REFRIGERATION SYSTEMS COMPONENTS

EXPANSION DEVICES

The basic functions of an expansion device are:

1. Reduce pressure from condenser pressure to evaporator pressure, and
2. Regulate the refrigerant flow from the high-pressure liquid line into the evaporator at a rate equal to the evaporation rate in the evaporator.

Types

FIXED OPENING TYPE

- The flow area remains fixed.

1. Capillary Tube

2. Orifice

VARIABLE OPENING TYPE

- The flow area changes with changing mass flow rates.

1. Hand (manual) expansion valves
2. **Constant pressure or Automatic Expansion Valve (AEV)**
3. **Thermostatic Expansion Valve (TEV)**
4. **Float type Expansion Valve**
   - **a) High Side Float Valve**
   - **b) Low Side Float Valve**
5. **Electronic Expansion Valve**

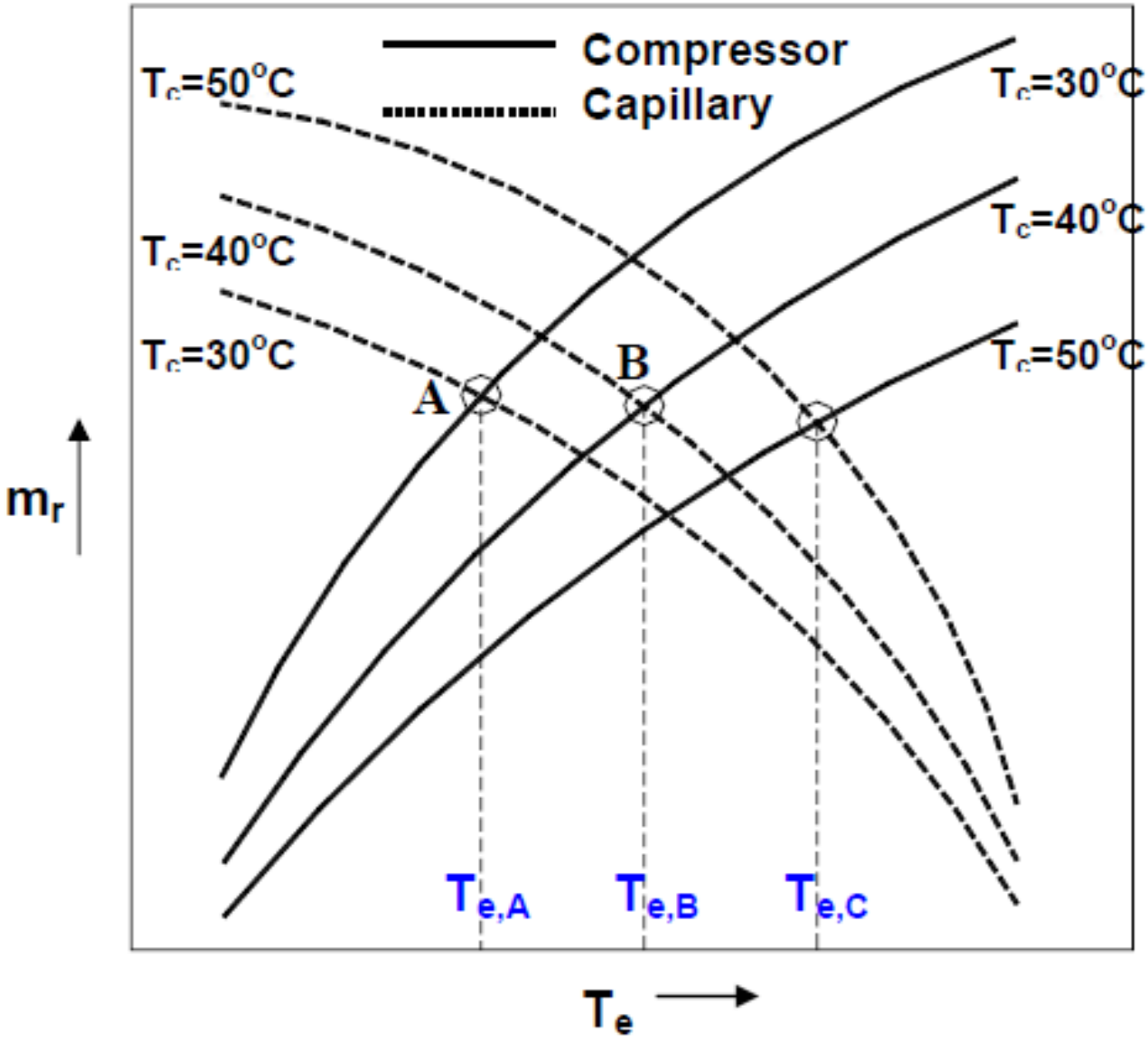
Capillary Tube

- A capillary tube is a long, narrow tube of constant diameter.
- Diameter range from 0.5 mm to 3 mm and the length ranges from 1.0 m to 6 m.

The pressure reduction occurs due to:

1. The refrigerant has to overcome the frictional resistance offered by tube walls. This leads to some pressure drop.
2. The liquid refrigerant flashes (evaporates) as its pressure reduces. So the **average density decreases.** The mass flow rate and tube diameter (hence area) being constant, the **velocity of refrigerant increases.** This requires pressure drop.

- Its mass flow rate is totally dependent upon the pressure difference across it; it cannot adjust itself to variation of load effectively.
- **The balance point :** The compressor and the capillary tube, under steady state must arrive at some suction and discharge pressures, which **allows the same mass flow rate** through the compressor and the capillary tube.



Variation of refrigerant mass flow with evaporator temperatures

Advantages:

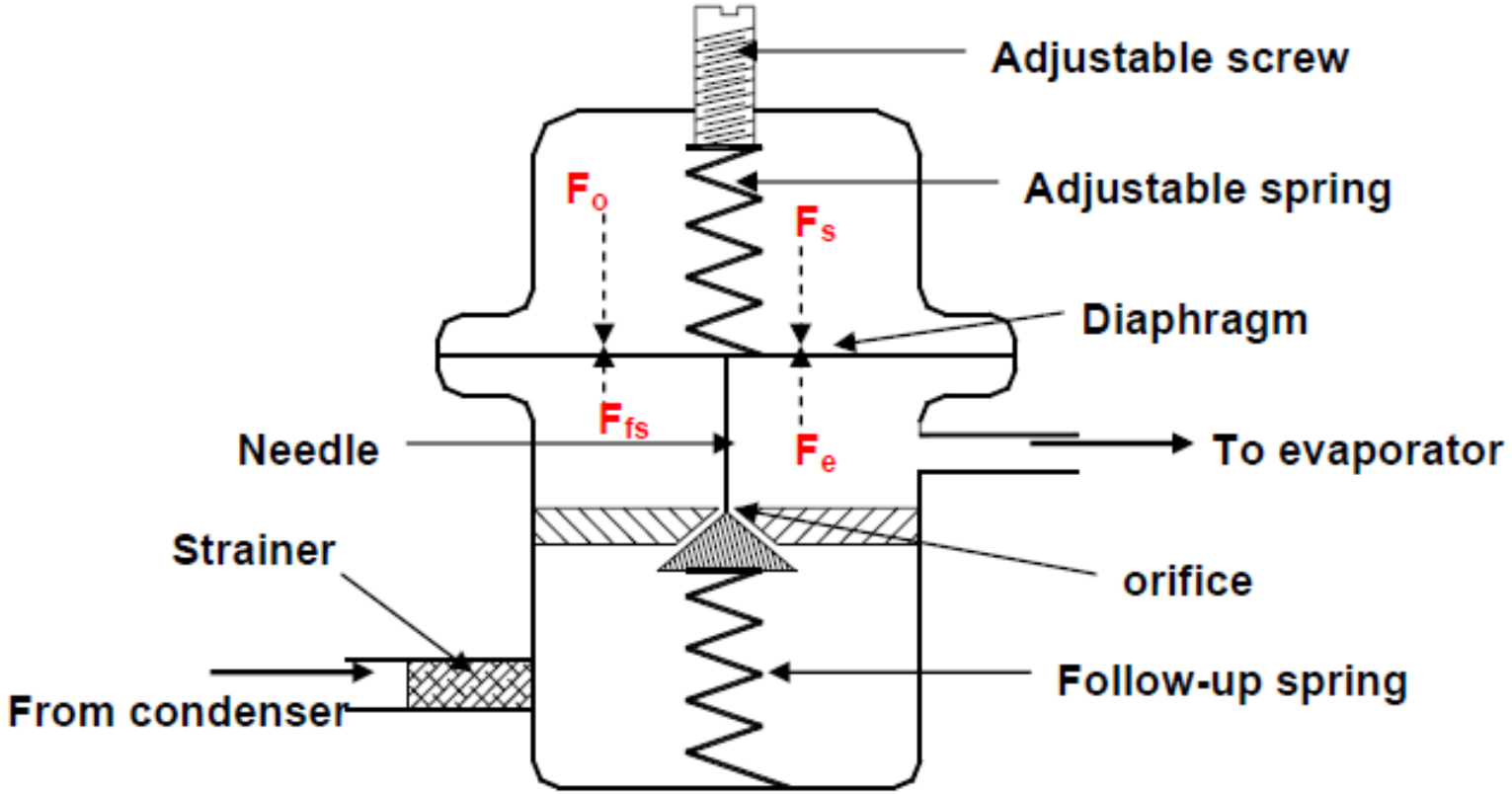
- It is inexpensive.
- It does not have any moving parts hence it does not require maintenance
- **Open connection** - during off-cycle, **pressure equalization occurs** between condenser and evaporator. This **reduces the starting torque** requirement of the motor. Hence, a motor with low starting torque (squirrel cage Induction motor) can be used.

Disadvantages

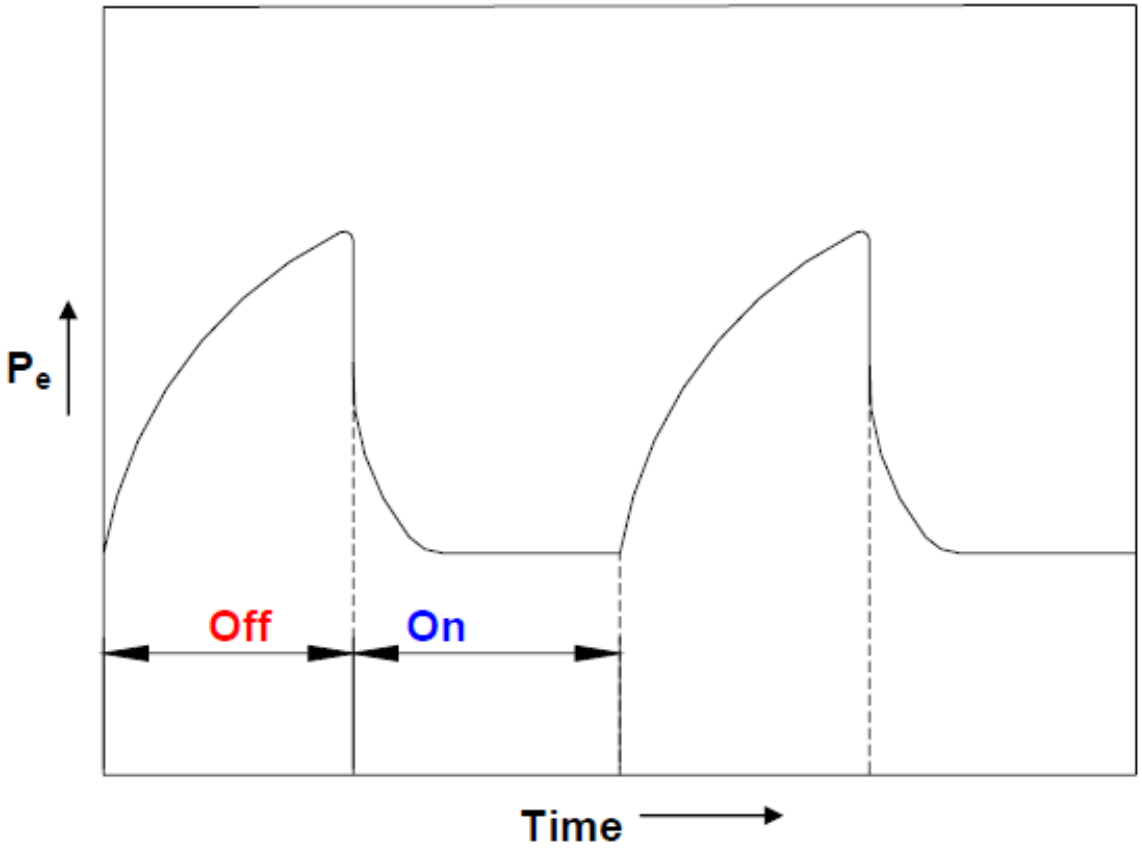
- It cannot respond to daily and seasonal variation in ambient temperature and load - **COP low** under off design conditions.
- **It is susceptible to clogging** because of narrow bore of the tube. A filter-drier should be used ahead of the capillary to prevent entry of moisture or any solid particles.
- During off-cycle **liquid refrigerant flows to evaporator** because of pressure difference. The evaporator may get flooded and the **liquid refrigerant may flow to compressor** and damage it when it starts. So it is used only with hermetically sealed compressors where refrigerant does not leak.

Automatic Expansion Valve (AEV)

- Also known as a **constant pressure expansion valve** - maintain a constant pressure and thereby a constant temperature in the evaporator.



- The adjustment spring is usually set such that during off-cycle the valve is closed.
- During the off-cycle, the refrigerant remaining in the evaporator will vaporize but will not be taken out by the compressor - the evaporator pressure rises.



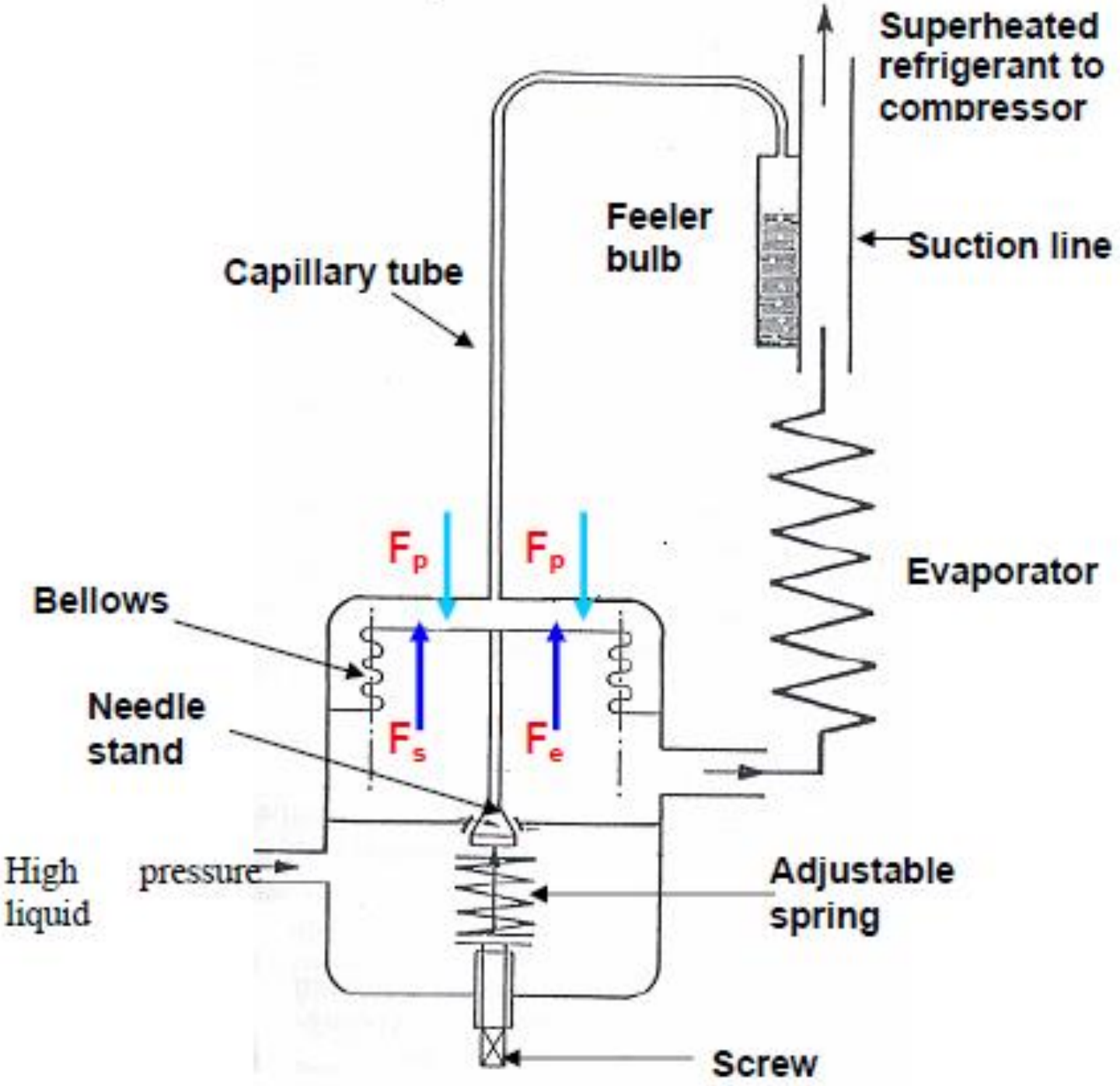
- At equilibrium position

$$F_e + F_{fs} = F_s + F_o = \text{constant}$$

- The valve acts in such a manner that the evaporator pressure remains constant as long as the refrigeration load is constant.
- At this point, the mass flow rate through the valve is the same as that through the compressor.

Thermostatic Expansion Valve (TEV)

- A thermostatic expansion valve **maintains a constant degree of superheat(ΔT_s) at the exit of evaporator** - prevent the slugging of the compressors.
- **Feeler bulb** at evaporator exit - senses the temperature at the exit of evaporator.
- The feeler bulb is connected to the top of the bellows by a **capillary tube**.
- The feeler bulb and the narrow tube contain some fluid called ***power fluid***.


Superheated refrigerant to compressor
Feeler bulb
Suction line
Capillary tube
Evaporator
F_p
F_p
Bellows
Needle stand
F_s
F_e
High pressure liquid
Adjustable spring
Screw

- The power fluid is the same as the refrigerant or different(TEV is called ***TEV with cross charge***).
- *The power fluid senses the evaporator exit temperature* $\boldsymbol{T_e+\Delta T_s}$ *by the feeler bulb and its pressure* P_p *is the saturation pressure at this temperature.*

$$F_p = A_b P_p \quad \& \quad F_e = A_b P_e$$

- In steady state there will be a force balance on the needle stand, that is,

$$F_s = F_p - F_e$$

- During off-cycle, evaporator temperature is same as room temperature, ie, $\Delta T_s = 0$.
- Then $P_p = P_e$ and $F_p = F_e$. So the spring force F_s acting upwards will keep the TEV closed.
- As the compressor is started - evaporator pressure decreases so the force F_e decreases at a very fast rate but F_p does not change.
- Hence, the difference F_p-F_e increases as the compressor runs for some time after starting.
- At one point this difference becomes greater than the spring force F_s and the valve is said to open up.
- Since a finite downward force is required to open the valve, a minimum degree of superheat is required for a finite mass flow rate.

- The spring gets compressed as the needle stand moves downward.
- If F_{s0} is the spring force in the rest position, that is, off-cycle, then during open valve position: $F_s = F_{s0} + \Delta F_s$
- Eventually, the needle stand reaches a position such that, $F_s = F_p - F_e = A_b (P_p - P_e)$
- *Ie,* $F_p > F_e$ or $P_p > P_e$. The pressure P_p and P_e are saturation pressures at temperature $(T_e + \Delta T_s)$ and T_e respectively.
- Hence, for a given setting force F_s of the spring, TEV maintains the difference between F_p and F_e or **the degree of superheat ΔT_s constant.**

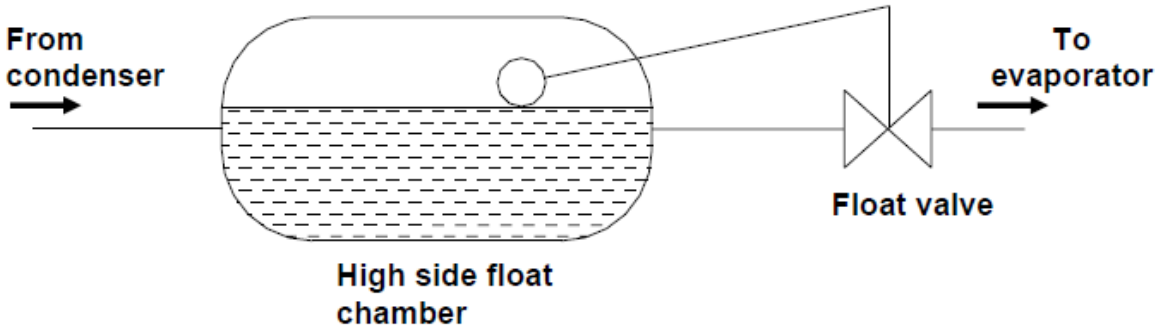
Float type expansion valves:

- Normally used with flooded evaporators in large capacity refrigeration systems.
- It opens or closes depending upon the liquid level as sensed **a float**(a hollow metal or plastic ball)
- The float valve always maintains a constant liquid level in a chamber called as float chamber.
- Depending upon the location of the float chamber, **a) Low-side float valve b) High-side float valve.**

Low-side float valve

- It maintains a constant liquid level in a flooded evaporator or a float chamber attached to the evaporator.
- When the load increases, more amount of refrigerant evaporates from the evaporator.
- As a result, the refrigerant liquid level in the evaporator or the low-side float chamber drops.
- The float then moves such that the valve opening is increased and more amount of refrigerant flows into the evaporator and the liquid level is restored.
- When the load falls, the float reduces the opening of the valve and less amount of refrigerant flows into the evaporator.

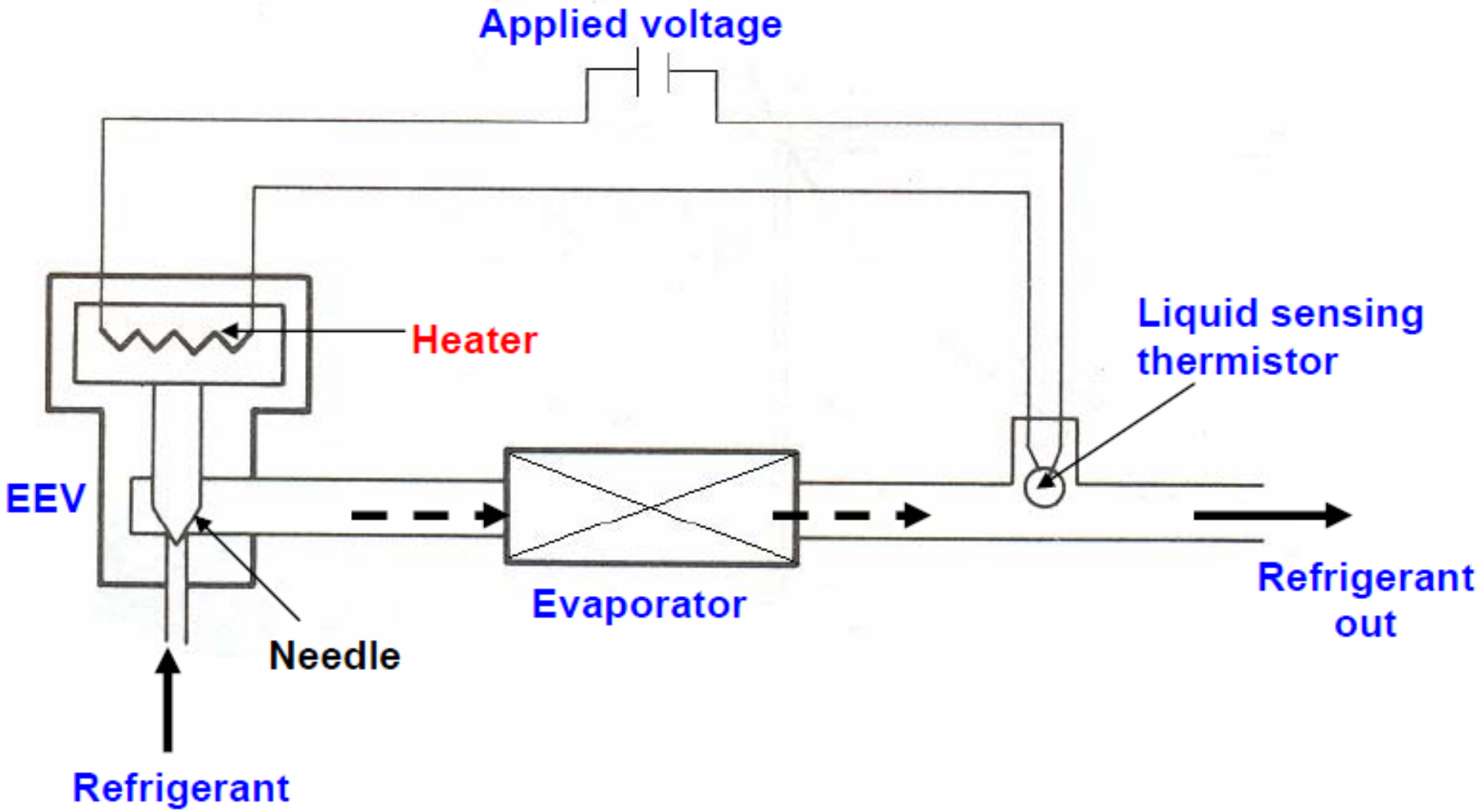
High-side float valves



- Maintains the liquid level constant in a float chamber connected to the condenser on the high pressure side.
- When the load increases, more amount of refrigerant evaporates and condenses.
- As a result, the liquid level in the float chamber rises momentarily.
- The float then opens the valve more to allow a higher amount of refrigerant flow so the liquid level drops back to the original level.

- It allows only a fixed amount of refrigerant on the high pressure side(condenser), the bulk of the refrigerant is stored in the low-pressure side (evaporator).
- Hence there is a possibility of flooding of evaporator followed by compressor slugging.
- But it can be used with both flooded as well as direct expansion type evaporators

Electronic Type Expansion Valve



- The needle moves up and down in response to magnitude of current in the heating element.
- A small resistance allows more current to the heater, hence the valve opens wider.
- A thermistor is placed in series with the heater.
- The heater current depends upon the thermistor resistance that depends upon the refrigerant condition.
- Superheated vapour lowering the thermistor resistance and increasing the heater current. This opens the valve wider and increases the mass flow rate.

- This continues until the vapour becomes saturated and some liquid refrigerant droplets appear.
- The liquid refrigerant cool the thermistor and increase its resistance, so it allows a small current to flow through the heater making the valve opening narrower.
- The control of this valve is independent of refrigerant and refrigerant pressure; hence it works in reverse flow direction also.
- It is convenient to use it in year-round-air-conditioning systems, which serve as heat pumps in winter with reverse flow.

APPLICATIONS OF REFRIGERATION

DOMESTIC REFRIGERATORS

- *Often called a "**fridge**", has become an essential household appliance.*
- *Used to store fruits, vegetables and other edible products which perish if not kept well below the room temperatures, normally a few degrees above 0^0C, the freezing point of water.*
- *A refrigerator is a cooling appliance that transfers heat from its thermally insulated compartment to the external environment, and thus cooling the stored food in the compartment.*
- *It also normally houses a "**freezer**", where temperatures below the freezing point of water are maintained, primarily to make ice and store frozen food.*
- *It also have **Crisper** which draws inside moisture to keep vegetables and fruits fresh for longer time, is normally inbuilt in most of home refrigerators.*

REFRIGERATOR COMPARTMENTS

TYPES

Two types of home refrigerators are typically available in market.

*1. **DIRECT COOL REFRIGERATORS**:*

- *These refrigerators are with or without crisper, ice making or frozen food storage compartment.*
- *Cooling of food is primarily obtained by **natural convection** within the refrigerator. However, some refrigerators may have a fan to avoid internal condensation of water but are not claimed as 'frost free'.*
- *Formation of frost/ice in the refrigerator reduces cooling. Therefore these refrigerators need manual defrosting periodically.*

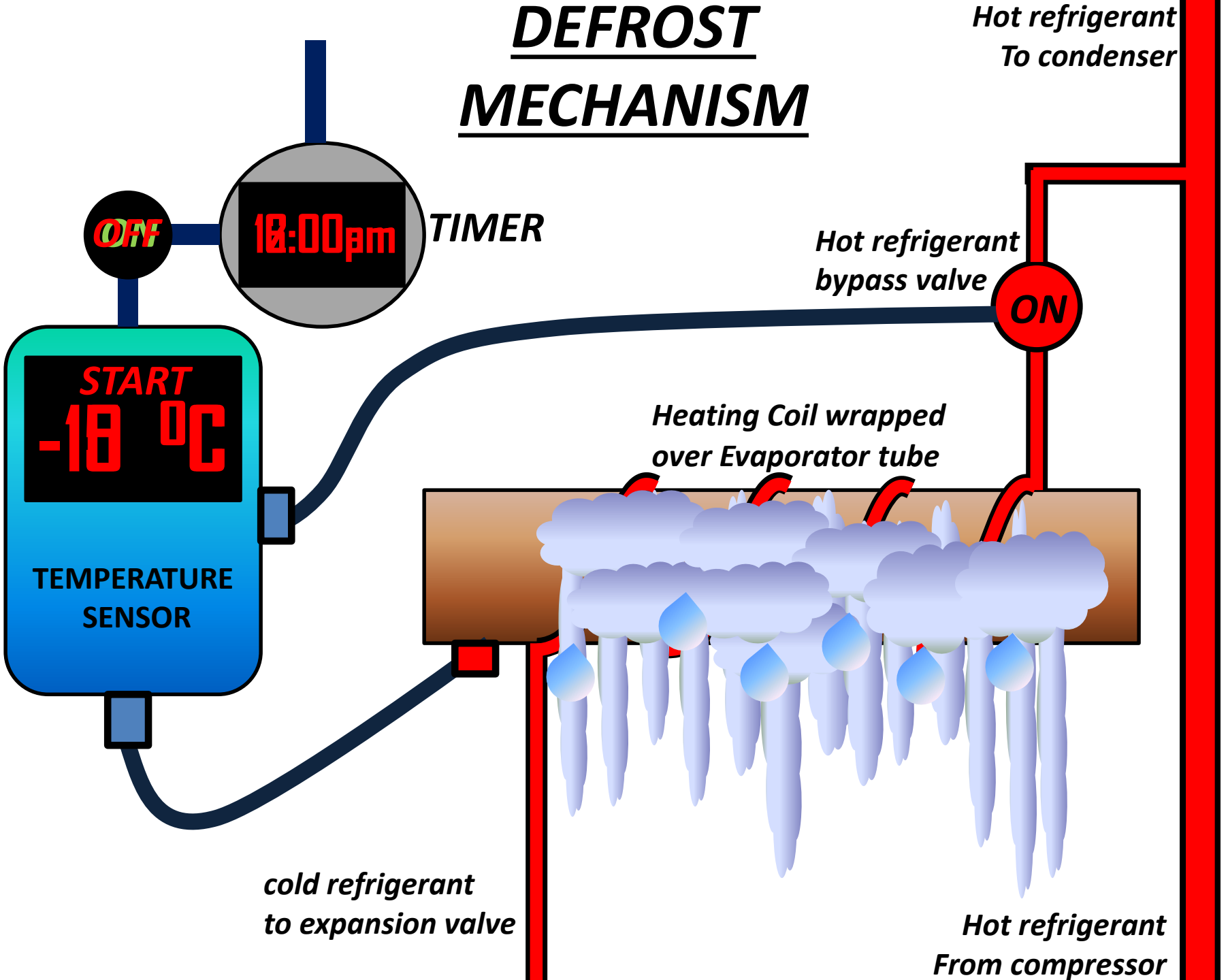
ICE BUILT UP IN DIRECT COOLING REFRIGERATION SYSTEM

- *The ice built up on the surface of the evaporator coil provides an additional resistance to heat transfer.*
- *This decreases the heat absorption rate. So this ice should be removed manually periodically .*

2. FROST FREE REFRIGERATORS:

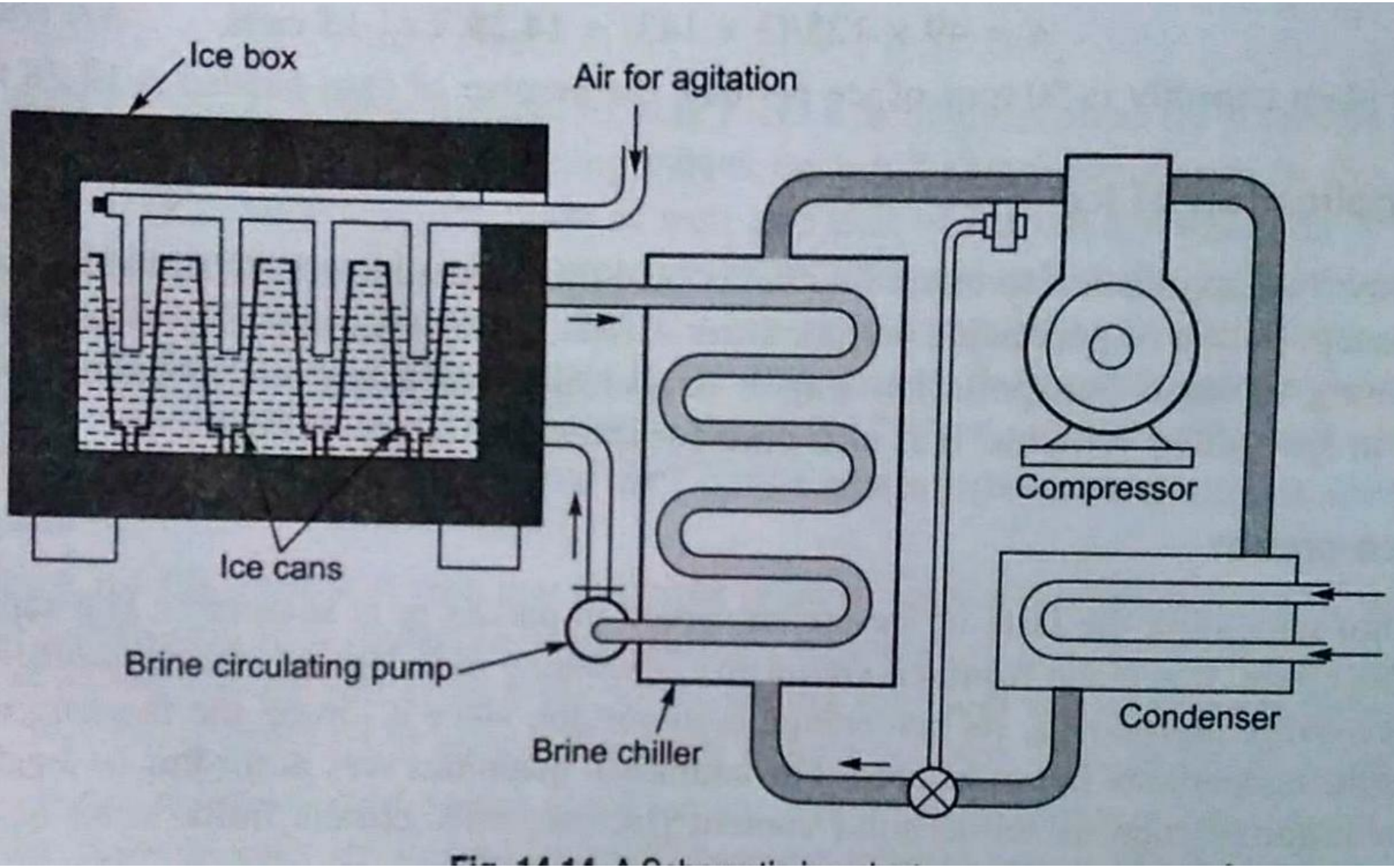
- *These refrigerators cool the stored food* ***through continuous internal movement of air*** *that restricts the formation of frost and sticking of food items with each other.*
- *A frost free freezer has three basic parts a* ***timer****, a* ***heating coil*** *and a* ***temperature sensor****. The heating coil is wrapped around the freezer coils. Every six hour or so, the timer turns on the heating coil and this* ***melts the ice off the coil****.*
- *When all the ice is removed, the temperature sensor senses the temperature rising above* $0^{o}C$ *and turns off the heating coil.*

DEFROST MECHANISM



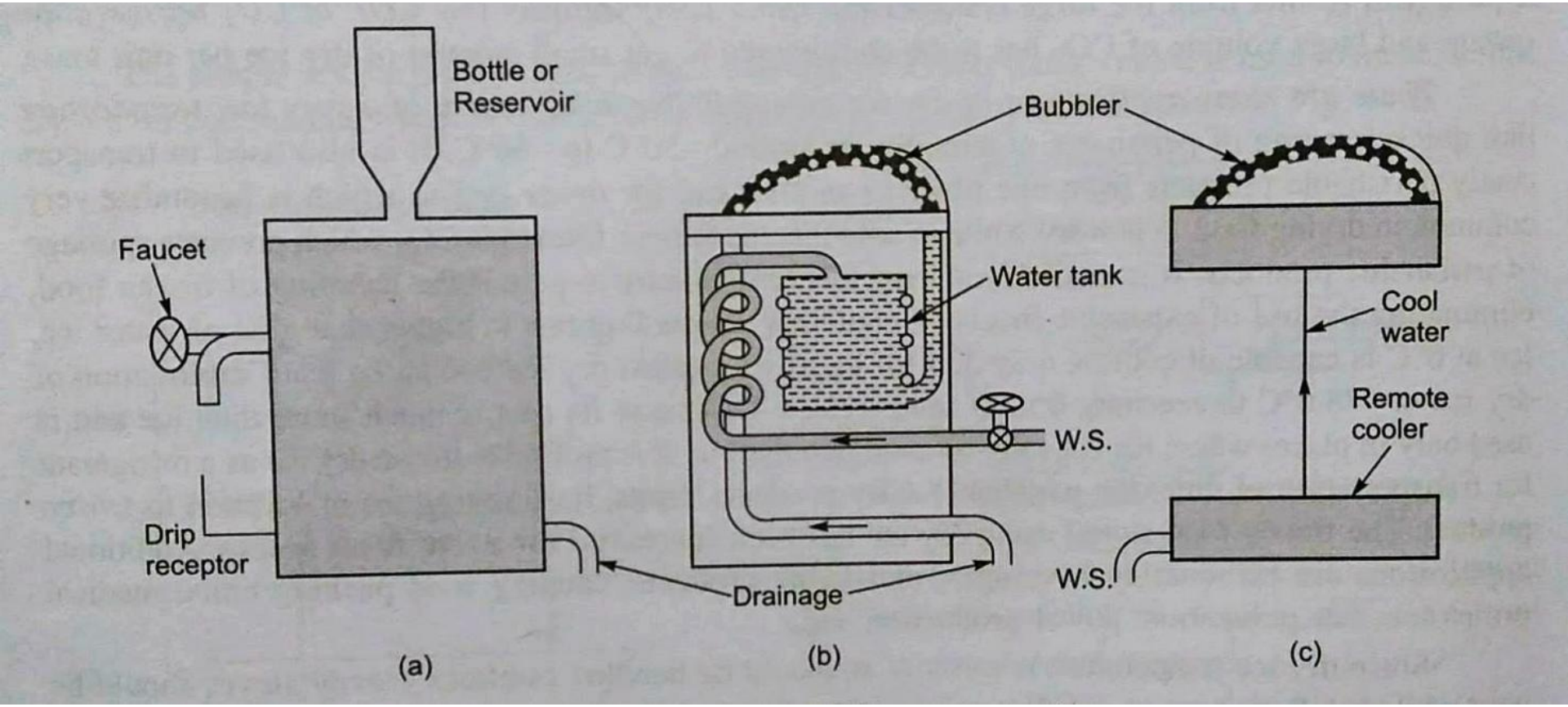
ICE PLANT

- It consists an ice box having heavy insulation.
- The size depends on the capacity of ice plant.
- Should contain sufficient no. of cans for ice harvest.
- Water level in the can should be around 20 to 30 mm below the brine level.
- Provided piping for air blowing into ice cans for air agitation. It helps form ice in the whole of can otherwise a small amount water remains at the center.


Ice box
Air for agitation
Compressor
Ice cans
Brine circulating pump
Brine chiller
Condenser

- Heat transfer between water and brine is either by free convection or forced convection.
- Latter is caused by suitable no. of agitators.
- The ice cans are usually tapered around 10 to 20 mm per meter depth.
- Cooling is achieved by brine(calcium chloride solution) circulation.
- Daily output of an ice plant is a function of the brine temperature.
- Number of cans needed for a plant of capacity 50 tons of ice per day is 715.

WATER COOLERS



- Used to produce cold water at about 280 to 286K.
- The temp is controlled by a thermostatic switch within 280 to 286 K range.

Types

1. **Storage type:** Cooling coil is wrapped around the water tank. There is a reservoir of cold water all the time.
2. **Instantaneous type:** Cooling coil is wrapped around the pipeline such that by the time water reaches the tank, it is cooled to the desired temp.

Instantaneous type

a) Bottle type
b) Pressure type and
c) Self contained remote type.