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DEPARTMENT OF FOOD TECHNOLOGY

**COURSE CODE & NAME: 19FTT301 & Refrigeration & Cold Chain
Management**

III YEAR / V SEMESTER

UNIT : IV LOW TEMPERATURE STORAGE SYSTEMS

TOPIC 6 : Linde and Claude system for liquefaction of air



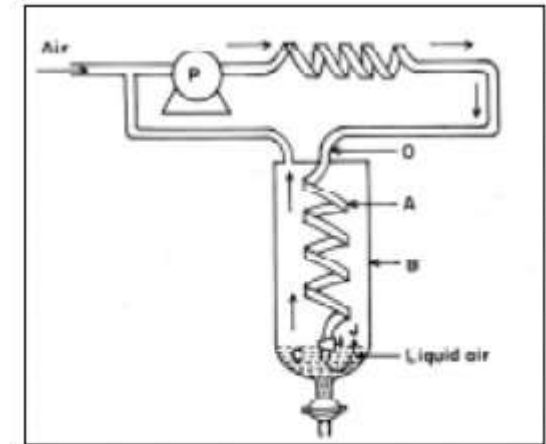
Conditions of liquefaction of gases

1. Many industrial processes require large quantities of liquid air, liquid ammonia, liquid carbon dioxide etc. The production of liquids from various gases is therefore an important commercial operation.
2. There are different methods of liquefaction of gases, such as (i) based on the concept of critical temperature followed by the compression (ii) based on Joule-Thomson effect (iii) Adiabatic demagnetisation.
3. In the case of gases like NH_3 , Cl_2 , SO_2 and CO_2 whose T_c values are near and below the ordinary temperatures, they can be liquefied easily by increasing the pressure alone at their respective T_c values.
4. Gases like H_2 , O_2 , N_2 and He have very low T_c values and hence Joule Thomson effect may be applied to bring in effective cooling.
5. Helium is cooled by Joule-Thomson effect to a lower temperature and further cooling for its liquefaction, is carried out by the method of adiabatic demagnetisation.



Linde's Method

- This method makes use of Joule Thomson effect and is used to liquify air or any other gas.
- Pure air or any gas is first compressed to about 200 atmospheres and is allowed to enter the inner tube of the concentric pipes as shown in Fig.
- The valve *v* of jet *J* is then opened and the gas is allowed to expand suddenly into the wider chamber *C*.
- The gas gets cooled due to expansion and its pressure is reduced to about 50 atm. The gas is now allowed to pass through the outer tube 'O'. At this stage the incoming gas is initially cooled by the outgoing gas.
- Further cooling of the incoming gas occurs during expansion in the chamber *C*. The cooled gas is again compressed and is circulated in.
- By repeating the process of cooling and compression followed by expansion, the gas is liquefied and finally the liquid air drops out from the jet into the bottom of chamber *C*.



Linde's apparatus for liquefaction of gas



Merits and demerits

- The Hampson–Linde cycle introduced regenerative cooling, a positive-feedback cooling system. The heat exchanger arrangement permits an absolute temperature difference (e.g. $0.27\text{ }^{\circ}\text{C/atm}$ J–T cooling for air) to go beyond a single stage of cooling and can reach the low temperatures required to liquefy "fixed" gases.
- The Linde cycle uses isenthalpic expansion which has two drawbacks: firstly the expansion work is lost, and secondly cooling cannot be achieved if the fluid thermodynamic state is such that the Joule Thomson expansion leads to a temperature lowering.



Claude's process

- In this method compressed air is allowed to do mechanical work of expansion.
- This work is done at the expense of the kinetic energy of the gas and hence a fall of temperature is noted.
- This principle is combined with Joule-Thomson effect and utilised in Claude's process of liquefaction of air. Air is compressed to about 200 atmospheres and is passed through the pipe ABC (Fig).
- At C, a part of the air goes down the spiral towards the jet nozzle J and a part of the air is led into the cylinder D provided with an air tight piston. Here the air moves the piston outwards and expands in volume as a result of which considerable cooling is produced.
- The cooled air passes up the liquefying chamber during which process it cools the portion of the incoming compressed air. The precooled incoming compressed air then experiences Joule-Thomson expansion when passed through Jet nozzle J and gets cooled further. The above process takes place repeatedly till the air is liquefied.

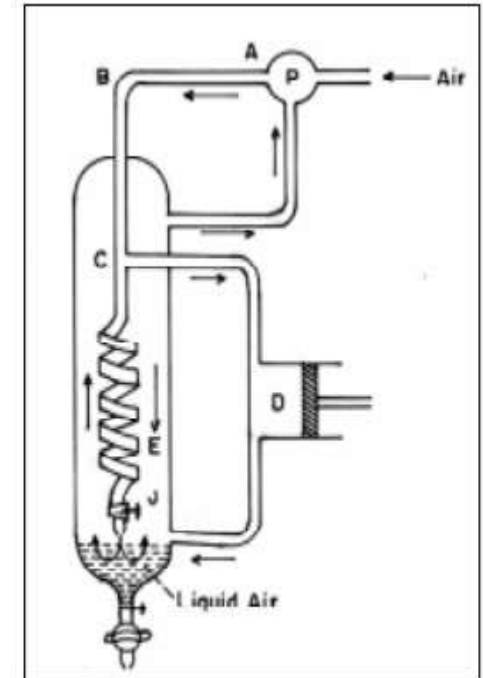


Fig. Claude's apparatus for liquefaction of air



Merits and demerits of **Claude's process**

- The advantage of this cycle is that the compression ratio can be significantly lower than in the case of the Linde cycle.
- One difficulty is that the expansion machine cannot operate with good efficiency if the fluid remains in the vapor zone or keeps a high quality.



Adiabatic demagnetisation



- Generally, the method used to reach the very low temperature of about 10^{-4} K is adiabatic demagnetisation.
- In this method the paramagnetic samples such as Gadolinium sulphate is placed surrounding the gas sample and cooled to about 1K along with the gas in any one of the cooling methods.
- The paramagnetic sample used in this method is suddenly magnetised by the application of strong magnetic field. This magnetisation (ordering of molecular magnets) occurs while the sample surrounds the cooled gas and has thermal contact with the walls of the container.
- When the magnetic field is suddenly removed, demagnetisation occurs which brings in a disordered state of the molecular magnets.
- To reach this state thermal energy is taken away from the cooled air such that its temperature gets further lowered. By this technique, as low as zero kelvin can be reached.



The **drawbacks** of adiabatic demagnetization are listed as follows below:

- If the sample material is an electronic paramagnet, the lowest temperatures possible can be achieved using these methods.
- Due to weaker interactions between dipoles, temperatures can be achieved at much lower temperatures if the sample contains a nuclear paramagnet.

Adiabatic Demagnetization Applications

The application of adiabatic demagnetization is mentioned as well as explained below:

- It is a cooling process. It is found in magneto-caloric material.
- These materials heat up in magnetic fields and then cool down when they are removed from the magnetic field.
- It is used in the magnetic refrigeration process to attain low temperatures such as cryogenic labs.



THANK YOU..."