Date 27-10-23

# Unit-3
## [Refrigeration and Air conditioning]

• Refrigerator → (Refrigeration) Refrigeration may be define as the process of HEV and maintaing a temperature below that of the surroundings. The aim is to being cool some product or space to the required temperature. One of the most ~~useful~~ ~~or~~ important application of refrigeration is to preserve food products by storing them at a low temperature. Refrigeration system are also used extensively for providing thermal comfort to human by means of Air conditioning.

• Application of Refrigeration →
1. Food processing Industry
2. Chemical Industry
3. Cold treatment of metals (Manufacturing Industries)
4. Medical
5. Ice-skating
6. Comfort air-conditioning

• Unit of Refrigeration →
The standard unit of refrigeration is 'Ton'. It is denoted by 'Ton' or 'TR', it is defined as the amount of refrigeration effect produced by the uniform melting of 1 Ton (907.14 kg) of ice from and at 0° c —— in 24 hours.

1 TR = 210 KJ/min or 3.5 KJ/sec

$$1\ TR = \frac{907.14 \times 335}{24 \times 60} = 211\ kJ/min \approx 210\ kJ/min$$

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TH = Source

TL = Sink

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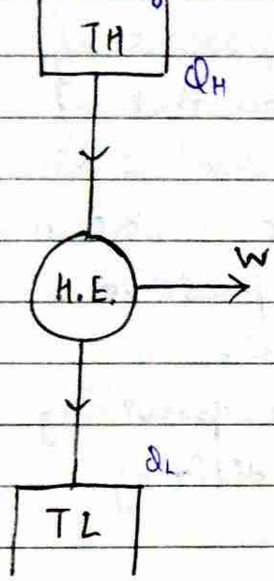
• Heat Engine → work developing device. which takes heat from a higher temp. reservior & converts it into methanical work, while rejecting remaining Heat to a lower temp. reservior




Output → $Q_W + Q_L$ (waste) → from 1st law of Thermodynamics

Input → $Q_H$

effeciency → $\eta = \frac{\text{output}}{\text{input}} = \frac{\text{Work}}{Q_H} = \frac{Q_H - Q_L}{Q_H} = \frac{T_h - T_L}{T_H}$

$Q_H = m.C.\Delta T$

$= m.c.(T_H)$

$Q_L = m.c.(T_L)$

(Source) TH → High temporium

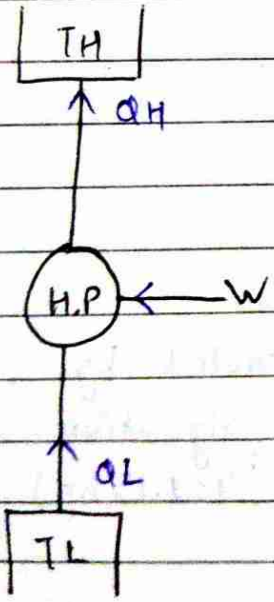
(Sink) TL → Low temporium

$Q_H = Q_L + W$

$Q_H - Q_L = W$

$\boxed{\eta_{HE} = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H}} = \frac{T_H - T_L}{T_H} = 1 - \frac{T_L}{T_H}$ → Efficiency of Heat Engine

• Heat Pump




Coefficient of performance (C.O.P) $= \frac{\text{output}}{\text{Input}} = \frac{Q_H}{Q_W}$

$= \frac{Q_H}{Q_H - Q_L} = \frac{T_H}{T_H - T_L}$ — ①

$\boxed{(COP)_{HP} - (COP)_R = 1}$

Heat pump is a device which transfer heat from a lower temp. space to a higher temp space while the desired space is at higher temp.

$COP = \frac{Q_H}{W} = \frac{1}{\eta_{HE}}$

$\boxed{(COP)_{HP} = \frac{Q_H}{Q_H - Q_L}}$

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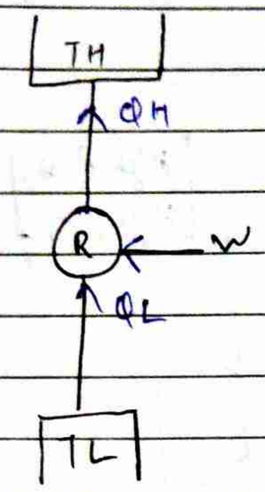
## Refrigeration →




Ref. box

Input = W
Output = $Q_L$

$$(C.O.P) = \frac{Q_L}{Q_H - Q_L} = \frac{Q_L}{W}$$

$$(C.O.P) = \frac{T_L}{T_H - T_L} \quad \text{—} \textcircled{2}$$

It is a device which transfer heat from a lower temp. space to a higher temp. space while the desired space is at lower temp.

From eqn ① and ②
eq ① − eq ②

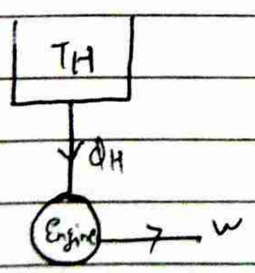
$$(COP)_{HP} - (COP)_{Ref} = \frac{T_H}{T_H - T_L} - \frac{T_L}{T_H - T_L}$$

$$= \frac{T_H - T_L}{T_H - T_L} = 1$$

★★ Relation

$$\boxed{(COP)_{HP} - (COP)_{Ref} = 1}$$

★ → Extra




$\eta = 100\%$

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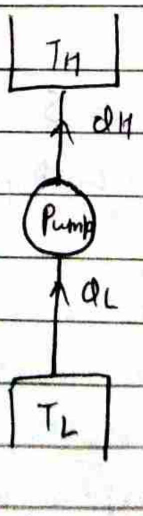


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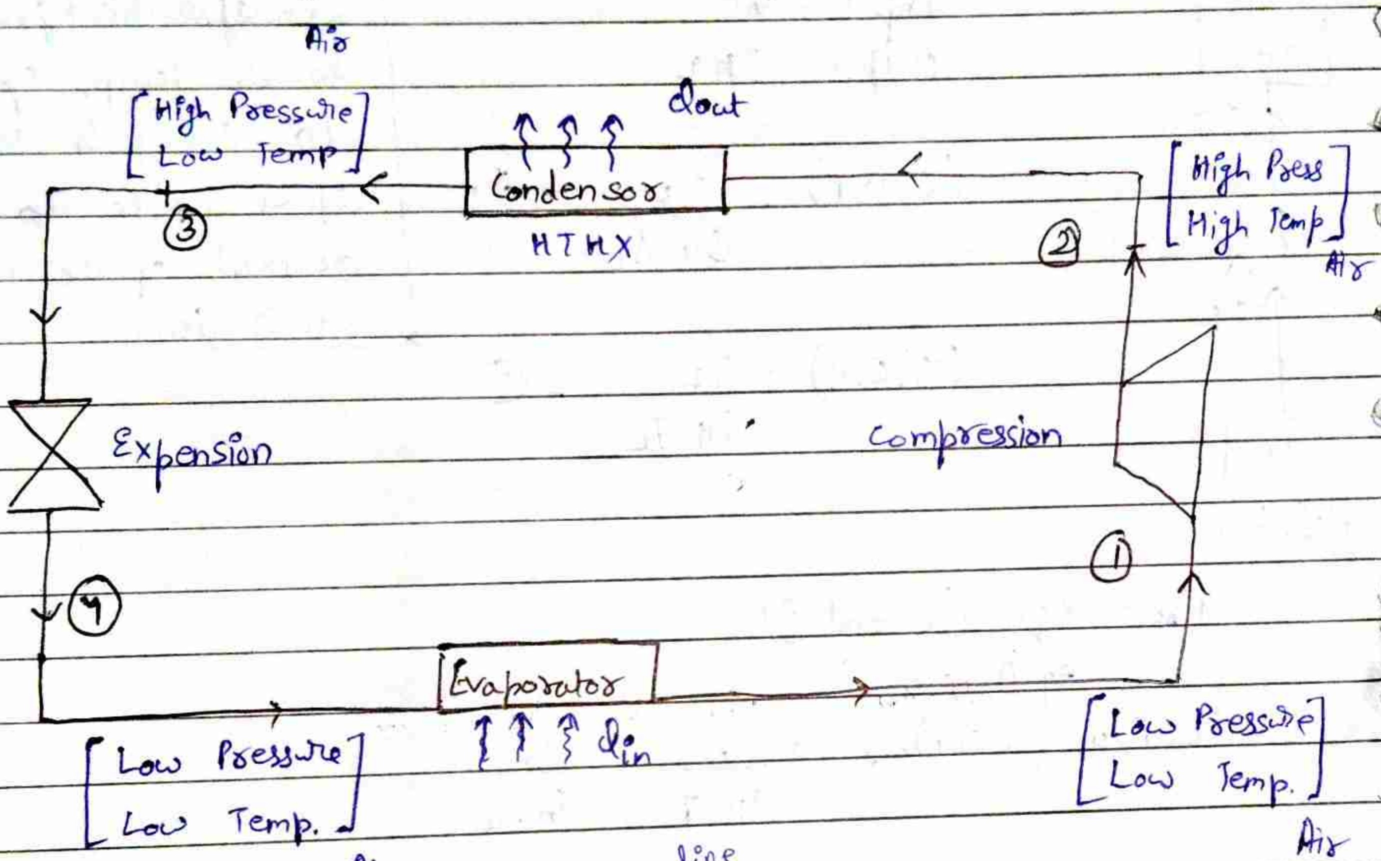
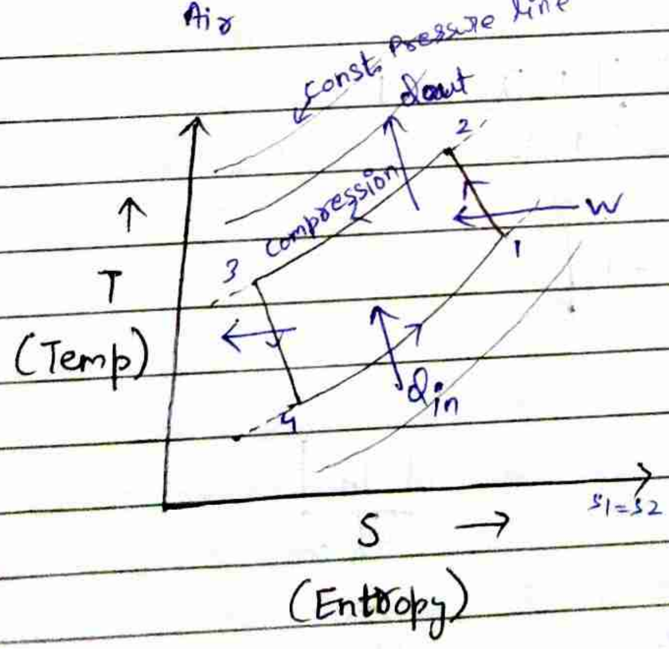
• Close

Air - Refrigeration Cycle




1-2 → Rev. adiabatic comp. Process

2-3 → Isobaric heat rejection Process

3-4 → Rev. adi Expansion Process

4-1 → Isobaric heat absorption process

Rev. ~~adiable~~ adiabatic Process is also called isentropic process.

S = Constant.

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- Air cycle refrigeration system belong to the general class of gas - cycle refrigeration system, In which air is used as a working fuel. The air doesn't undergo any phase change during the cycle. So all the internal heat transfer process are sensible heat transfer process. Air cycle refrigeration system find application in air craft cabin cooling and also in liquification of various gases.
- Ideal Reverse Brayton cycle is used in air-cycle refrigeration system. This cycle is also called as Bell-coleman or Joule cycle.
- This reverse Bryton cycle / Bell-coleman / Joule cycle is shown is T-S diagram. It consists of following four process.

Process 1-2 => **Reversible adibatic compression Process** → reversible adibetic compression / Isentropic compression Process. in compressor. Air is compressed here.

Process 2-3 => Isobaric heat rejection process → In condensor

Process 3-4 => Reversible adibetic expension process → or Isentropic ~~compre~~ expension process in expandor.

Process 4-1 => Isobarric heat absorption process → In evaporator.

1. Process → 1-2 => During this process compressor, compress the air isentropicly from state 1 to state 2. Pressure and temperature of air increase from low to high.

2. Process → 2-3 => High Temp. and High Pressure air flow through a heat exchanger (HTHX), (Condensor) and reject heat seansibly and isobaricly. The enthalpy and temp. of air

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drop during the process due to heat exchange. and entropy of air is also decreased.

3. Process 3-4 => High pressure air from the condensor flow through a expansion device (expandor, turbine) and undergoes isentropic expansion ~~process~~ process. The temp. of air goes down to its lowest temperature ($T_3 - T_4$)

4. Process 4-1 => Low pressure and Temperature air flow through the evaporator (LTHX) and extract heat seansibly and isobarricly from a heat source and provide a useful refrigeration effect. The enthalpy and temp. of air during the process rise and the entropy of air also increase.

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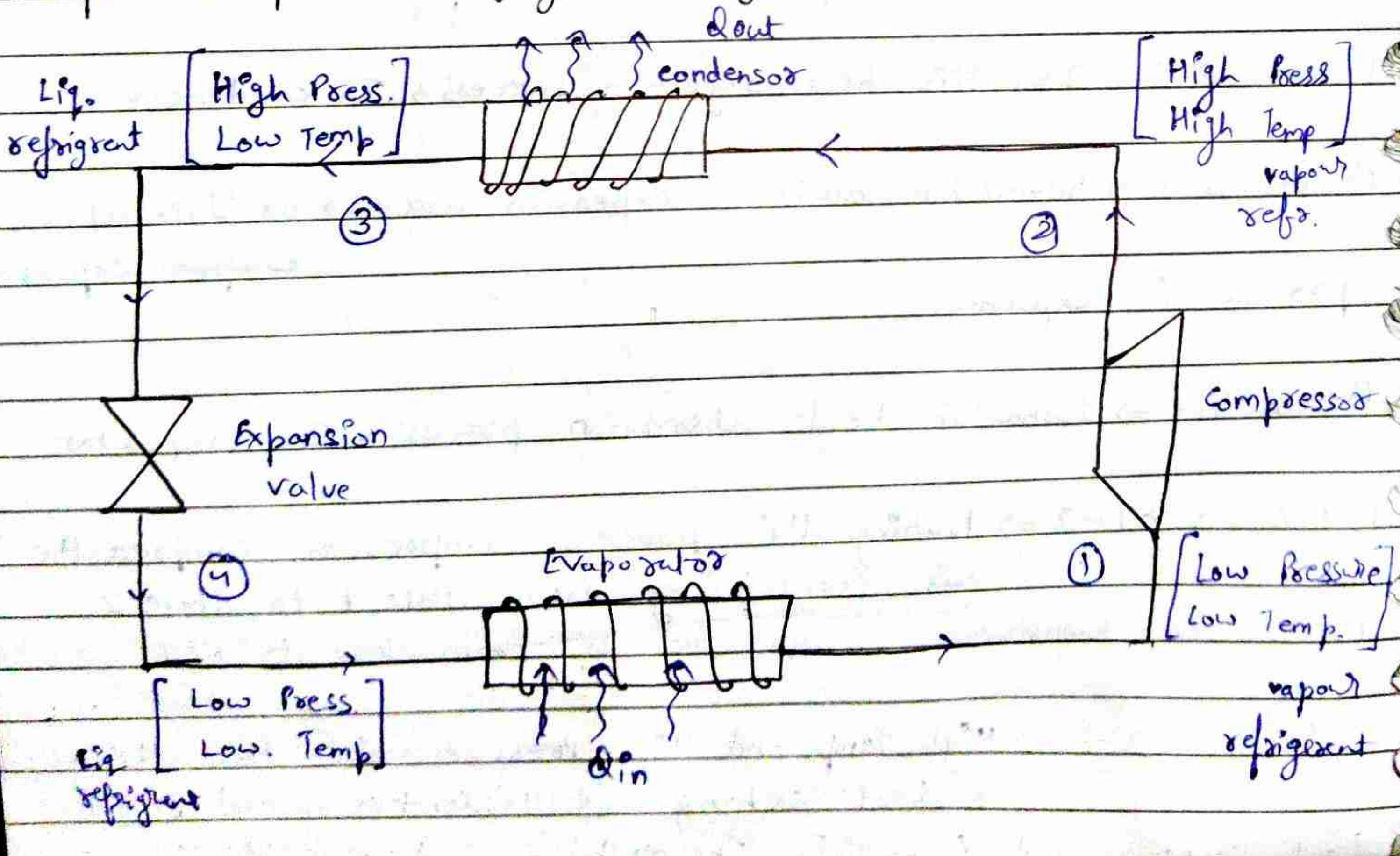
• Vapour Compression Refrigeration System [VCRS] ->



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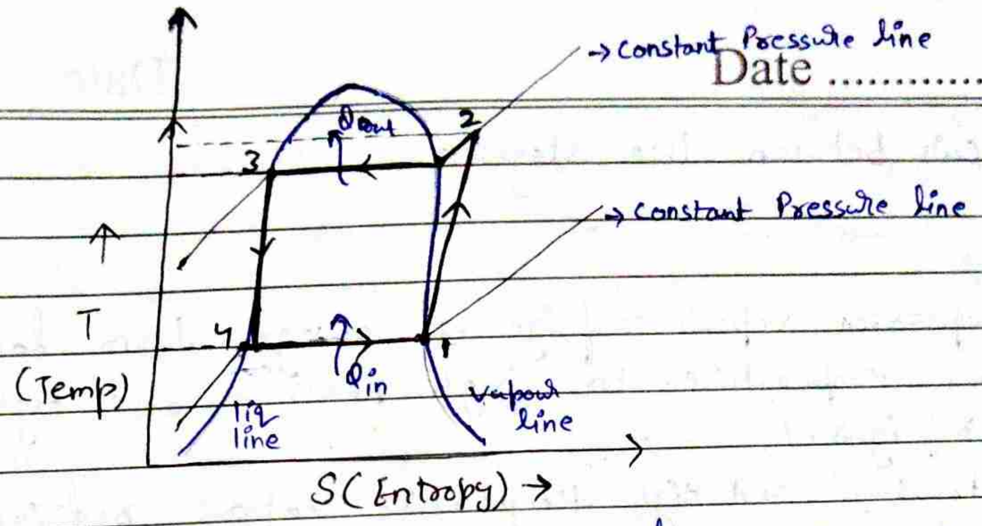


Figure shows the systematic diagram of vapour compression refrigeration system and the operating cycle on the T-S diagram. Mainly four process is used →

1. Process 1-2 → Reversible adibatic (Isentropic) compression process (in compressor)
2. Process 2-3 → Isobarric heat rejection process (in condensor)
3. Process 3-4 → Reversible adibatic (Isentropic) expansion process (in expandor)
4. Process 4-1 → Isobarric heat expration process (in (evaporator).

Vapour compression refrigeration system (VCRS) is a system that use liquid refrigrent in a close system which circulate the refrigerant through four stages in which it is alternatively compressed and expand and changing it to liquid from vapour. As this change happens, heat is either absorbed or expelled by the system resulting in a change in temperature. Nearly, all of the refrigeration system we use today, use this cycle to accomplish cooling.

• Components →

VCRS system is made up of four main components. These are → 1. compressor, 2. Condensor, 3. Expansion device, 4. Evaporator. The evaporator and condensor are both a series of coils that are designed to create more surface area for the refrigerant meanwhile the compressor and expansion value are mechanical units that control the amount of pressure and temperature change

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that occur between two stages.

• Working →

1. In compressor vapour refrigerent changes from low pressure and low temperature to high pressure and high temperature vapour refrigerent.
2. High Pressure and High temperature vapour refrigerent enter in condensor where heat is removed. Here vapour refrigerent converts into high pressure and low temperature liquid refrigrent.
3. Then High pressure and low temperature moves to expandor where it is expands and convert in Low pressure and low temperature liquid refrigrent.
4. Low pressure and low temperature liquid refrigerent moves to evaporator where heat is entered.
5. In evaporator, low pressure and low temperature liq refrigrant converts to low pressure and low temperature vapour refrigrent.
6. Hence, the cycle is continous.

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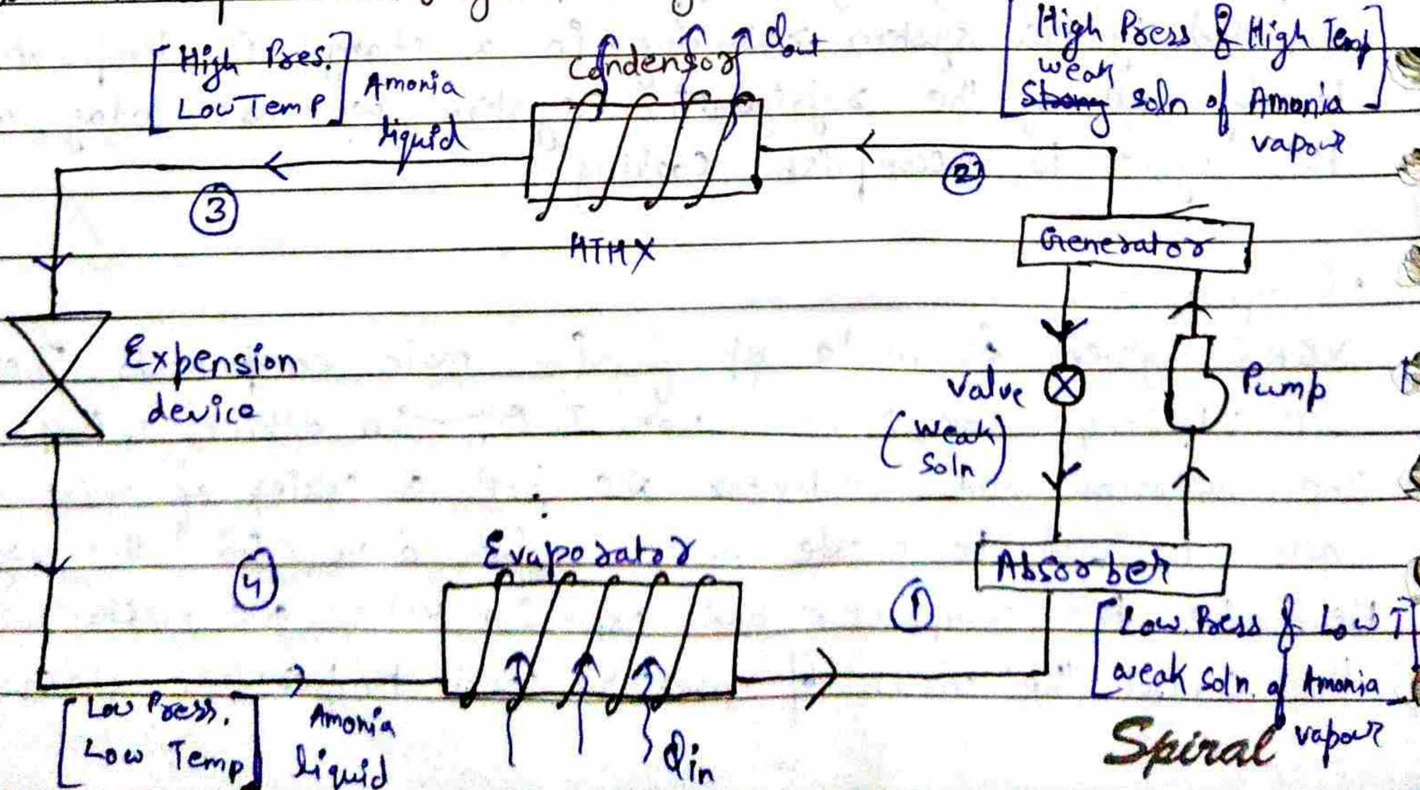
• Vapour Absorption Refrigeration System →

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ref.

- A simple vapour absorption system consist of absorber, generator, pump, valve, condensor, expansion device and evaporator. In this system amonia is used as refrigrent and solution is use to known a Aqua-amonia. Strong solution of aqua-ammonia contain as much as amonia contain as it can and heat sol.
- The compressor of vapour-compression refrigeration system is replaced by an absorber, generator, pump and valve in this system.
- Amonia vapour coming out of evaporator are drawn in absorber. This weak solution of amonia absorb amonia in absorber and get converted into strong solution. This strong solution is pumped into generator. The addition of heat liberates amonia vapour and solution get converted into weak solution. The released vapour is passed to condensor and weak solution to absorber through a valve. Thus the function of compressor is done by absorber, generator, value & pump.
- This system is used where there is scarcity of electricity

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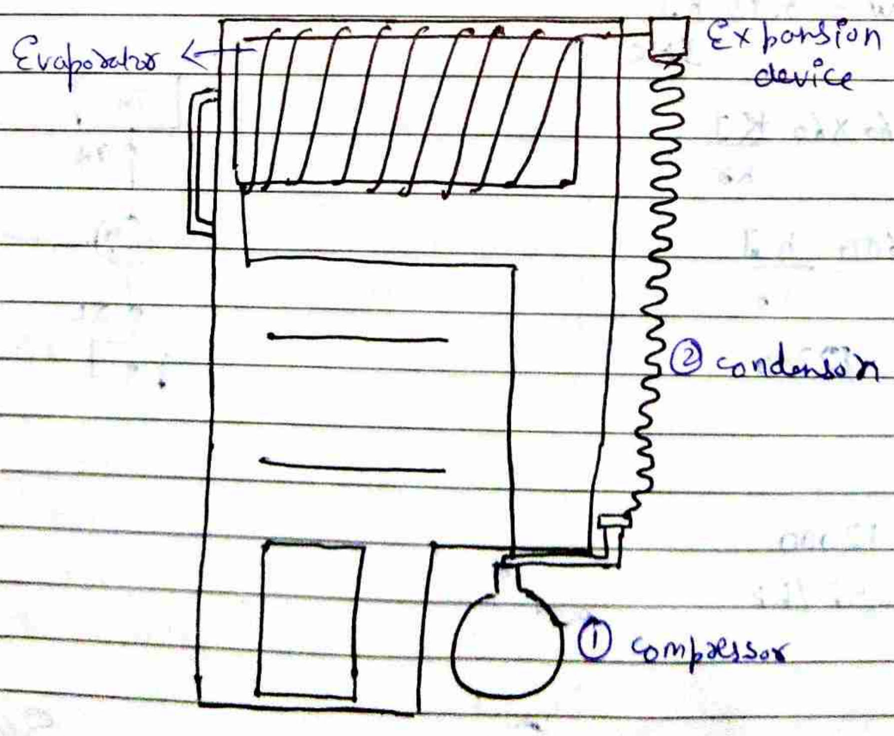
- Domestic Refrigerator →




The cycle that is used in domestic ref. is VCRS

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The cycle that is used in domestic refrigerator is vapour compression cycle.

• Refrigerent → It is also called as coolant and is the working fluid for the refrigerator, it takes the heat from inside of the refrigerator and transport it to the outside.
Most commonly refrigerent used are → isobutane, CFC's, and Ammonia [toxic] not used in domestic as well as in modern fridge.

Q → Find the coefficient of performance and heat transfer rate in the condensor of the refrigerator in KJ/hr which has ref. capacity of 12000 KJ/hr. when power input is 0.75 KW.

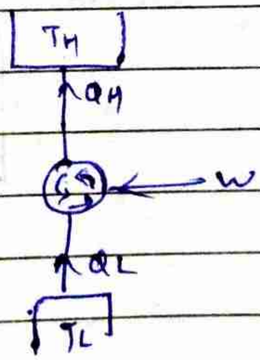
Soln → $Q_H = ?$

$Q_L = 12000\ KJ/hr$

$(C.O.P)_{ref} = ?$

$$W = 0.75\ KW = 0.75\ \frac{KJ}{sec}$$

$$= 0.75 \times 60 \times 60\ \frac{KJ}{hr}$$




$$= 0.75 \times 3600\ \frac{KJ}{hr}$$

$$= \cancel{2700}\ 2700$$

$$Q_H = W + Q_L$$

$$= 2700 + 12000$$

$$= 14700\ KJ/hr$$

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$C.O.P = \frac{Q_L}{W} = \frac{12000}{2700} = 4.44$

Q → A domestic food refrigerator maintain a temp. of −12°c the ambient air temp is 35°c. If heat leaks into the freezer the ~~cont~~ continuous rate of 2kJ/sec. determine the least power necessary to pump this heat out continuously.

Soln given → $T_L = -12°c$

$T_H = 36°c$

$Q_L = 2\ kJ/sec$

$W = ?$

$T_L = -12 + 273 = 261\ K$

$T_H = 35 + 273 = 308\ K$

$C.O.P = \frac{Q_L}{Q_H - Q_L} = \frac{T_L}{T_H - T_L} = \cancel{\frac{-12}{35+12}} = \cancel{\frac{-12}{47}}$

$\cancel{C.O.P = \frac{Q_L}{W}}$ $\frac{Q_H - Q_L}{Q_L} = \frac{T_H - T_L}{T_L}$

$\cancel{\frac{-12}{47}} = \cancel{\frac{2}{W}}$ $\frac{Q_H}{Q_L} \cancel{-1} = \frac{T_H}{T_L} \cancel{-1}$

$\boxed{W = \frac{Q_H}{Q_L} = \frac{T_H}{T_L}}$

$\Rightarrow Q_H = Q_L \times \frac{308}{261}$

$= \frac{2 \times 308}{261} = 2.36\ kJ/sec$

$W = Q_H - Q_L$

$= 0.36\ kJ/sec$

$C.O.P = \frac{Q_L}{W}$

$= \frac{2}{0.36}$

$= 5.55$

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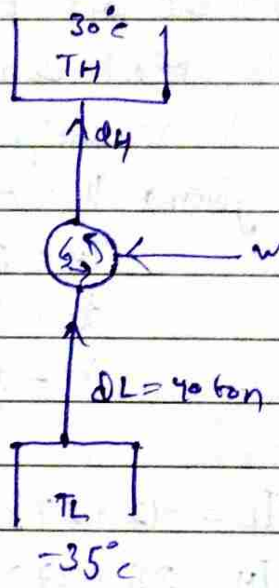
Q→ A freezing plant req. 40 Ton of refrigeration the freezing temp. is $-35°c$ and the ambient temp $= 30°c$, If the performance of the plant is 20% of the theoretical then calculate the power required.

Soln: given → $T_L = -35°c \rightarrow -35 + 273 = 238°k$

$T_H = 30°c \rightarrow 30 + 273 = 303\ K$




$Q_L = 40$ tons

$= 40 \times 210$ kJ/min

$= 8400$ kJ/min

ATQ

$$\boxed{(C.O.P)_A = 20\%\ (C.O.P)_{Th}}$$

$$(C.O.P)_{Th} = \frac{T_L}{T_H - T_L} = \frac{238}{303-238} = 3.66$$

$$(C.O.P)_{Actual} = (0.2) \times C.O.P = (0.2) \times (3.66)$$

$$= 0.73$$

$$\frac{Q_L}{W} = 0.73$$

$$\boxed{W = \frac{8400}{0.73}\ \text{kJ/min}} = 1.91\ \text{kJ/sec}$$

Date 7-11-23

# Air conditioning → Psychrometry → study of Air

1. Basic Terminology → moist Air
   Dry Air
   Saturated Air
   Dry bulb Temp
   wet bulb Temp
   Humidity / Humidity Ratio
   Relative Humidity
   Human comfort

2. Working of A/C (cold air cycle)
   and
   (Hot air cycle)

• Psychrometry → It is the study of the properties of mixture of air and water vapour. The moist air is the mixture of dry air and moisture.

• Dry air → is basically having no moisture content. Composition of Dry air is constant and the amount of water vapour present in the air may vary from 0 to a maximum depending upon the temperature and pressure at a given temp. and pressure. The dry air can only hold a certain max. amount of moisture. This air is known as **Saturated air**.

• Humidity Ratio → The Humidity ratio or specific humidity is the mass of water associated with each kilogram of dry air.

• Psychrometers → The dry and wet bulb temperatures are simultaneously measured by instruments called psychrometers.

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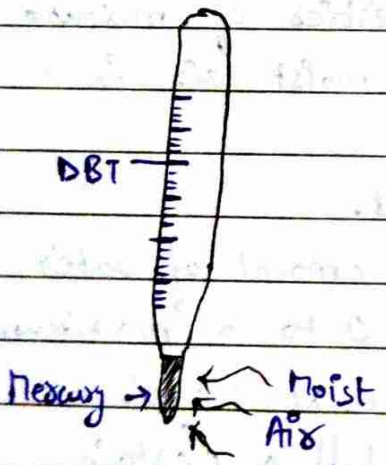
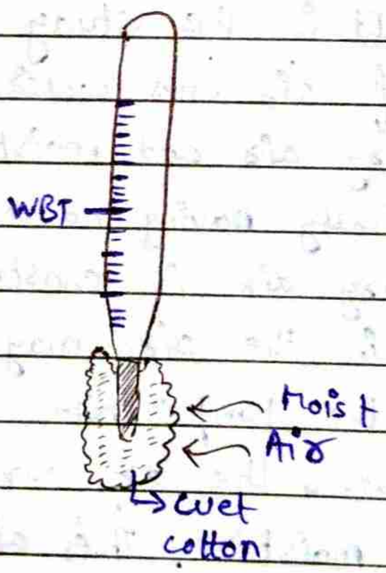
- Relative Humidity → It is defined as the ratio of water vapour in moisture air to the water vapour in saturated air at the same temp. and pressure. Relative Humidity is normally expressed in percentage (%).

- Dry Bulb Temperature → [DBT] → DBT is the temp. of moist air as measured by standard thermometer

- Wet Bulb Temperature → [WBT] → WBT is the temp. of saturated air as measured by standard thermometer. In this before contact with mercury bulb of thermometer moisture air passes through wet cotton which cover the bulb.




Dry Bulb Temp.




Wet Bulb Temp.

- Human Comfort Condition →
  Temp → 22°c – 27°c
  Humidity → 40% – 60%.

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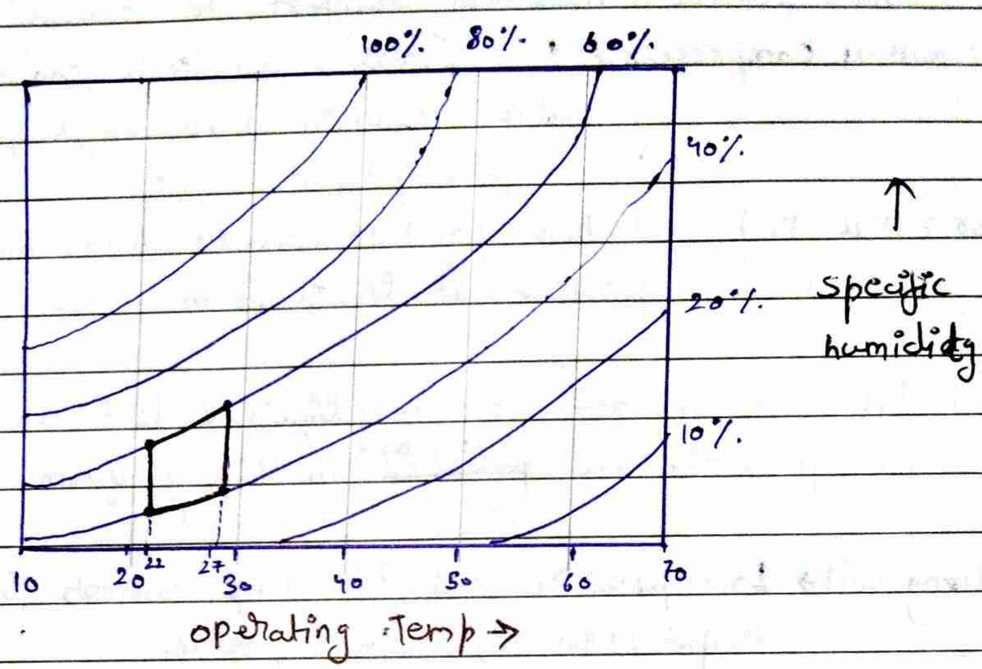
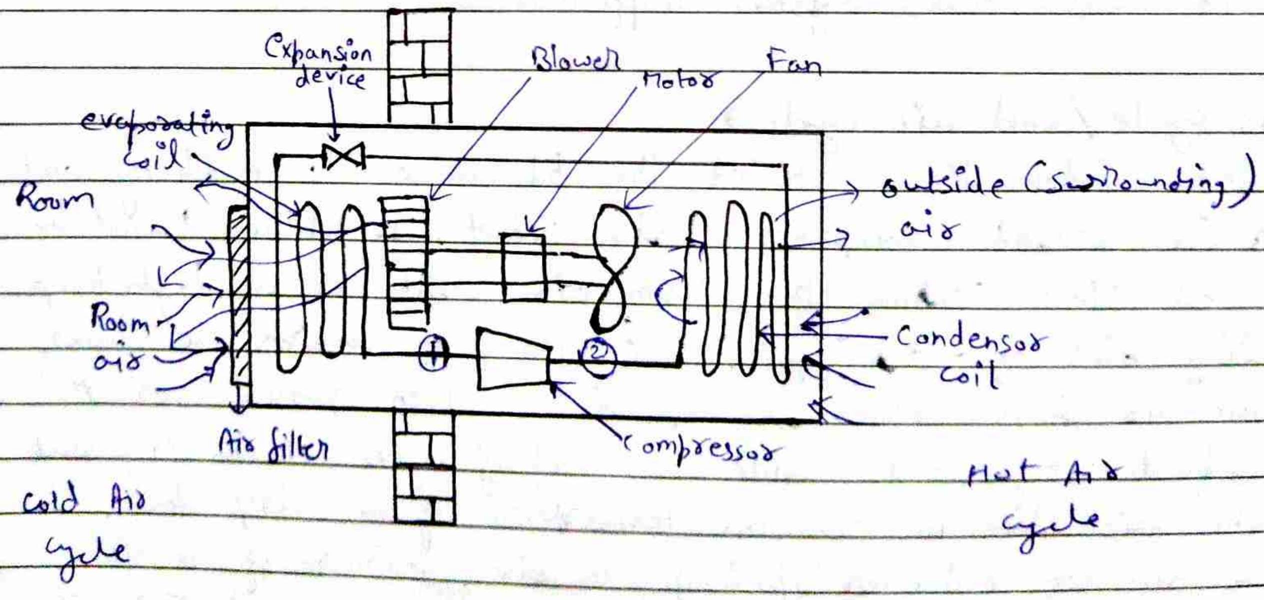
• Psychometry chart




Comfort air condition temperature and humidity are the factor affecting comfort air conditioning. Temperature range between 22°C to 27°C. Humidity level must be in between 40% - 60%

• Working of Air Conditioning System →

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In Air conditioning we control temperature and moisture level of room air and provide maximum comfort to human being. Main components are → 1. **Compressor** → Low press. , Low temp. coolent in vapor form convert into high pressure and high temperature.

2. Condensor → High temp. and high pressure convert into high pressure and low temperature ~~in~~ in liquid form.

3. Expandor → High pressure ~~low~~ high pressure liquid coolent convert into low pressure low ~~pressure~~ temperature in liquid form.

4. Evaporating coil → Low pressure and low temp. converts into lowest temperature and low pressure.

5. Blower, 6. Fan

7. Air-filter

The cleaning function of air is performed by filter which removes contaminates from the air. If filter is clogged they restrict the flow of air and creates system inefficient.

Room Air cycle / cold air cycle →

when the window AC is started the blower starts immediately and after a few seconds compressor also start. The blower behind the cooling coil start sucking the room air which is at high temp. and carry dirt and dust particle on its path towards the blower, the room air first passes through filter then passes over the cooling coil. The refrigerent inside the cooling coil absorb the heat from the air, due to this the temperature of air drop down. Secondly due to reduction of temp. in air, moisture of air is removed. So the relative humidity of the air reduced. This air at low temp. and low humidity then passes through small duct

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inside the air conditioner and then from outside the AC through the opening in the front panel.
The cool air inside the room absorb the heat and moisture and so its temp. and moisture content becomes higher. This air is again suck by the blower and the cycle repeats.

• Hot Air Cycle / Surrounding or envirsoment
The hot air cycle includes the atmospheric air that is used for cooling. Fan is situated behind the condensor. Suck the atmospheric air at high temperature and it blows air over the condensor. The refrigerent inside the condensor at very high temp. when the atm air passes it absorbs the heat and thrown to the atmosphere. This cycle continuosly repeat to control the condensor temperature is known as hot air cycle.