The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur

Department of Mechanical Engineering

NAME OF COURSE: - Power Engineering (PER)

CODE OF COURSE: - 315371

SEMESTER: - SYME-5K

SUBJECT TEACHER: - Mr. B. S. Patil

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R. C. Patel College of Engineering and Polytechnic, Shirpur

QUESTION BANK

Chapter 1. Refrigeration

Program Name: Mechanical Engineering
Name of Subject & Code : Power Engineering (315371)
Date – 02/07/2026

Program Code: ME5k
Semester : Fifth

Q. NO.	QUESTION	DETAIL	MAPPING
1	Represent the Bell-Coleman cycle on P.V. and T.S. diagram and name the processes involved in it.	W-25 4 M	TLO-1.1-U
2	Explain the terms subcooling and superheating and state its effect on the performance of vapour compression cycle.	W-25 4 M	TLO-1.2-U
3	Define C.O.P. of refrigerating unit.	W-25 2 M	TLO-1.2 –R
4	The temperature limits of an ammonia refrigerating system are 25°C and –10°C. The gas is dry at the end of compression and there is no under cooling of the liquid ammonia. The fluid flow at the rate of 5 kg/min. Calculate :– i) C.O.P. of cycle ii) Capacity of the refrigerator. Use the following table for properties of ammonia : Temperature (°C) | Liquid heat (kJ/kg) | Latent heat (kJ/kg) | Liquid entropy (kJ/kg. K) 25 | 298.9 | 1166.94 | 1.1242 –10 | 135.37 | 1297.68 | 0.5443	W-25 6M	TLO-1.2-A
5	State the any four advantages and disadvantages of vapour compression cycle.	OTHER- 4M	TLO-1.2-U
6	A refrigeration system works on vapour compression cycle. Enthalpies at various points are given below : Compressor inlet: 1460 kJ/kg Compressor outlet : 1796 kJ/kg. Inlet to expansion valve : 322KJ /kg. Calculate: a. COP b. Power required for one kg of refrigerant circulated per min. The refrigerant is superheated by 15 °C before it enters the compressor and subcooled by 3 °C before expansion. Sketch the cycle on P-H and T-S diagrams.	OTHER- 6M	TLO-1.2-A
7	Name the components used in the Vapor Absorption Refrigeration System.	W-25 2 M	TLO-1.3 -R
8	Draw a neat sketch of vapour absorption refrigeration system.	OTHER- 4M	TLO-1.3-U
9	Differentiate between VCRS and VARS. system.	OTHER- 4M	TLO-1.2,1.3-A
10	Expain desirable properties of refrigerant,	OTHER- 4M	TLO-1.4-U
11	Define GWP and ODP.	OTHER- 4M	TLO-1.4-R
12	Give examples of primary and secondary refrigerants.	OTHER- 4M	TLO-1.4-R
13	Explain with a neat sketch construction and working of a storage-type water cooler. Write specifications of it.	W-25 6M	TLO-1.5-U
14	Draw the layout of water cooler. Name all important components of it and explain its working in brief.	OTHER- 6M	TLO-1.5-U
15	Draw the layout of ice plant. Name all important components of it and explain its working in brief.	OTHER- 6M	TLO-1.5-U

04/07/2026
Mr. B. S Pat

02/07/26

chapter. 01

Refrigeration [12m - 4R, 4U, 8A, 16Hr]

1.1 Definition of refrigeration

It is a process of cooling a space, substance or system to a temperature lower than the ambient temperature & maintaining that lower temperature

it involves removing heat from a substance or space & transferring it to a higher temperature area.

Refrigeration system utilize a refrigerant that undergoes a cycle of evaporation & condensation facilitated by a compressor & expansion valve.

Refrigerating effect:-

It is a rate at which heat is removed from a substance or space to create a lower temperature.

unit ⇒ 1] Tonnes of Refrigeration [TR]

2] KW or KJ/sec

$\boxed{1 TR = 3.56 KW}$.

* Tonnes of Refrigeration [TR]

Amount of heat removal required to cool the one ton [1000kg] of water at $0^\circ C$ & convert it into a ice at $0^\circ C$ in 24 Hrs.

$$1\ TR = 211\ KJ/min \quad OR$$
$$= 3.5\ KW.$$

Derivation :-

Heat removed from water at $0^\circ C$ & convert into ice at $0^\circ C$ is a latent of fusion which is 334 KJ/Kg.

$\therefore$ total heat removed (Q) = m × latent heat
$= 1000 \times 334\ [kg \times \frac{KJ}{kg}]$
$= 334000\ KJ.$

Time taken = 24 Hrs

rate of heat removal [TR] $= \dfrac{334000}{24 \times 60} \quad \left[\dfrac{KJ}{MIN}\right]$

$\approx 232\ KJ/min$

$\approx \dfrac{232}{60}\ KJ/sec$

$\approx 3.86\ KW$

$$\boxed{\text{Practically it is taken as, } 1\ TR = 3.56\ KW}$$

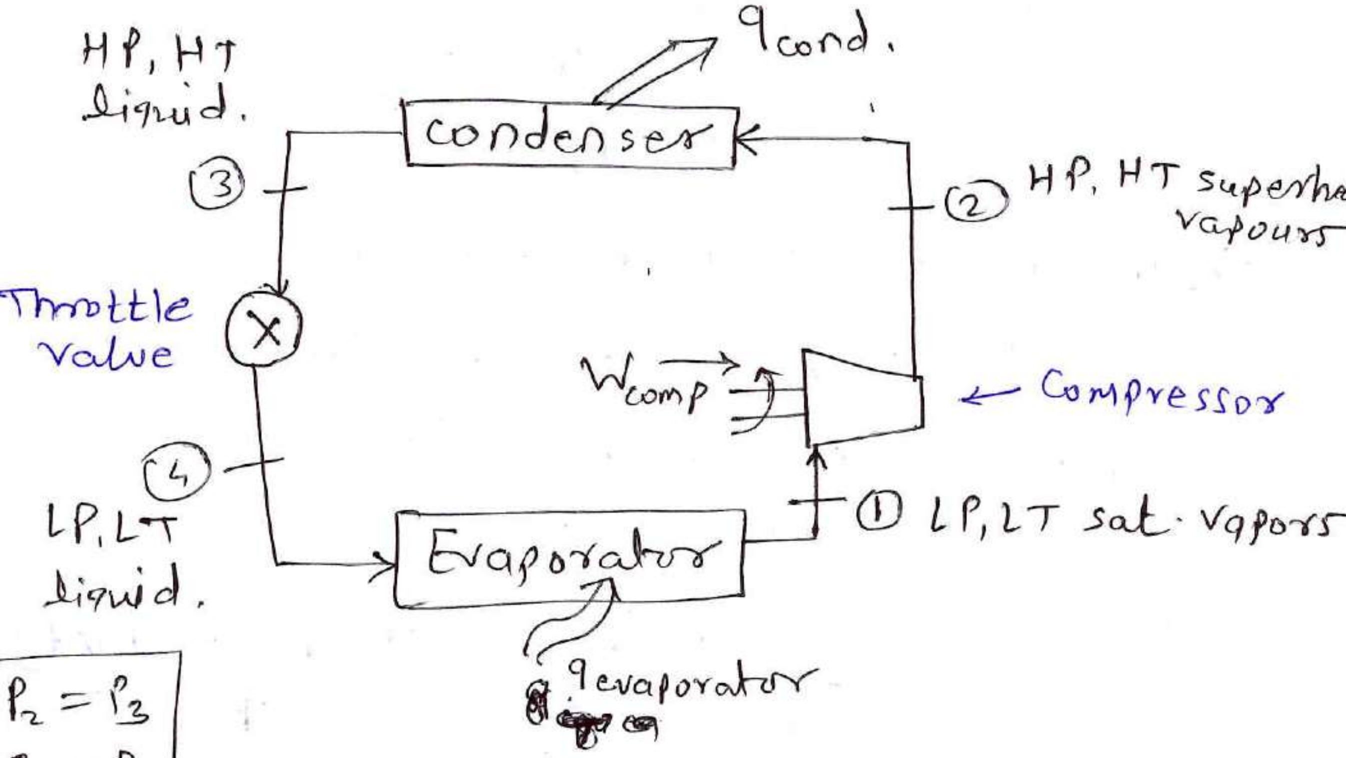
* Bell coleman cycle applications:→

1) used in aircraft cooling system to maintain the cabin temperature at high altitude.

2) used in defence & Aerospace for cooling purposes & for equipment that operates at high altitude.

1.2] Vapour Compression Refrigeration system [VCR system]

flow diagram:-



$$\boxed{\begin{matrix} P_2 = P_3 \\ P_4 = P_1 \end{matrix}}$$

fig. flow diagram of VCR system

Components & their functions:-

1] Compressor 2] Condenser 3] Throttle valve 4] Evaporator.

1] Compressor:- It is a heart of VCR system. It compresses the low pressure Refrigerant vapour from evaporator pressure to ~~compr~~ Condenser pressure.

Process:- Isentropic Compression process. [$S_1 = S_2$ = Entropy constant]

~~S_1 = at evaporator pressure, S_2~~

6

2] Condenser:- It condenses the Refrigerant vapour to liquid at constant pressure. Heat is rejected to atmosphere from Refrigerant.

Process :- Isobaric process
Heat rejection
[$P_2 = P_3$]

3] Expansion device or Throttle valve :-

The liquid Refrigerant from Condenser pressure is Expanded / Throttle from condenser pressure to evaporater pressure.

Process :- Isenthalpic [Enthalpy Constant]
Expansion process. [$h_3 = h_4$]

4] Evaporator :-

It is a device where cooling effect is obtained. liquid refrigerant at low pressure enters into evaporator & absorbs it's latent heat of evaporation & converted into vapours.

Process :- Isobaric heat absorption process.
[$P_4 = P_1$].

Working of VCR :-

Starting on point ①,
Low pressure, Low temperature saturated Refrigerant vapour from evaporator is compressed into

compressor adiabaticaly to condenser pressure. Refrigerant leaves the compressor as super--heated vapours, at point 2.

These vapours are condensed into condenser at constant pressure into subcooled liquid by rejecting lattent heat of condensation to atmosphere. at point 3.

This subcooled liquid at condenser are throttled to evaporator pressure in throttling valve. As a result of reduction of pressure, temperature of refrigerant also falls beyond the evaporator temperature at point 4.

This low pressure, low temperature subcooled liquid passed through evaporator & converted into vapours at point 1 by absorbing its. latent heat of evaporation. & cycle repeats

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other components of VCR system:-

a] Dryer & strainer:- Removes moisture & impurities from the refrigerant system. It is installed inbetween condenser & throttle valve.

b] Receiver:- It is device used to store condensed refrigerant from condenser. & supply the refrigerant to evaporator through capillary tube. ~~Installed~~

It is installed between condenser & capillary tube.

c] Accumulator :-

It is device used to trap the liquid refrigerant droplet & avoid it's entry to compressor.
Entry of liquid refrigerant to compressor damages the compressor.

P-H & T-S diagram of VCR system :-

1]

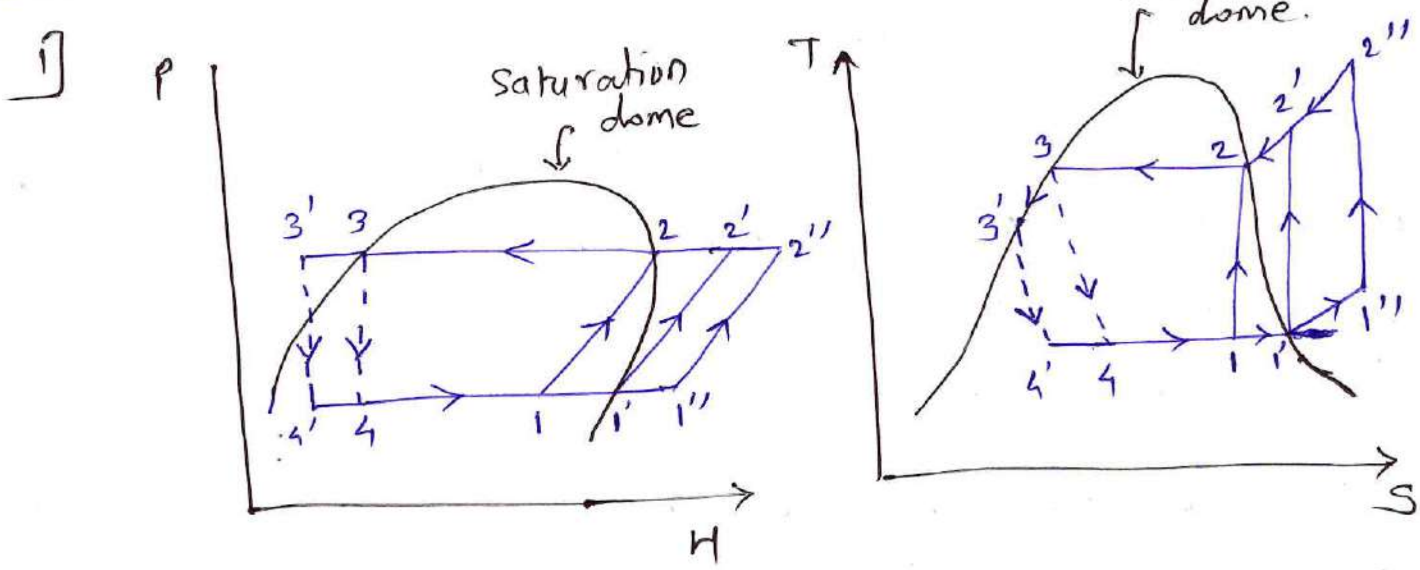


fig. P-H & T-S diagram for various VCR system

Types of VCR system :-

1] process (1→2→3→4) = Wet compression without subcooling.

2] process [1→2→3→4] = Wet compression with sub cooling

3] process [1'→2'→3→4] = Dry compression without subcooling with saturated vapour at inlet of compressor.

4] process [1'→2'→3'→4'] = Dry compression with subcooling with saturated vapour at inlet of compressor.

5] Process [$1'' \rightarrow 2'' \rightarrow 3 \rightarrow 4$] = Dry compression without subcooling with superheated vapour at inlet of compressor.

6] Process [$1'' \rightarrow 2'' \rightarrow 3' \rightarrow 4'$] = Dry compression with subcooling & superheated vapour at inlet of compressor.

A] Wet compression :- at inlet of compressor, the refrigerant is wet.
[Process $1 \rightarrow 2$]

It is not desirable because liquid droplet of refrigerant damages the compressor.

B] Dry Compression :- [Process $1' \rightarrow 2'$ & $1'' \rightarrow 2''$]

At the inlet of compressor, the refrigerant is either dry saturated vapour or superheated vapour.

It is desirable because it increases the life of compressor.

* Process $1' \rightarrow 1''$ is superheating process, refrigerant is superheated in superheater before it enters into compressor.

Effects of superheating :-

1] It increases the refrigerating effect.
2] It increases specific work of compressor.
3] It slightly decreases COP of system & capacity of system.
Superheating upto 5°C is generally used.

c] <u>Subcooling</u> :- process $3 \rightarrow 3'$.

liquid refrigerant is cooled below saturation temperature corrospond to pressure before throttled.

It is done by installing sub-cooler between a condenser & the expansion valve.

Effects of Subcooling :-

1] It reduces splashing of liquid during Expansion in throttle valve.

2] It increases refrigerating effect, & power per ton.

COP of ~~refrigerator~~ (VCR) system :-

$$[COP] = \frac{\text{Refrigerating effect}}{\text{Compressor work}} = \frac{R.E.}{W_c}$$

$R.E = m_r [h_1 - h_4]$ — for process $1 \rightarrow 2 \rightarrow 3 \rightarrow 4$

$= m_r [h_1' - h_4]$ — for process $1' \rightarrow 2' \rightarrow 3 \rightarrow 4$

$= m_r [h_1'' - h_4]$ — for process $1'' \rightarrow 2'' \rightarrow 3 \rightarrow 4$

$= m_r [h_1 - h_4']$ — for process $1 \rightarrow 2 \rightarrow 3' \rightarrow 4'$

& so on.

$W_c = m_r [h_2 - h_1]$ — for process $[1 \rightarrow 2 \rightarrow 3 \rightarrow 4]$

$= m_r [h_2' - h_1']$ — for process $[1 \rightarrow 2 \rightarrow 3 \rightarrow 4]$

& so on.

Problem on VCR System:-

Q.1] A refrigerating system works on vapour Compression cycle. Enthalpies at various points are given below,

Compressor inlet = 1460 KJ/kg

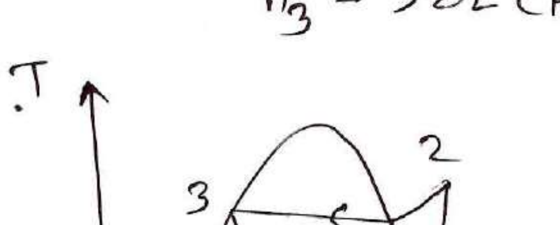
Compressor outlet = 1796 KJ/kg

Expansion valve inlet = 322 KJ/kg

Calculate:- a] COP b] Power required for one kg of refrigerant circulated per min

→ Here, $h_1 = 1460$ KJ/kg $h_2 = 1796$ (KJ/kg)

$h_3 = 322$ (KJ/kg), $m_r = 1$ kg/min



$$R.E = \dot{m}_r [h_1 - h_4]$$

$$= \frac{1}{\quad} [h_1 - h_4]$$

Here, $h_3 = h_4$ = Isenthalpic Process

$$\therefore RE = [1460 - 322]$$

$$W_c = \dot{m}_r [h_2 - h_1]$$

$$= 1 [1796 - 1460]$$

$$\therefore \quad COP = \frac{R.E}{W_c} \Rightarrow \frac{1460 - 322}{1796 - 1460} \Rightarrow \frac{1138}{336}$$

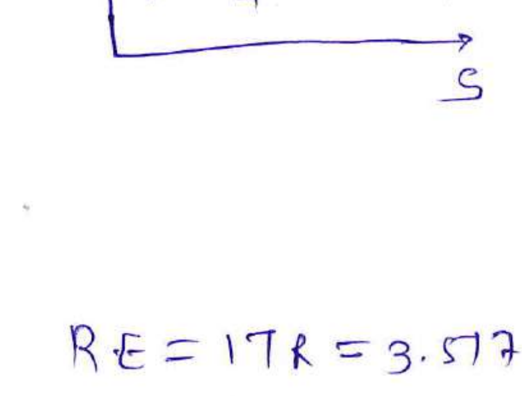
$$\boxed{COP = 3.38}$$

Power required $= \dot{m}_r [h_2 - h_1] = \frac{1}{60} [1796 - 1460]$

$= 5.6$ [KJ/sec] $=$ 5.6 KW.

Q.2] A VCR working on R-134a operates between saturation temperature -2°C & 34°C. refrigerant is saturated at entry to the compressor & assume no sub-cooling. Entropy of refrigerant at the end of compression is 444 kJ/kg. find COP of the system. find also power required per ton of refrigeration capacity. use following data for R-134a.

Saturation temperature [°C]	Enthalpy in kJ/kg	
	Liquid	vapour
-2	197.33	397.51
+34	247.47	418.85



$H_1 = 397.51$ kJ/kg

$H_2 = 444$ kJ/kg

$H_3 = H_4 = 247.47$ kJ/kg

$$COP = \frac{H_1 - H_4}{H_2 - H_1} = \frac{397.51 - 247.47}{444 - 397.51}$$

$$\boxed{COP = 3.22}$$

$RE = 1TR = 3.517$ kW

$RE = m[H_1 - H_4]$

$3.517 = m[397.51 - 247.47]$

$$\boxed{m = 0.02344 \text{ kg/sec}}$$

Power required $= \dot{m}[H_2 - H_1]$

$= 0.02344[444 - 397.51]$

$$\boxed{\text{Power required} = 1.089 \text{ kW}}$$

1.3 Vapour absorption Refrigeration system [VARS]

Components :- Evaporator, absorber, generator, Condenser, Expansion valve, pump & Reducing valve etc

Here, absorber & generator combination is used to replace the Compressor in VCR system.

Working medium = Aqua Ammonia, Ammonia is Refrigerant & Water is absorbent.

Diagram :-

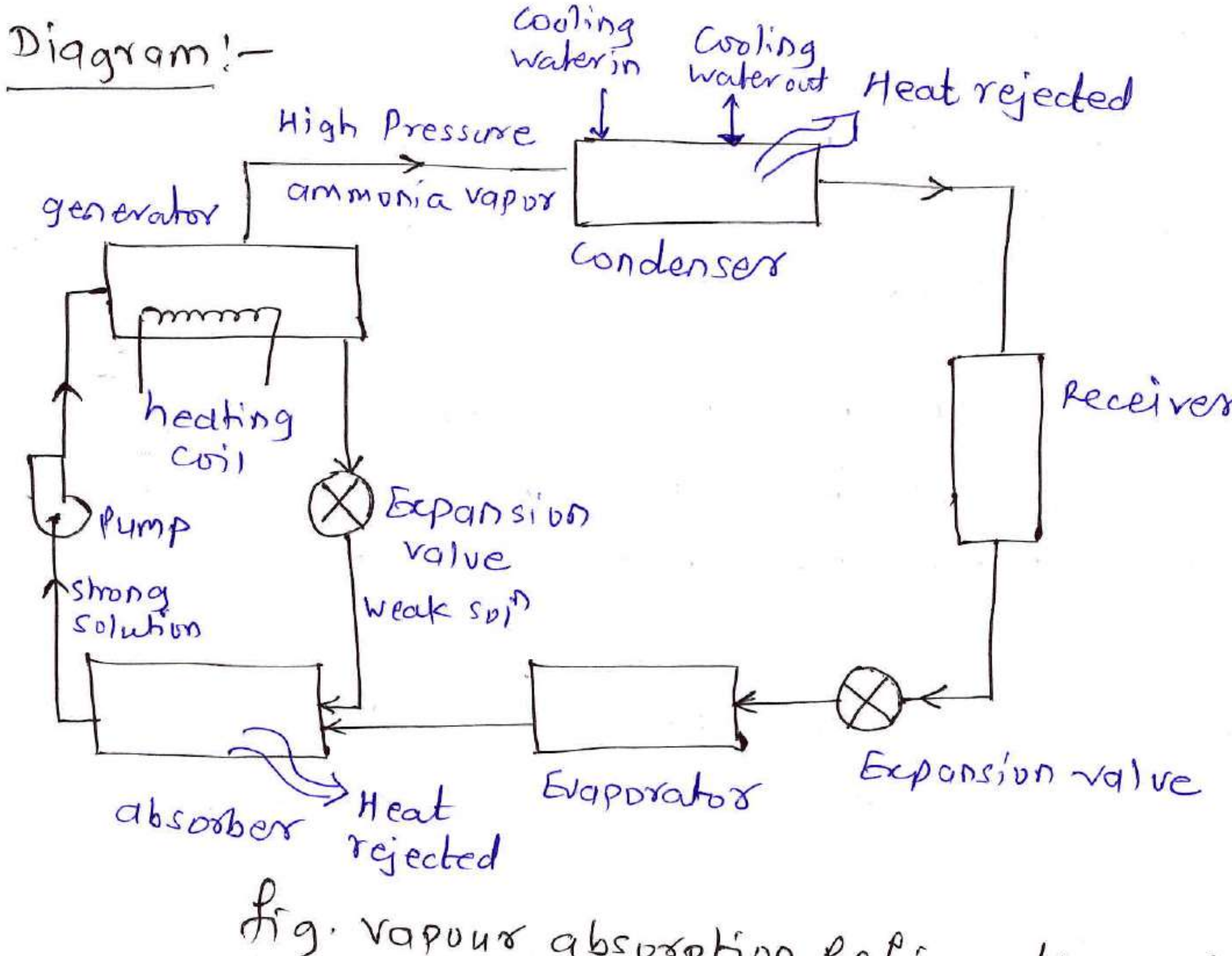


fig. vapour absorption Refrigeration system.

In this system, the low pressure ammonia ~~pressure~~ vapours ~~from~~ are absorbed by weak solution in absorber.

The water has the ability to absorb very large quantity of Ammonia vapour & the strong aqua Ammonia solution is formed.

Cooling arrangement is provided in the absorber to cool & lower the pressure in absorber. to ~~facilitated~~ at facilited the more absorption of ammonia solution at lower temperation.

Strong aqua Ammonia solution is formed in the absorber.

The strong solution formed in the absorber is pumped to the generator by the liquid pump. & heated into the generator by heating coil.

Because of heating process, the ammonia vapours are seperated from Aqua Ammonia solution leaving behind the hot weak solution in the generator.

This weak solution, flows back to the absorber at low pressure after passing through Expansion valve.

· The high pressure ammonia vapor from the generator is condensed in the condenser to a high pressure liquid Ammonia.

This liquid Ammonia is passed through Expansion valve & receiver & then to evaporator. This completes the cycle.

Actual vapor absorber system :-

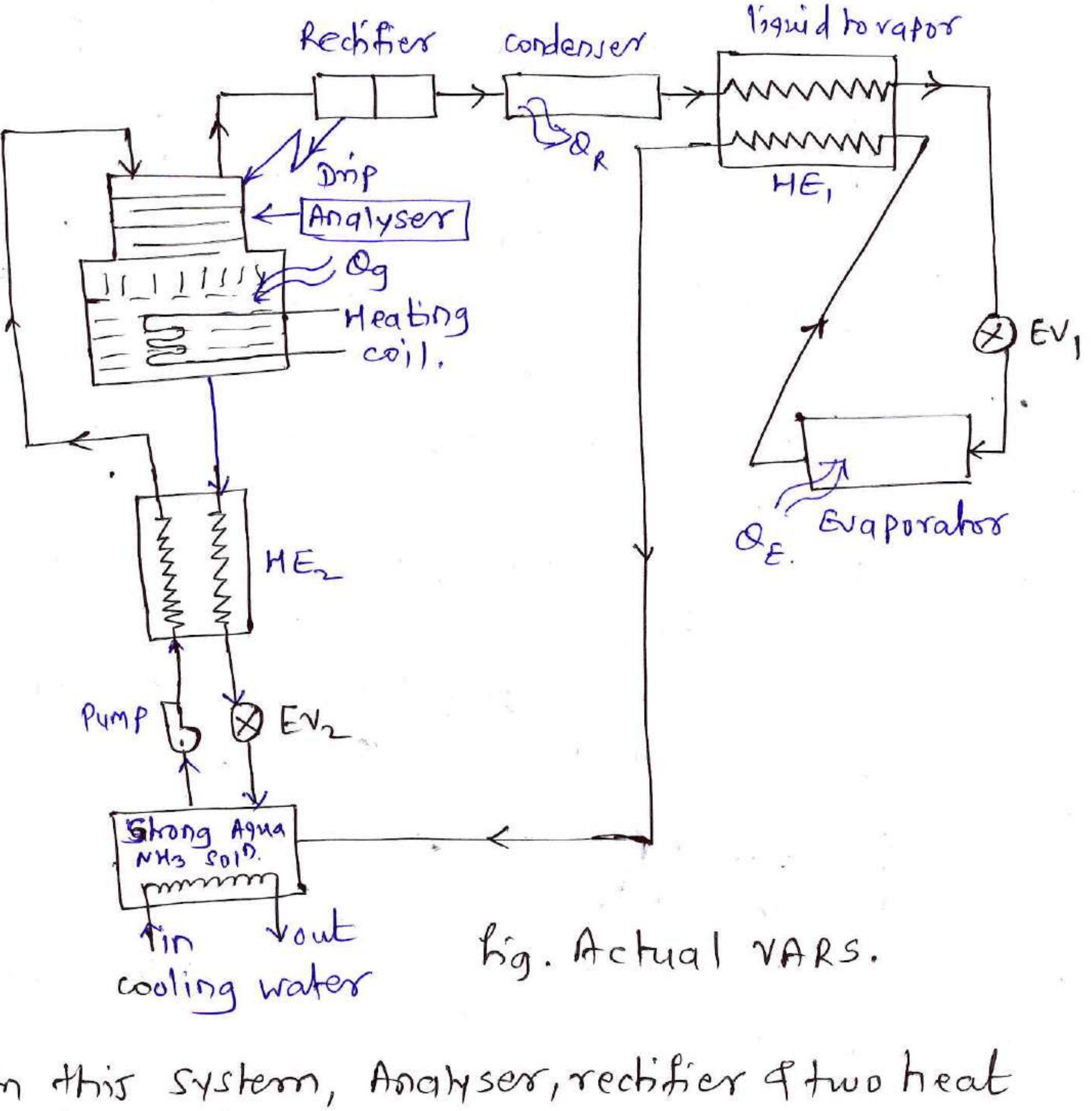


fig. Actual VARS.

In this system, Analyser, rectifier & two heat Exchanger are added to the VARS to increase the performance.

- In Actual VARS system, vapours generated in generator are passed through Analyser where the dehydration of this aqua takes place to produce strong aqua NH_3.
- If dehydration is not complete then this water particles are seperated in rectifier & water again reback to generator & strong Ammonia vapours passed through the condenser, where it is cooled & change the phase rejecting the latent heat to cooling water. This liquid ammonia is send to Expansion valve [EV_1] through first Heat Exchanger [HE_1]
- The liquid refrigerant [NH_3] is subcooled by using low temperature ammonia vapour. This subcooled refrigerant is passed through Expansion valve [EV_2] to the evaporator.
- The refrigerant absorb heat in evaporator & pass to absorber through heat Exchanger HE_1.
- In absorber, cooling arrangement is provided to reduce the temperature & pressure of weak solⁿ from generator. Which draws more NH_3 vapours from evaporator.
- strong aqua-Ammonia solution is formed in absorber, which is again pumped to the generator through heat Exchanger [HE_2].
- In Heat Exchanger 2 [HE_2] heat transfer from weak

solution to strong solution takes place. & again cycle repeats from Analyser.

Comparison of VCRS & VARS.

VCRS	VARS
advantages	disadvantages
1] More COP	1] Less COP.
2] Less time required to produce refrigerating effect	2] more time required to produce refrigerating effect.
3] Compact & requires less space	3] It requires more space
4] charging of refrigerant is easy	4] difficult in charging of Refrigerant.
disadvantages	advantages
1] movings parts, so more wear, noise & maintainance	1] No moving parts, so No noise, wear & less maintainance.
2] ~~Saving~~ Operating cost is more beacause of compressor work input.	2] saving in operating cost because of absense of Compressor
Application	Application
1] It is prefered for domestic commercial refrigeration	1] It is preferred for large capacity & industrial application waste heat & steam is available.

1.4 - Refrigerants:-

Refrigerants is a substance that changes state [liquid to gas or vice-versa] as it absorbs & releases heat energy.

Refrigerants are classified into primary & secondary refrigerants.

A] Primary Refrigerants:-

Primary refrigerants are substances that changes state [liquid to gas or vice versa] as they absorbs & releases heat energy.

eg. CFCs, HCFCs, HFCs, Natural refrigerants.

CFCs & HCFCs are phased out due to ODP & only HFCs are used.

B] Secondary Refrigerants:-

Secondary refrigerants are known as brines or coolants which are liquids cooled by primary refrigerants & then used to cool a system or product. They do not change state themselves.

eg. water, Brine solutions [NACL; $CaCl_2$]

Glycol solution [eg. ethylene Glycol].

* used where primary refrigerant use is prohibited eg. food Industry.

Commonly used. R-134a – HFC, used in automotive AC

R717 [NH_3] – industrial. Refrigeration

R744 [CO_2] –

R11 & R12 – phased out CFCs.

R22 – being phased out HCFCs.

R11 – CCl_3F – Trichloroflo methane

R12 – CCl_2F_2 – Dichorodifloro methane

R22 – $CHClF_2$ –

Desirable properties :- for selection.

1] High latent heat of vaporization :- should be able to absorb a large amount of heat energy as it changes state from liquid to gas.

2] Low boiling point :- To allow it to evaporate easily.

3] Non-toxic & Non flammable - should be safe to use & not pose a risk to human health

4] Environmentally friendly :- should not contribute to ozone depletion or climate change

5] freezing temperature :- should be low to avoid freezing.

6] low viscosity. Non corrosive, should mix with oil.

* selection of Refrigerants :- same as above.

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* Global warming potential [GWP]

- It is a measure of how much a greenhouse gas contributes to global warming over a specific time period, usually 100 years.
- It is expressed as a relative value compared to Carbon dioxide [CO_2], which has a GWP of 1.
- High value of GWP. contributes significantly to global warming.

eg. GWP values for
1] R134a [HFC] = 1300
2] R410A [HFC] = 2300
3] R22 [HCFC] = 1810
4) CO_2 [R-744] = 1
5) NH_3 [R-717] = 0.

* **ozone depletion potential [ODP]:→**

- It is a measure of the potential of a substance to deplete the stratospheric ozone layer.
- chlorine in Refrigent causes the depletion of ozone layer.
- ODP values:- CFC [R11, R12) = 1 [High]
  HCFC [R12] = 0.05-0.01 [Medium]
  HFC [R134a, R410A] = 0 [low/Negligible]
  CO_2 & NH_3 = 0 [zero].

- High ODP Refrigerant must be phase out in order to a) Protect ozone layer.
  b) Protect life on earth.

- It can be acheived by
  a) use of ecofriendly refrigerant eg. R134a, CO_2 & NH_3
  b) use of CFC refrigerants must be banned & development of new ecofriendly refrigent substitutes to CFCs.

Importance of ODP & GWP:- 1] Evaluating environmental Impact of refrigerants & other substances.
2] selecting environmental friendly alternatives.
3) meeting regulatory requirements

Montreal protocol:-

It is international agreement aimed at reducing the production & comsumption of ozone-depleting substances, including CFCS & HCFCS.

1.5. Applications :-

1] Specification, Construction & working of domestic Refrigerator.

→ The construction of domestic refrigerator involves a series of components that work together to maintain the desired temperature for food storage

Components :-

1] Hermatically sealed compressor :-

Compresses the refrigerant gas to high pressure & temperature.

2] condenser :- positioned back of the refrigerator, it dissipates the heat & condenses the gas into liquid

4] Evaporator :- located Inside the refrigerator, it absorbs heat from the food items & converts the refrigerant ~~gas into~~ liquid into gas.

3] Capillary tube :-

It reduces the pressure of refrigerant before entering the evaporator.

5] Thermostat :-

Regulates the temperature by controlling the Compressor operation.

6] Drier & strainer :- Removes moisture from the Refrigeration system.

8]

diagram:-

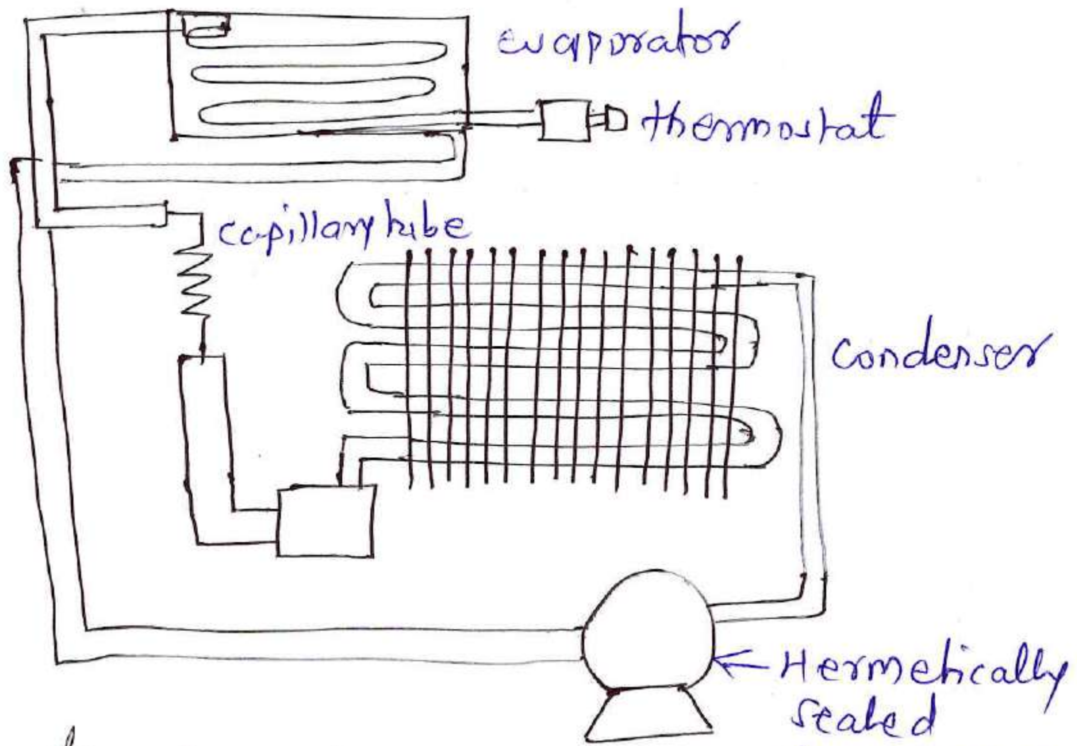

fig. domestic Refrigerator.

- works on VCRS system.
- Refrigerant used = R134a.
- Evaporator = plate & tube type, acts as freezer
- temperature = around -10°c in freezer
- Compressor = at bottom on back side of refrigerator Hermatically sealed.
-
- Expansion valve = Capillary tube on back side.
- Condenser = located on backside, grilled structure.

2] ICE plant:-

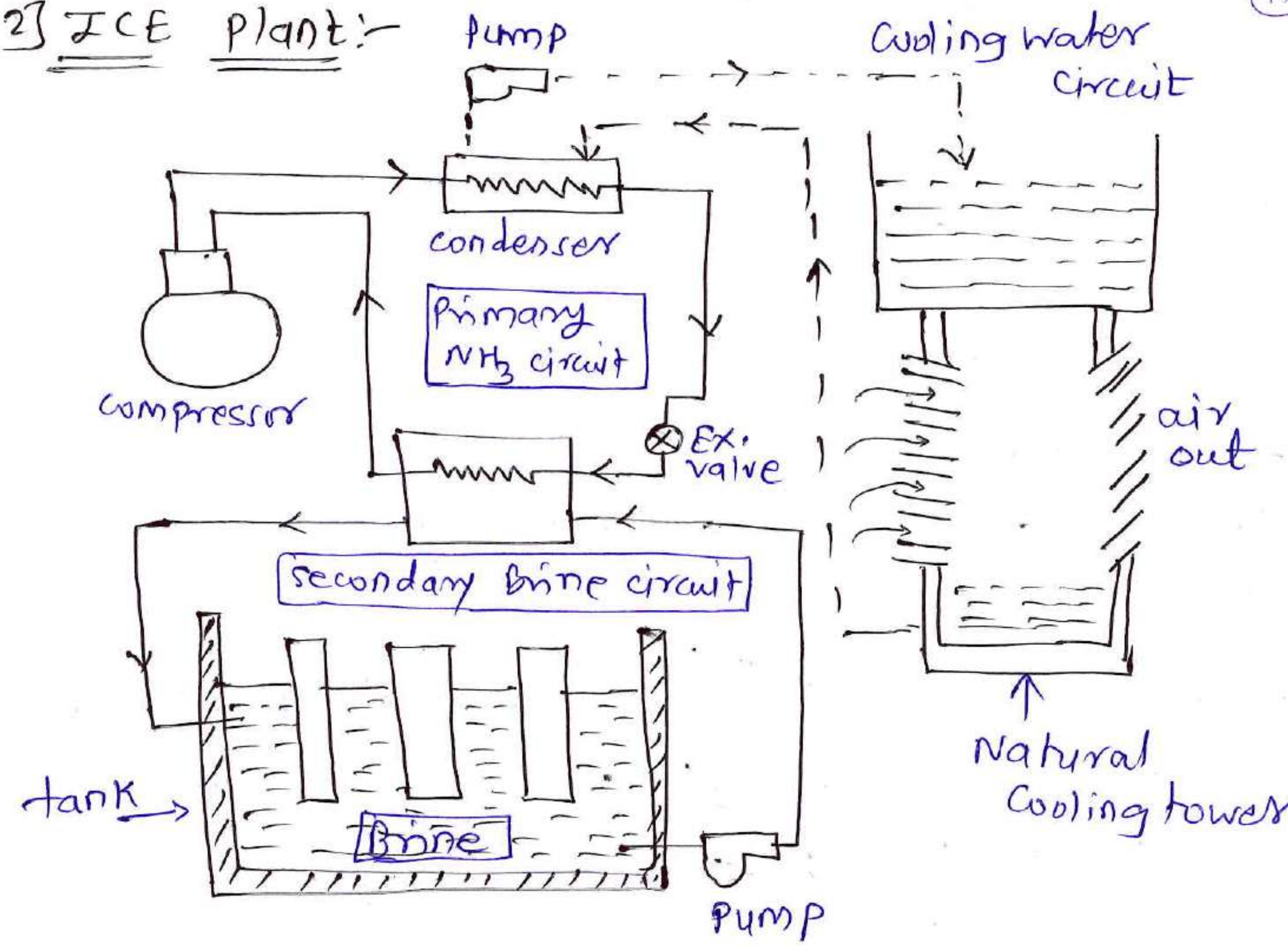

fig. ICE tank.

The Ice plant uses NH_3 as primary refrigerant & brine [NaCl + water] as secondary refrigerant.
temperature maintain = $-10°C$ to $-12°C$

- Systems — 1) Can ice 2] plate ice
- 1] CAN ice - galvanized iron cans containing water are placed in brine tank where brine is circulated by pump.
- water in ice can rejects heat to brine which is circulated in secondary circuits. This brine is pump through evaporator & again Return back to the tank.
- In evaporator the heat of brine is transfer to the

refrigerant ammonia in primary circuit & brine is cooled.

- The vapour NH_3 form in evaporator is suck by the compressor & compressed to high pressure & ~~d~~ condensed into condenser with the help of water by cooling water circuit.

- The high pressure liquid ammonia is collected in the ~~condenser~~ receiver & then passed through Expansion value.

- The throttled ammonia liquid at LP & LT enter in an evaporator. So brine is cooled & Ammonia absorbs heat & forms vapors & cycle is repeated.

- Can size,

25 kg = 5" × 12" × 35" GI, 18 g
45 kg = 8" × 6" × 36" GI, 16 g
135 kg = 11" × 22" × 48" GI, 16 g

- Brine tank can be concrete tank or fabricated from 6/8 mm ms plates.

- 100 to 125 mm thick thermocole is used as thermal insulation.

3] Cold storage:-

- cold storage is a large plant constructed to store certain goods such as, milk products, vegetables, sea foods, agricultural products etc.
- cold storage is one of the application of air conditioning, inwhich the air is cooled by passing it over an evaporator coil of refrigeration plant & supplied back to the room.
- It is used to fill the gap between demand & supply of food.
- Two categories:-

a] Temperature 0°c & above - eg - vegetables.

b] Temperature below 0°C - eg - dairy products.

1.5 Traditional methods of cooling used in Ancient India.

→ 1] Sun shading

2] Lattice screen

3] Natural evaporative cooling

4] step wells or "baori"

5] Smaller clay cooling devices eg. matka