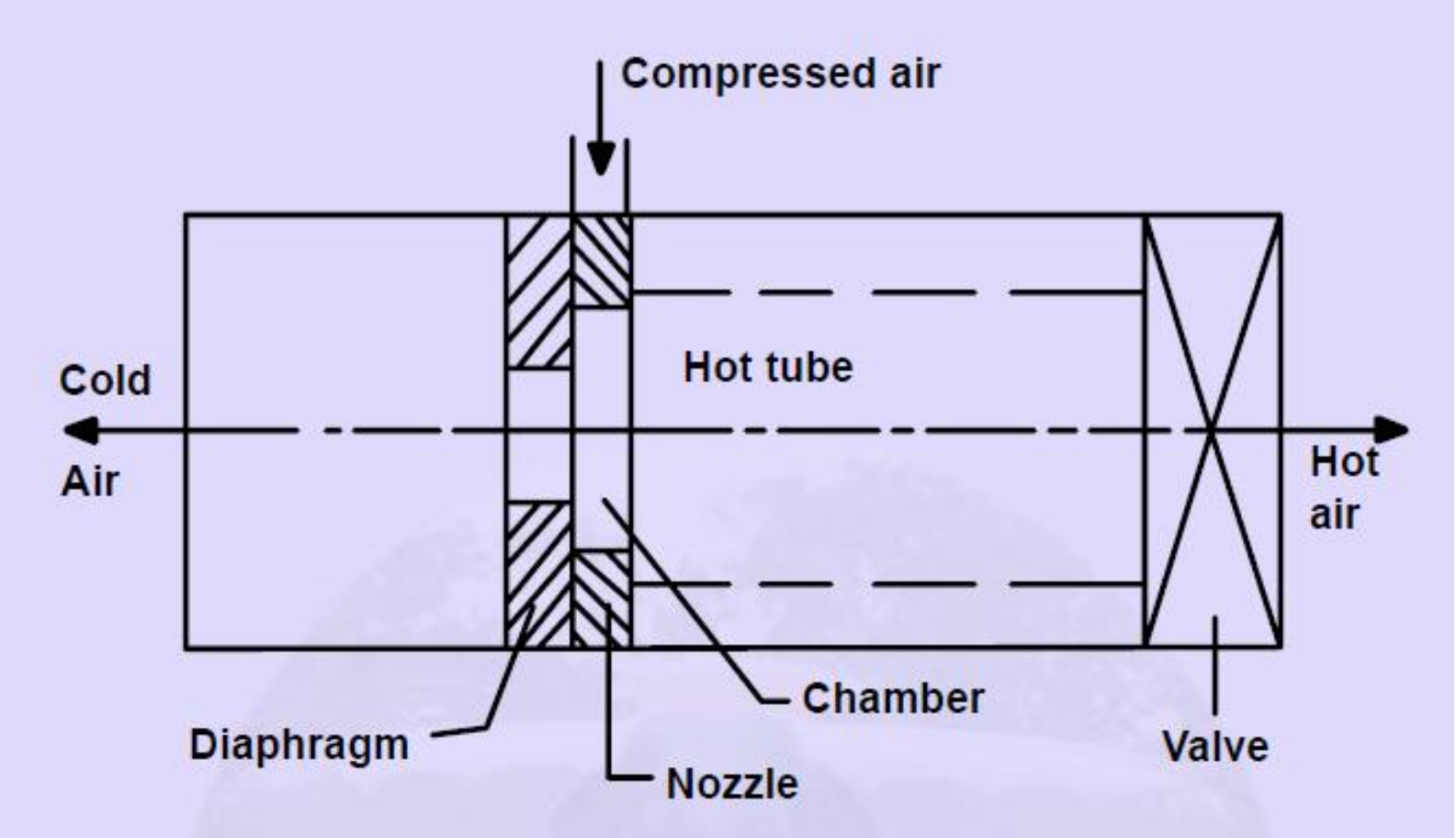
VORTEX TUBE REFRIGERATION

Vortex Tube Refrigeration

- It is one of the non-conventional type refrigerating systems for the production of refrigeration. The schematic diagram of vortex tube is shown in the figure below;



Vortex Tube Refrigeration

- It consists of nozzle, diaphragm, valve, hot-air side, cold-air side. The nozzles are of converging or diverging or converging-diverging type as per the design. An efficient nozzle is designed to have higher velocity, greater mass flow and minimum inlet losses.
- Chamber is a portion of nozzle that facilities the tangential entry of high velocity air-stream into hot side. Generally the chambers are not of circular form, but they are gradually converted into spiral form.
- Hot side is cylindrical in cross section and is of different lengths as per design. Valve obstructs the flow of air through hot side and it also controls the quantity of hot air through vortex tube.
- Diaphragm is a cylindrical piece of small thickness and having a small hole of specific diameter at the center. Air stream traveling through the core of the hot side is emitted through the diaphragm hole. Cold side is a cylindrical portion through which cold air is passed.

Vortex Tube Refrigeration

Working:

- Compressed air is passed through the nozzle as shown in figure above. Here, air expands and acquires high velocity due to particular shape of the nozzle.
- A vortex flow is created in the chamber and air travels in spiral like motion along the periphery of the hot side. This flow is restricted by the valve. When the pressure of the air near valve is made more than outside by partly closing the valve, a reversed axial flow through the core of the hot side starts from high-pressure region to low-pressure region. During this process, heat transfer takes place between reversed stream and forward stream.
- Therefore, air stream through the core gets cooled below the inlet temperature of the air in the vortex tube, while air stream in forward direction gets heated up. The cold stream is escaped through the diaphragm hole into the cold side, while hot stream is passed through the opening of the valve. By controlling the opening of the valve, the quantity of the cold air and its temperature can be varied.

Vortex Tube Refrigeration

Advantages:

- It uses air as refrigerant, so there is no leakage problem.
- Vortex tube is simple in design and it avoids control systems.
- There are no moving parts in vortex tube.
- It is light in weight and requires less space.
- Initial cost is low and its working expenses are also less, where compressed air is readily available.
- Maintenance is simple and no skilled labors are required.

Disadvantages:

Its low COP, limited capacity and only small portion of the compressed air appearing as the cold air limits its wide use in practice.

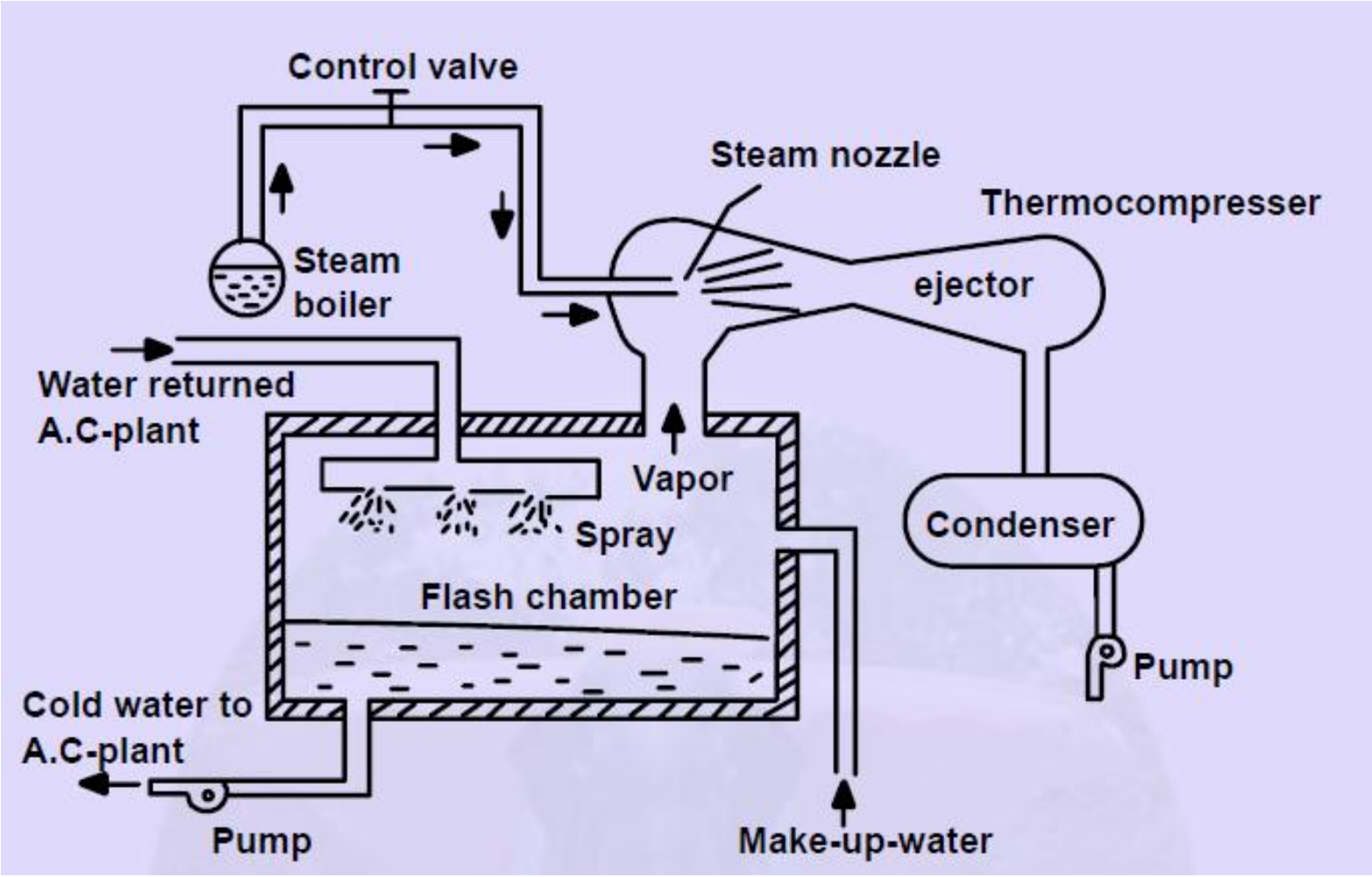
Vortex Tube Refrigeration

Applications:

- Vortex tubes are extremely small and as it produce hot as well as cold air. It may be of use in industries where both are simultaneously required.
- Temperature as low as -50^0C can be obtained without any difficulty, so it is very much useful in industries for spot cooling of electronic components.
- It is commonly used for body cooling of the workers in mines.

STEAM JET REFRIGERATION

Steam Jet Refrigeration



Steam Jet Refrigeration

- This system uses the principle of boiling the water below 100^0C. If the pressure on the surface of the water is reduced below atmospheric pressure, water can be made boil at low temperatures.
- Water boils at 6^0C, when the pressure on the surface is 5 cm of Hg and at 10^0C, when the pressure is 6.5 cm of Hg.
- The very low pressure or high vacuum on the surface of the water can be maintained by throttling the steam through jets or nozzles.
- The general arrangement of the system is shown in the figure above.

Steam Jet Refrigeration

- Consider a flash chamber contains 100 kg of water. If suddenly 1 kg of water is removed by boiling, as pressure is reduced due to throttling of steam through nozzles. Approximately 2385 kJ of heat will be removed from the water, which is equivalent to heat of evaporation of water. The fall in temperature of the remaining water will be,

$$Q = mc_p \Delta T$$

$$\Delta T = \frac{2385}{99 \times 4.187} = 5.7^0 C$$

Steam Jet Refrigeration

- Evaporating one more kg of water reduces the remaining water temperature by 5.7^0C further. Thus by continuing this process, the remaining water can be made to freeze.
- Water is the refrigerant used in the steam jet refrigeration system. As water freezes at 0^0C, then either refrigeration has to be stopped or some device is required to pump the ice.

Steam Jet Refrigeration

Operation:

- High pressure steam is supplied to the nozzle from the boiler and it is expanded. Here, the water vapor originated from the flash chamber is entrained with the high velocity steam jet and it is further compressed in the thermo compressor.
- The kinetic energy of the mixture is converted into static pressure and mass is discharged to the condenser. The condensate is usually returned to the boiler.
- Generally, 1% evaporation of water in the flash chamber is sufficient to decrease the temperature of chilled water to 6^0C. The chilled water in the flash chamber is circulated by a pump to the point of application.
- The warm water from the load is returned to the flash chamber. The water is sprayed through the nozzles to provide maximum surface area for cooling. The water, which is splashed in the chamber and any loss of cold water at the application, must be replaced by makeup water added to the cold water circulating system.

Steam Jet Refrigeration

Advantages:

a) It is flexible in operation; cooling capacity can be easily and quickly changed.

b) It has no moving parts as such it is vibration free.

c) It can be installed out of doors.

d) The weight of the system per ton of refrigerating capacity is less.

e) The system is very reliable and maintenance cost is less.

f) The system is particularly adapted to the processing of cold water used in rubber mills,, distilleries, paper mills, food processing plants, etc.

g) This system is particularly used in air-conditioning installations, because of the complete safety of water as refrigerant and ability to adjust quickly to load variations and no hazard from the leakage of the refrigerant.

Steam Jet Refrigeration

Disadvantages:

a) The use of direct evaporation to produce chilled water is usually limited as tremendous volume of vapor is to be handled.

b) About twice as much heat must be removed in the condenser of steam jet per ton of refrigeration compared with the vapor compression system.

c) The system is useful for comfort air-conditioning, but it is not practically feasible for water temperature below 4^0C.