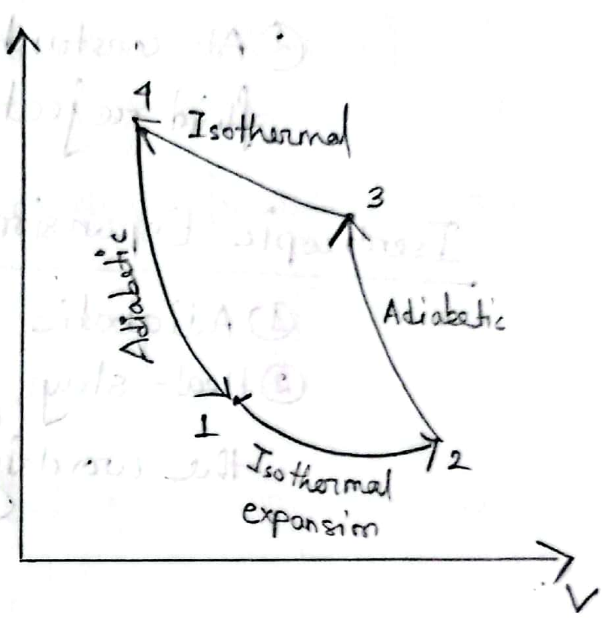
③ Explain Reversed Carnot Cycle with P-V and T-s diagram.

Answer :





Isothermal Process (1-2)

① Isothermal expansion is done.

② At constant low temperature, heat is absorbed from the fluid.

Isentropic 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.

Isentropic Expansion Process (4-1):

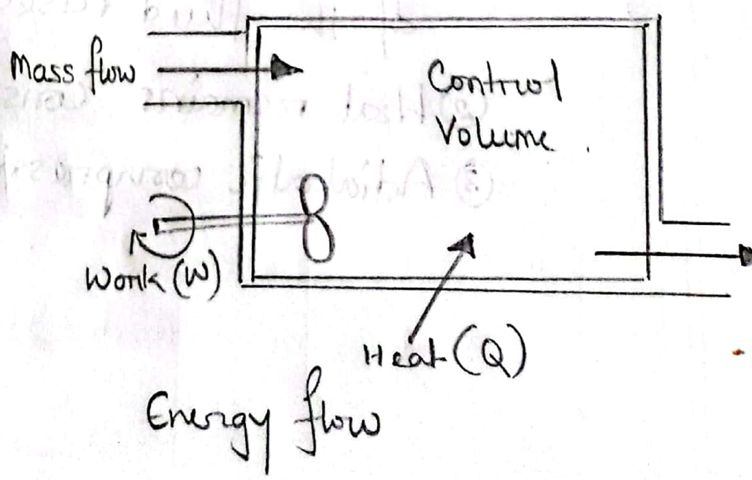
① Adiabatic expansion occurs here.

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 Compressor, Diffuser, Throttling Process and Heat Exchanger.

Answer: Assumptions of Steady Flow Process:

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



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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.

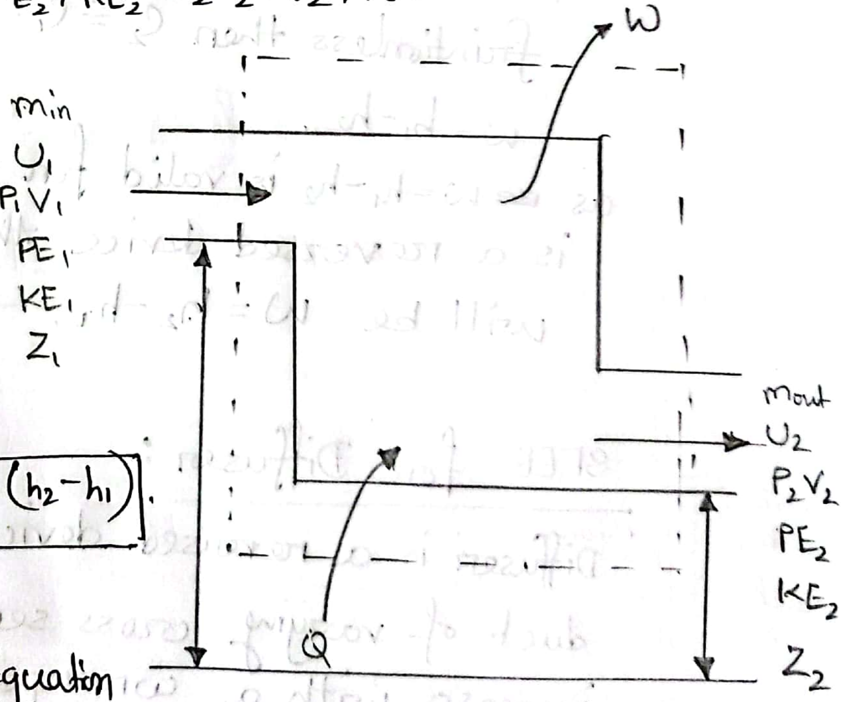
So, $PE_1 + KE_1 + P_1V_1 + U_1 + Q = PE_2 + KE_2 + P_2V_2 + U_2 + W$.

$\Rightarrow Q = \Delta PE + \Delta KE + [(P_2V_2 + U_2) - (P_1V_1 + U_1)] + W$

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

$\Rightarrow Q - W = mg(Z_2 - Z_1) + \frac{1}{2}m(C_2^2 - C_1^2) + m(h_2 - h_1)$.

$$\boxed{\Rightarrow q - w = g(Z_2 - Z_1) + \frac{1}{2}(C_2^2 - C_1^2) + (h_2 - h_1)}$$



→ Steady Flow Energy Equation (SFEE).

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SFEE for Rotary Compressor :

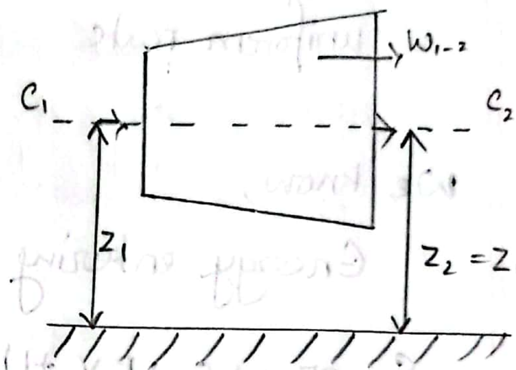
A rotary compressor is a reversed turbine and a turbine is a device which produces work by expanding high pressured fluid to a low pressured fluid.

we know,

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

For turbines,

Here, $q = 0$; $z_1 = z_2$



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 frintionless then $c_2 \cong c_1$.

$w = h_1 - h_2$.

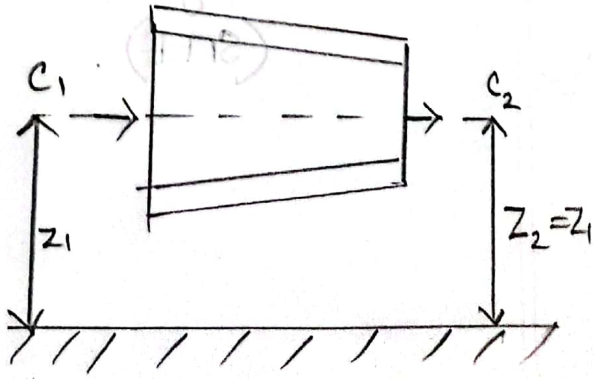
as. $w = h_1 - h_2$ is valid for turbine and rotary compressor is a reserersed device the SFEE for compressor will be $W = h_2 - h_1$.

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.

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

Here, $z_2 = z_1$; $q = 0$; $w = 0$.



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.

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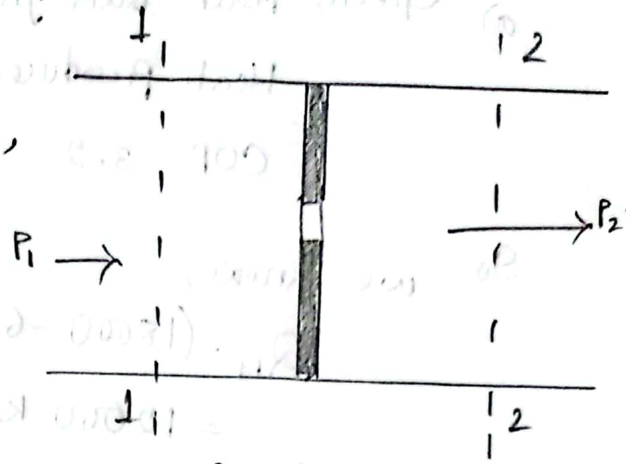
SFEE for Throttling process:

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.



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 $c_2 \cong c_1$

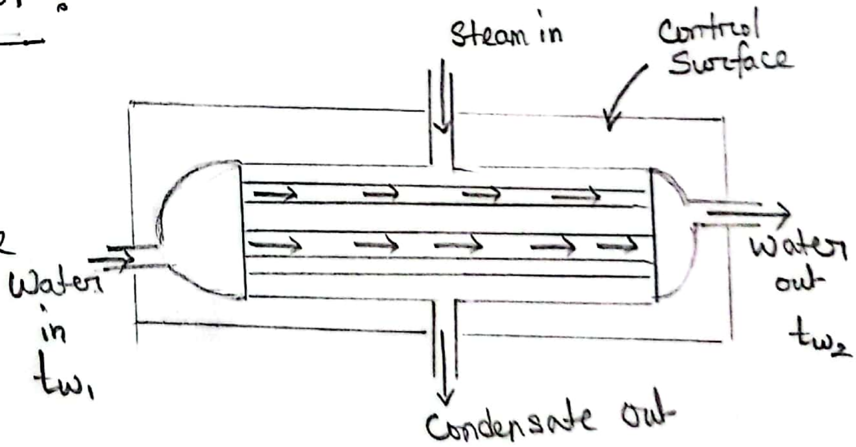
So, $0 = (h_2 - h_1)$

$\Rightarrow h_2 = h_1$.

[Here, enthalpy remain constant]

SFEE for Heat Exchanger:

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



So, $w = 0$; $z_1 = z_2$; $c_2 \cong c_1$

Thus putting them in the SFEE, we get,

$q = (h_2 - h_1)$.

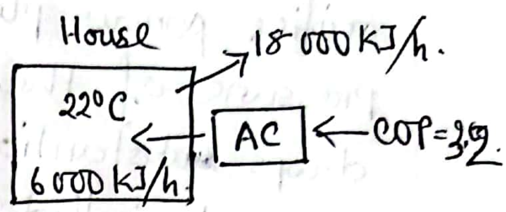
(10)

a) Given, Heat leak from air conditioning = 18000 KJ/h.

Heat produced inside the house = 6000 KJ/h.

COP = 3.2.

So, we know,



$$Q_H = (18000 - 6000)$$

$$= 12000 \text{ KJ/h}.$$

$$W_{in} = \frac{Q_H}{COP} = \frac{12000}{3.2} \times \frac{1}{3600} = 1.0417 \text{ KW}.$$

b) We know,

$$\text{Cost of operation} = \text{Power in KW} \times \text{electricity cost KW/h} \times \text{time}$$

$$= 1.0417 \times 0.1 \times \left(\frac{3}{2}\right) \quad \left[\because \text{time} = 1\tfrac{1}{2} \text{ hours}, \ \text{cost} = 0.1 \text{ cents/KW-h}\right]$$

$$= \$ \, 0.1562 \text{ cents daily}.$$

(Ans).