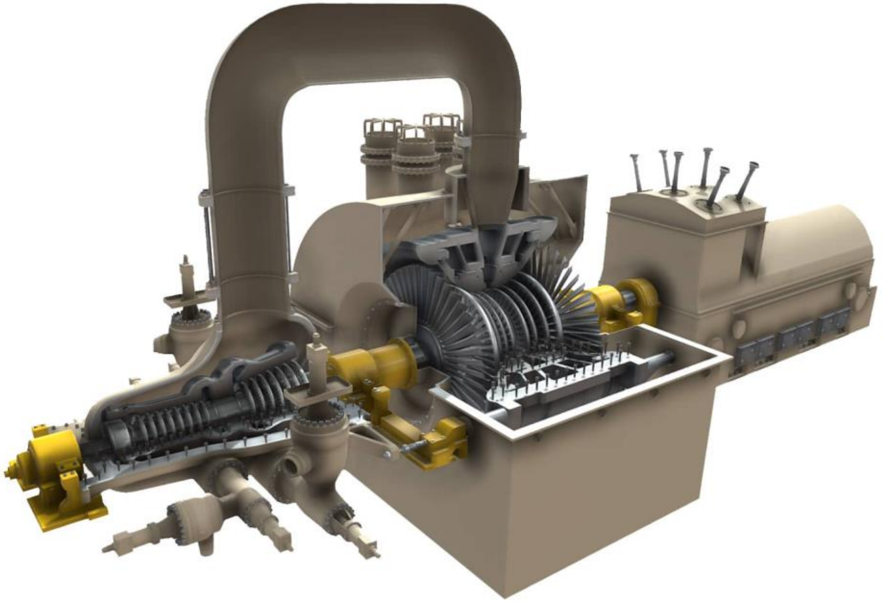
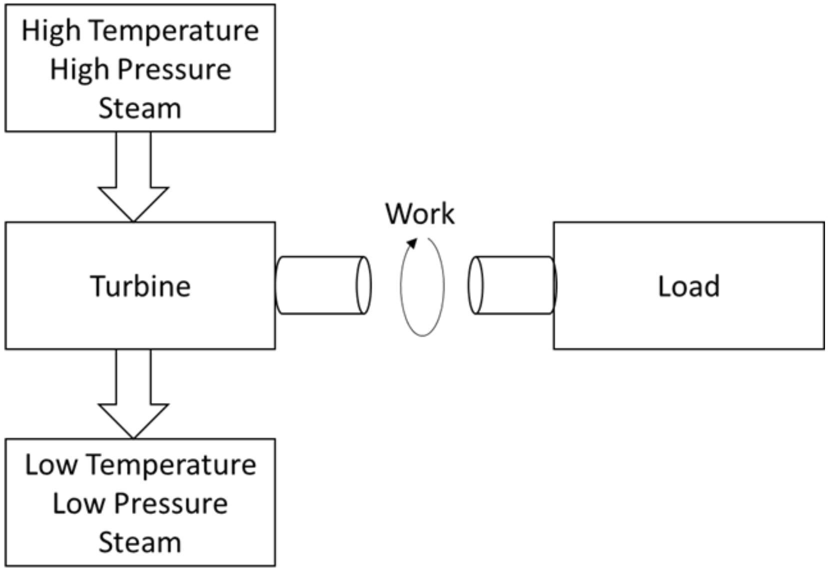
General Engineering



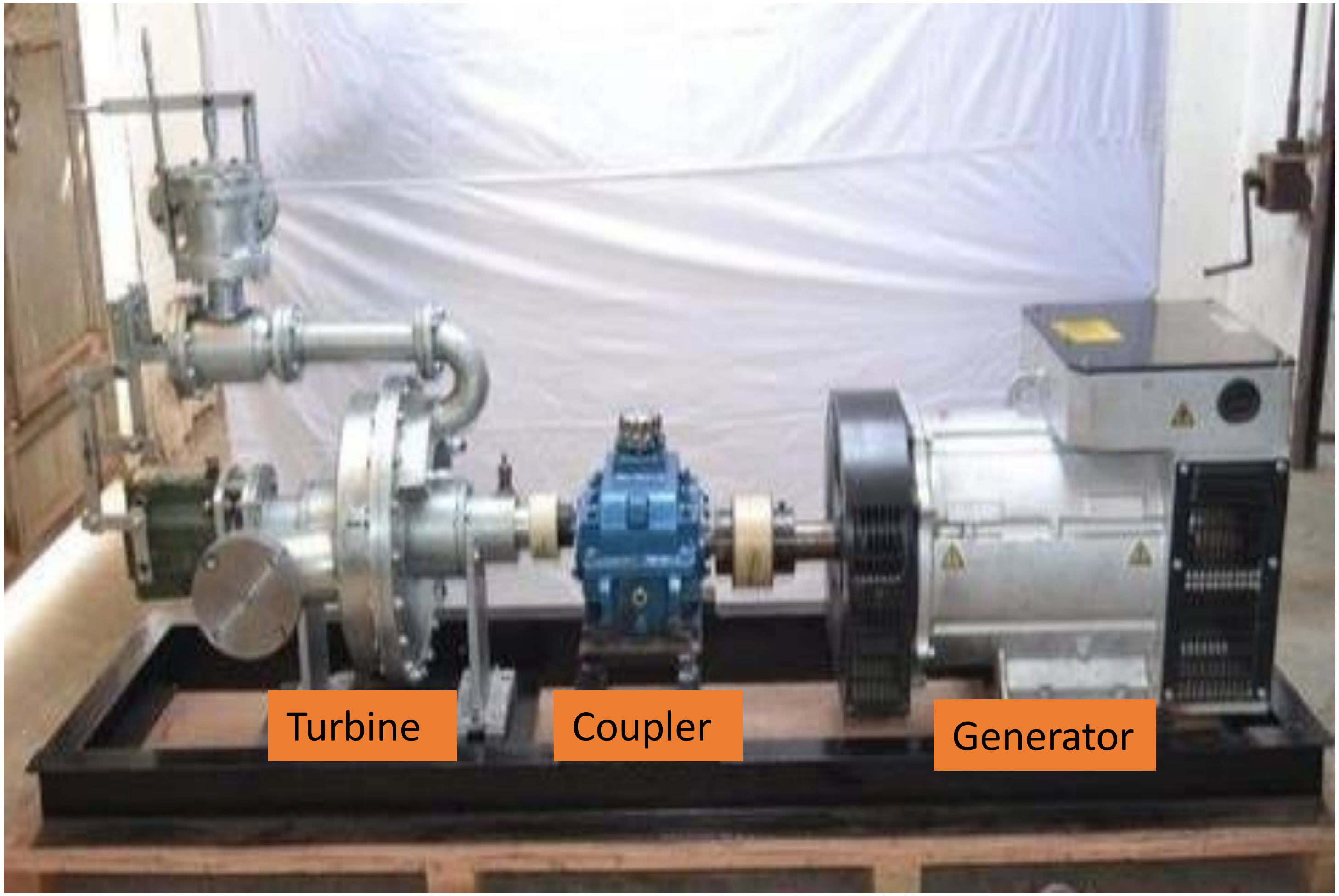
Unit 3 STEAM TURBINE AND REFRIGERATION SYSTEM

Steam turbine

A steam engine is a machine used to create rotational movement from steam. A high pressure and high temperature steam is injected towards the turbine blades. This high speed steam hits the turbine blades and rotates the turbine. The shaft is now rotating. This rotation can be used to connect to other devices like a electrical generator, pump or compressor.

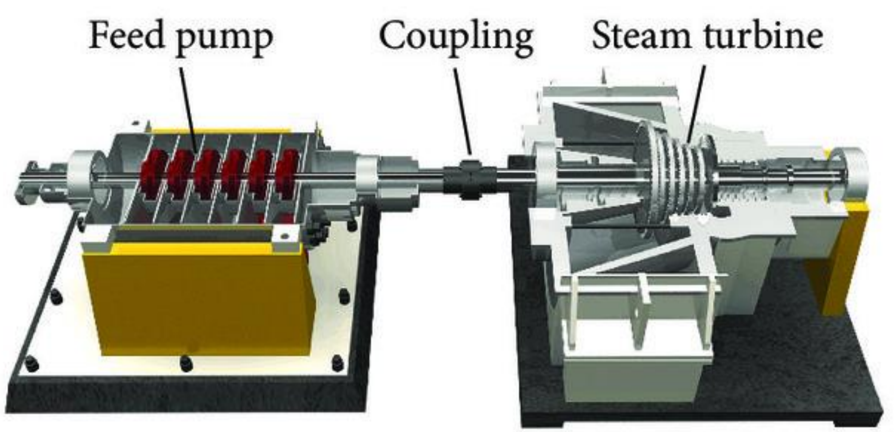


Steam turbine



Purpose of steam turbine in process industries

- Steam turbines are widely used in different driver applications for mechanical drives and power generation units.
- A large proportion of the world's electrical power is generated by turbo generators.
- Steam turbine is used as a primemover in pumps and compressors.



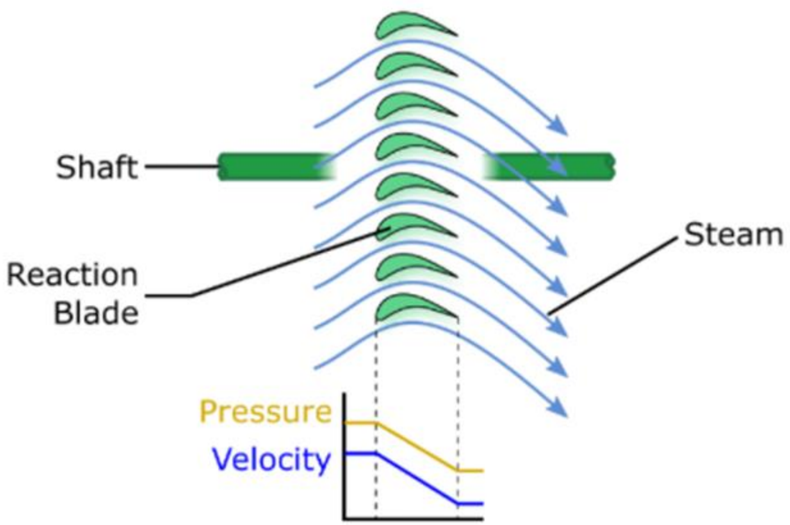
Common types of steam turbines

- Reactive steam turbine
- Impulse turbine
- Condensing turbine
- Non-condensing turbine

Reactive steam turbine

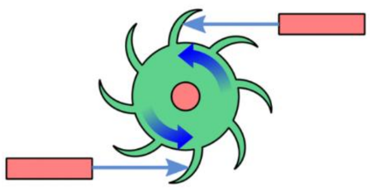
This is a turbine with rotating blades curved and arranged so as to develop torque from gradual decrease of steam pressure from inlet to exhaust.

This type of turbine makes use of the reaction force produced as the steam accelerates through the nozzles formed by the rotor.

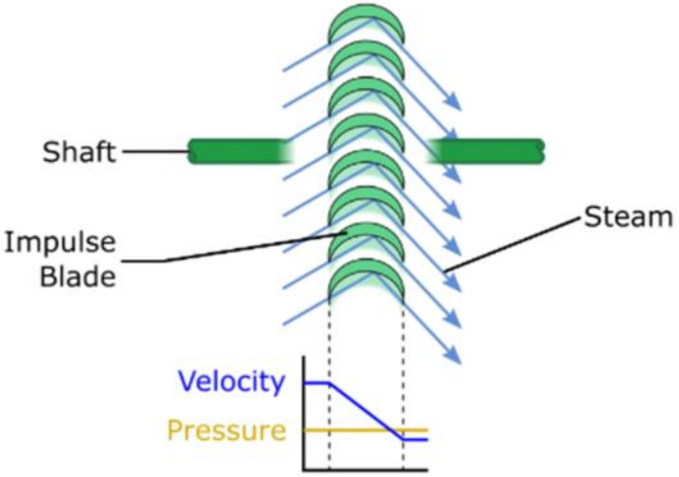


Impulse turbine

In this turbine, the rotor is driven by fluid jets impinging directly against the blades.

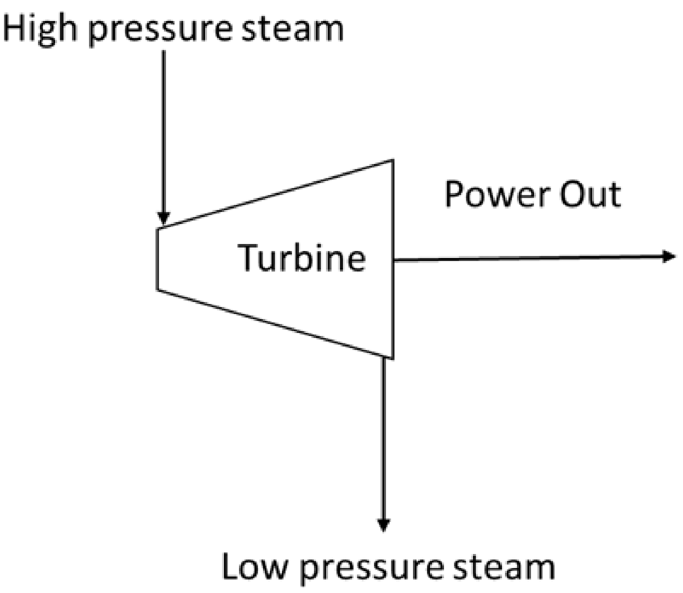


The impulse turbine consists of a set of stationary blades (nozzles) followed by a set of rotor blades (Buckets) which rotate to produce the rotary power. The fixed nozzles orient the steam flow into high speed jets.



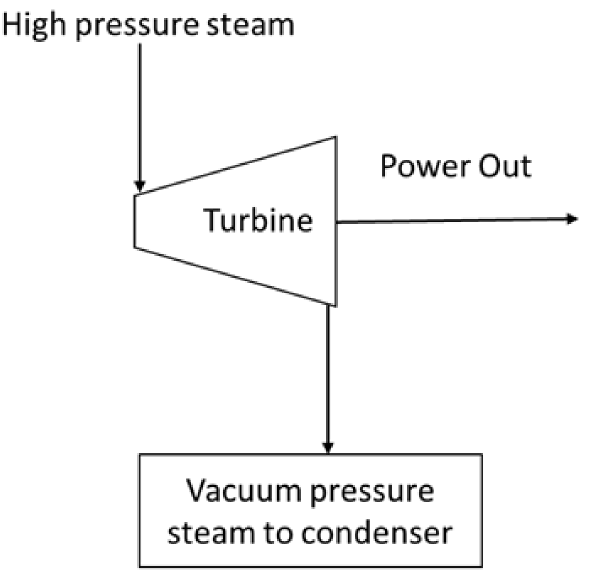
Non-condensing turbine

- In this turbine high pressure and high temperature steam enters into the turbine chamber.
- This steam rotates the turbine blades.
- After the work done, the high pressure and high temperature steam becomes low pressure and low temperature steam and goes out of exhaust.
- This steam can be used for other purposes like heating, cleaning.



Condensing turbine

- In this turbine steam enters into the turbine chamber, rotates the blades and the exhaust goes to condensers.
- The condenser is cooled by cooling water.
- This cooling makes the steam to condense into water.
- This condensation creates vacuum in the condenser.



Construction and working principle of steam turbine

The main parts of a steam turbine are

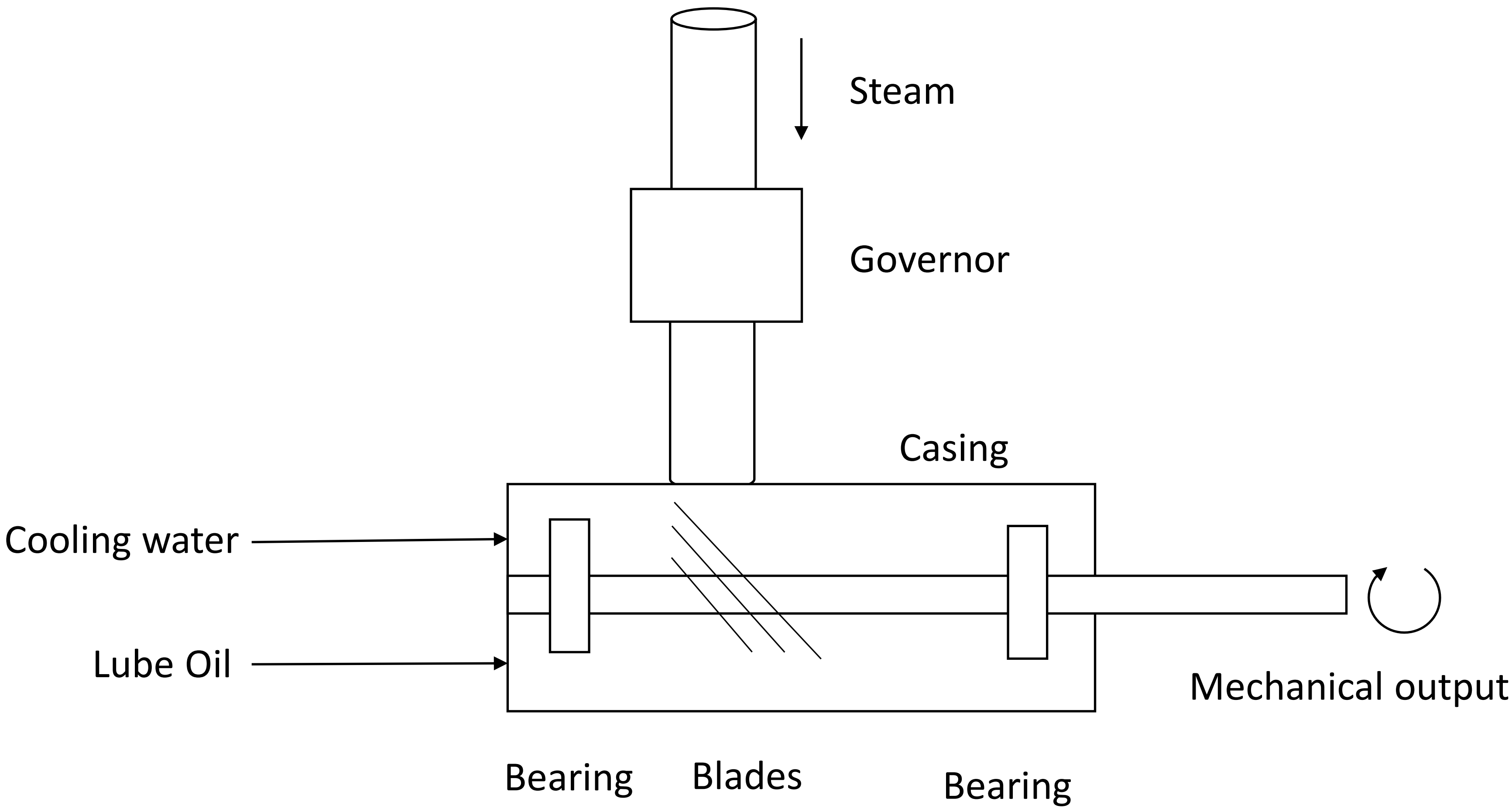
(1) the rotor that carries the blading to convert the thermal energy of the steam into the rotary motion of the shaft

(2) the casing, inside of which the rotor turns, that serves as a pressure vessel for containing the steam (it also accommodates fixed nozzle passages or stator vanes through which the steam is accelerated before being directed against and through the rotor blading)

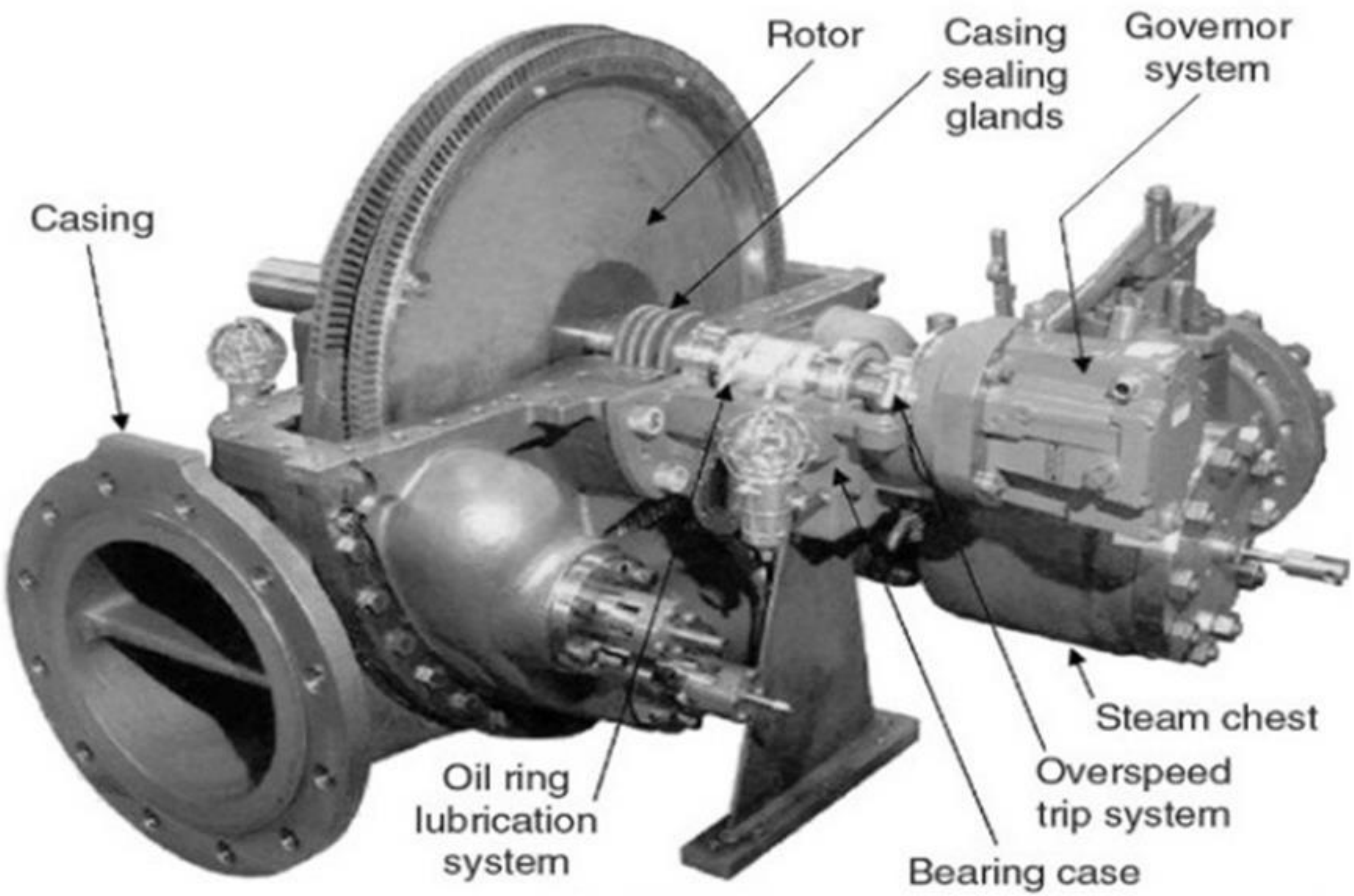
(3) the speed-regulating mechanism

(4) the support system, which includes the lubrication system for the bearings that support the rotor and also absorb any end thrust developed

Construction and working principle of steam turbine



Construction and working principle of steam turbine



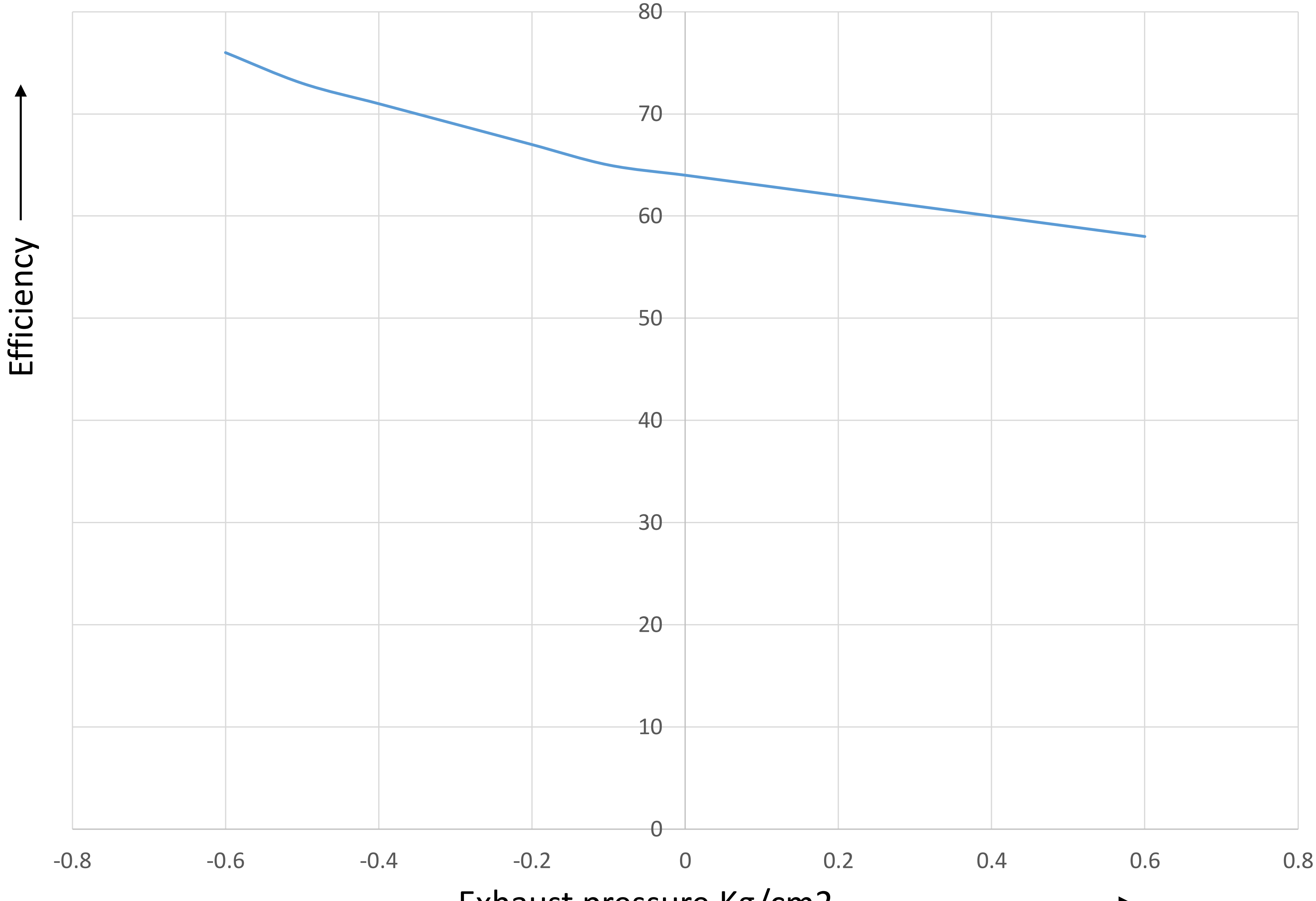
Turbine efficiency

- The efficiency of any turbine or engine can be defined as its ability to convert the input energy into useful output energy.
- Efficiency (η) = Output / Input
- Efficiency (η) = Work Done / Input Kinetic Energy
- The following factors decides the overall efficiency of the turbine.
  - Velocity of input steam (which in turn depends on the temperature and pressure of steam)
  - Angle of guiding vanes
  - Blade angle on the rotor
  - Radius of rotor

Turbine efficiency

- The efficiency of the cycle is strongly influenced by the LP turbine exhaust pressure. The back pressure of the condenser sets the saturation temperature at which the expanded steam rejects its latent heat of vapourisation to the cooling water. Consequently, changes in back pressure affect the temperature of cycle heat rejection.
- Generally, a low exhaust pressure is sought as it improves cycle efficiency.
- However, there are several plant constraints affecting the selection design exhaust pressure. Consider the effect of lowering the exhaust pressure on the turbine condition line on the Mollier diagram. Expansion to a lower pressure results in increased wetness, and increased specific volume at the exhaust.

Turbine efficiency



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Refrigeration system

- Refrigeration means cooling a space, substance or system to lower and/or maintain its temperature below the ambient temperature.
- A typical refrigeration system is composed of four basic components: compressor, condenser, expansion device and evaporator.
- A volatile fluid (refrigeration fluid) flows through the refrigeration system where it is repeatedly converted into liquid and vapor forms.
- The compressor is responsible for compressing superheated vapor from low pressure (evaporating pressure) to high pressure (condensation pressure).
- After that, the refrigeration fluid at high pressure and temperature runs towards the condenser.
- Condenser releases the heat to other medium generally to atmosphere.

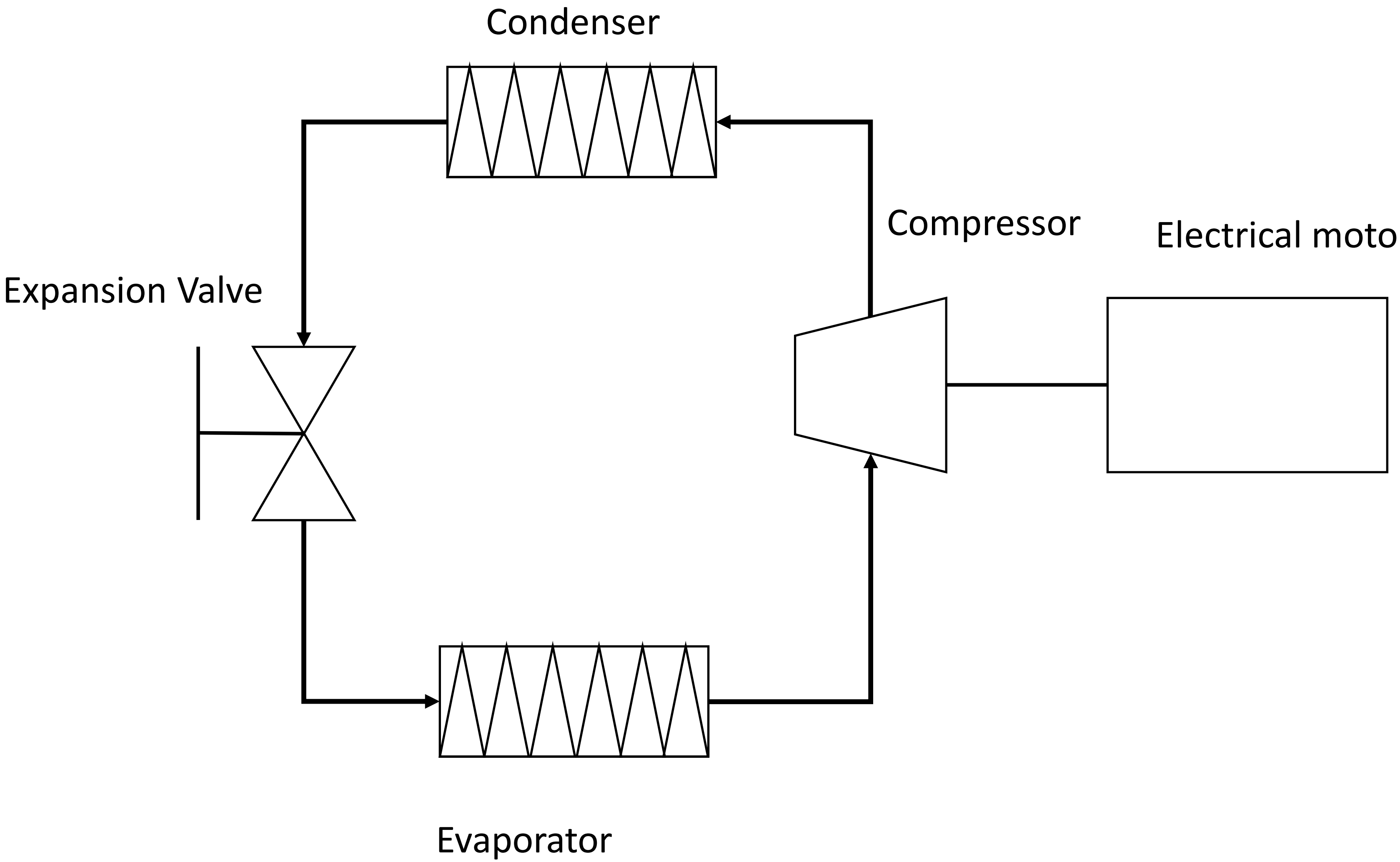
Refrigeration system

- Refrigeration and cooling systems are paramount for many industries to work adequately.
- Chemical & Petrochemical : For water cooling, Rotating machine cooling, Heavy electrical equipment cooling, Control room cooling.
- Pharmaceutical : Many production procedures imply biological or biochemical reactions that only take place in cool conditions in which microbiological species generate chemical compounds at their maximum yield.

Refrigeration system

Food & Beverages : Maintaining the cold chain in the F&B industry is vital for preserving products and avoiding possible microbiological contamination. Each product has its own optimal conditions for storage and preservation. In the preparation process, temperature is one of the most important parameters to assure food safety. In products like fish, poultry, meat, dairies or fruits, refrigeration systems are necessary to keep products in low temperatures and extend the recommended consumption period.

Vapour compression refrigeration system



Vapour compression refrigeration system

Step 1: Compression

The refrigerant enters the compressor at low temperature and low pressure. It is in a gaseous state. Here, compression takes place to raise the temperature and refrigerant pressure. The refrigerant leaves the compressor and enters to the condenser. Since this process requires work, an electric motor may be used. Compressors themselves can be scroll, screw, centrifugal or reciprocating types.

Vapour compression refrigeration system

Step 2: Condensation

The condenser is essentially a heat exchanger. Heat is transferred from the refrigerant to a flow of water. This water goes to a cooling tower for cooling in the case of water-cooled condensation. Note that seawater and air-cooling methods may also play this role. As the refrigerant flows through the condenser, it is in a constant pressure. One cannot afford to ignore condenser safety and performance. Specifically, pressure control is paramount for safety and efficiency reasons. There are several pressure-controlling devices to take care of this requirement

Vapour compression refrigeration system

Step 3: Throttling and Expansion

When the refrigerant enters the throttling valve, it expands and releases pressure. Consequently, the temperature drops at this stage. Because of these changes, the refrigerant leaves the throttle valve as a liquid vapor mixture, typically in proportions of around 75 % and 25 % respectively. Throttling valves play two crucial roles in the vapor compression cycle. First, they maintain a pressure differential between low- and high-pressure sides. Second, they control the amount of liquid refrigerant entering the evaporator.

Vapour compression refrigeration system

Step 4: Evaporation

At this stage of the Vapor Compression Refrigeration Cycle, the refrigerant is at a lower temperature than its surroundings. Therefore, it evaporates and absorbs latent heat of vaporization. Heat extraction from the refrigerant happens at low pressure and temperature. Compressor suction effect helps maintain the low pressure. There are different evaporator versions in the market, but the major classifications are liquid cooling and air cooling, depending whether they cool liquid or air respectively.

Capacity of refrigeration unit

- Within one hour, how much heat can be absorbed by the refrigeration unit is called Capacity of refrigeration unit.
- The basic SI units equation for deriving cooling capacity is of the form:

$$\dot{Q} = \dot{m}\, C_p \Delta T$$

Where,

$\dot{Q}$ = the cooling capacity [kW]

$\dot{m}$ = the mass rate [kg/s]

C_p = the specific heat capacity [kJ/kg K]

ΔT = the temperature change [K]

Coefficient of performance

- The coefficient of performance of a refrigerator or air conditioning system is a ratio of useful heating or cooling provided to work (energy) required.
- The equation is:

COP = Q/W

Where,

Q = Useful heat supplied or removed by the considered system.

W = Work required by the considered system.

Ton of Refrigeration

- A ton of refrigeration is a unit of power to describe the heat-extraction capacity of refrigeration and air conditioning equipment.
- It is defined as the rate of heat transfer that results in the freezing or melting of 1 ton of pure ice at 0 °C in 24 hours.
- A refrigeration ton is approximately equivalent to 12,000 BTU/h or 3.5kW.

Refrigerants

- Air conditioners contain refrigerant inside copper coils.
- It absorbs heat from the container or room.
- As refrigerant absorbs heat from indoor air, it transitions from a low-pressure gas to a high-pressure liquid.
- Air conditioning components send the refrigerant outside where a fan blows hot air over the coils and exhausts it to the exterior.
- The refrigerant then cools down and turns back into a low-pressure gas. Another fan located inside the home blows air over the cool coils to distribute the resulting cold air throughout the building. Then the cycle repeats.

DESIRABLE PROPERTIES OF AN IDEAL REFRIGERANT

1. Thermodynamic Properties:

   (i) Low boiling point

   (ii) Low freezing point

   (iii) Positive pressures (but not very high) in condenser and evaporator.

   (iv) High saturation temperature

   (v) High latent heat of vapourization

2. Chemical Properties:

   (i) Non-toxicity

   (ii) Non-flammable and non-explosive

   (iii) Non-corrosiveness

   (iv) Chemical Stability in reacting

   (v) No effect on the quality of stored (food and other) products

DESIRABLE PROPERTIES OF AN IDEAL REFRIGERANT

3. Physical Properties:

   (i) Low specific volume of vapour

   (ii) Low specific heat

   (iii) High thermal conductivity

   (iv) Low viscosity

   (v) High electrical insulation

4. Others Properties:

   (i) Ease of leakage location

   (ii) Availability and low cost

   (iii) Ease of handling

   (iv) High COP

   (v) Low power consumption per tonne of refrigeration

   (vi) Low pressure ratio and pressure difference

List of common types at refrigerants

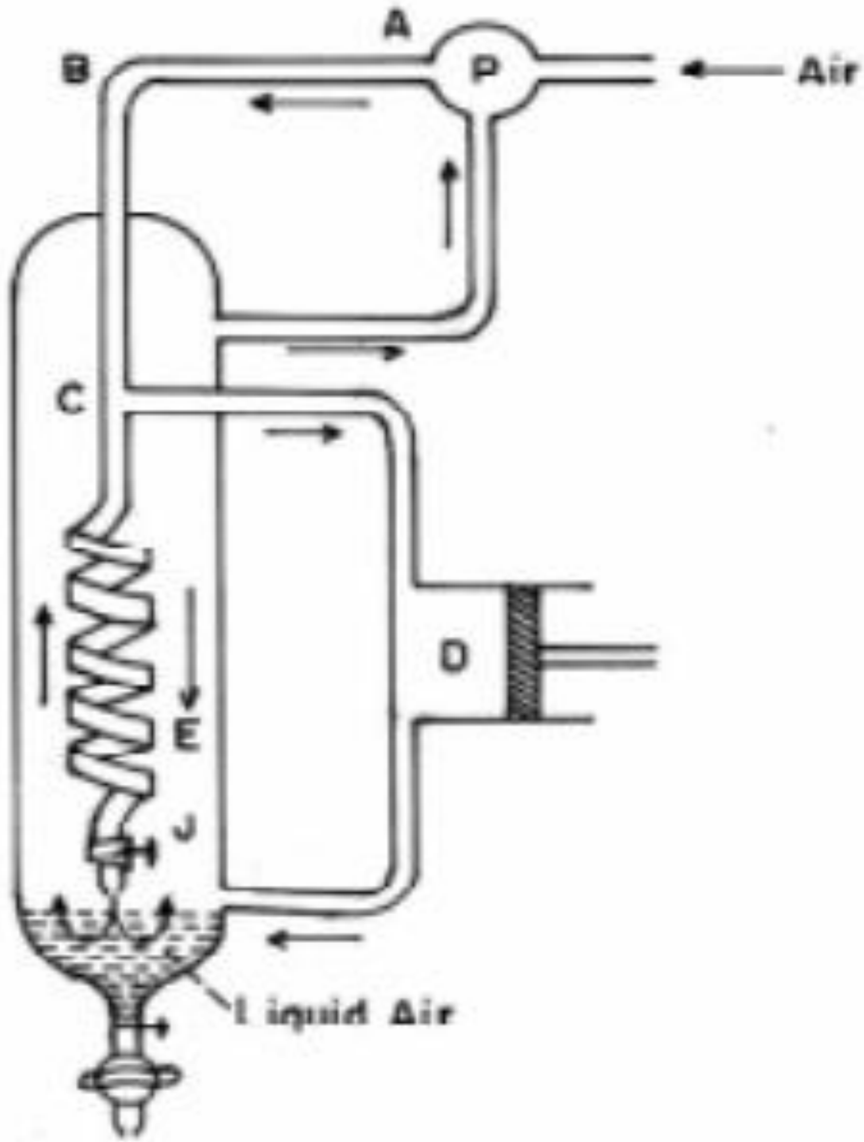
The chemical arrangement of the refrigerants decides in which group it should be considered. The four main refrigerant types are

- CFCs – Chlorofluorocarbons
- HCFCs – Hydro chlorofluorocarbons
- HFCs – Hydro fluorocarbons
- Natural Refrigerants

Claude Liquefaction 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.

Claude Liquefaction process



Claude Liquefaction process

- Air is compressed to about 200 atmospheres and is passed through the pipe ABC. 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.