Unit 2
Vapour Power Cycles & Refrigeration and Air Conditioning

VAPOUR POWER CYCLES

INTRODUCTION TO VAPOUR POWER CYCLES

Vapour power cycles are a class of thermodynamic cycles in which the working fluid undergoes a phase change. Typically, water is used as the working fluid which evaporates into steam and later condenses back into water during the cycle. These cycles are commonly found in power plants to produce mechanical work through turbines. The purpose is to convert heat energy into mechanical energy and ultimately into electrical energy.

The main advantage of using vapour as a working medium is the ability to absorb and reject large amounts of heat at constant temperature due to the phase change process. Two major vapour power cycles are:

- Carnot Cycle (ideal, theoretical)
- Rankine Cycle (practical, used in real plants)

CARNOT CYCLE (IDEAL VAPOUR POWER CYCLE)

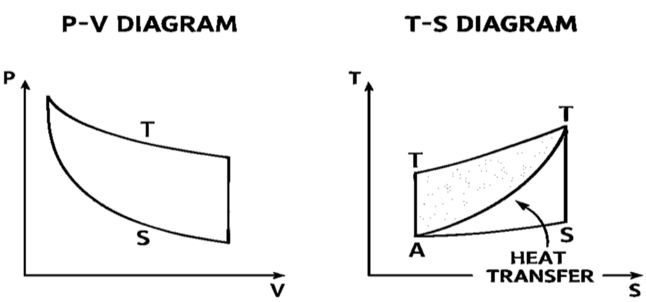
The Carnot cycle is a theoretical cycle proposed by Sadi Carnot. It represents the maximum possible efficiency a heat engine can achieve operating between two temperature reservoirs.

Processes in the Carnot Cycle

- Process 1–2: Isothermal heat addition at high temperature (evaporation)
- Process 2–3: Isentropic (adiabatic and reversible) expansion in turbine
- Process 3–4: Isothermal heat rejection at low temperature (condensation)
- Process 4–1: Isentropic compression by a pump

Assumptions

- All processes are reversible.
- The working fluid is a perfect gas or ideal steam.
- Heat addition and rejection occur at constant temperature.



Efficiency

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

Where:

- T_H: Temperature of heat source
- T_L: Temperature of heat sink

Limitations

- Isothermal processes are difficult to achieve practically.
- Compression of wet vapour is not feasible.
- Requires perfect insulation and no entropy generation.

RANKINE CYCLE (REALISTIC VAPOUR POWER CYCLE)

Rankine cycle is the ideal cycle for vapor power plants. It replaces the isothermal processes of Carnot cycle with constant pressure processes, making it more feasible for real applications.

Processes

- Process 1–2: Isentropic compression in a pump
- Process 2–3: Constant pressure heat addition in boiler
- Process 3–4: Isentropic expansion in a turbine
- Process 4–1: Constant pressure heat rejection in condenser

Major Components

- Boiler: Provides thermal energy for phase change
- Turbine: Expands steam and converts heat energy into work
- Condenser: Rejects waste heat to environment
- Pump: Pressurizes condensed liquid to complete the cycle

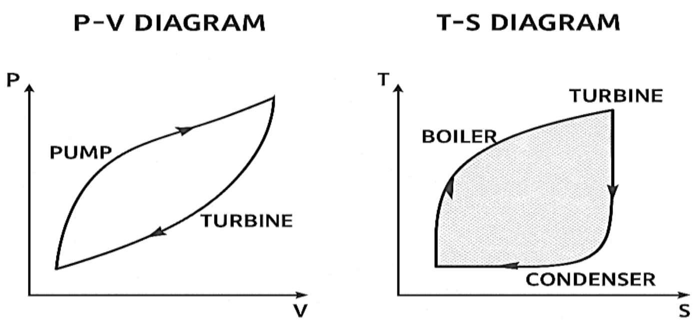
Rankine Cycle Efficiency

$$\eta = \frac{W_{turbine} - W_{pump}}{Q_{in}}$$

Efficiency is improved by minimizing irreversibility's and increasing the mean temperature of heat addition.

Improvements to the Rankine Cycle

- Superheating the steam before expansion
- Reheating: expanding steam partially, reheating it and then expanding again
- Regeneration: using part of steam to preheat feedwater



REFRIGERATION AND AIR CONDITIONING

INTRODUCTION TO REFRIGERATION

Refrigeration is a process in which heat is removed from a space or substance to lower its temperature. It works opposite to a heat engine. Instead of converting heat to work, it uses work to extract heat from a cold region and reject it to a hot region.

SECOND LAW OF THERMODYNAMICS IN REFRIGERATION

It is impossible to transfer heat from a colder body to a hotter body without external work. Hence, refrigeration systems consume power to achieve cooling.

COEFFICIENT OF PERFORMANCE (COP)

$$\mathrm{COP} = \frac{Q_L}{w}$$

Where:

- Q_L: Heat extracted from low temperature region
- W: Work input

Higher COP means higher efficiency.

VAPOUR COMPRESSION REFRIGERATION CYCLE (VCRC)

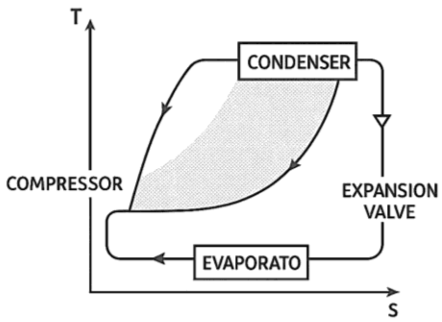
Most common refrigeration cycle in domestic and industrial applications.

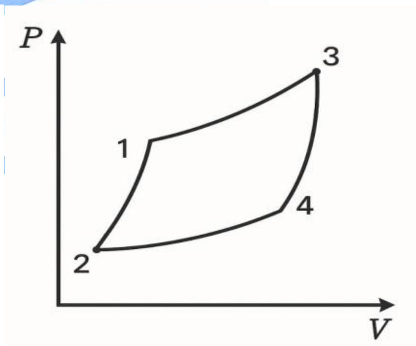
Components

- Compressor: Compresses refrigerant and increases its pressure and temperature
- Condenser: Condenses the refrigerant and releases heat to environment
- Expansion Valve: Reduces the pressure of the liquid refrigerant
- Evaporator: Absorbs heat from the refrigerated space

Cycle Processes

- 1–2: Isentropic compression
- 2–3: Constant pressure heat rejection in condenser
- 3–4: Throttling through expansion valve
- 4–1: Constant pressure heat absorption in evaporator





AIR-CONDITIONING SYSTEMS

Air-conditioning systems not only cool but also control air humidity, cleanliness, and distribution.

Types

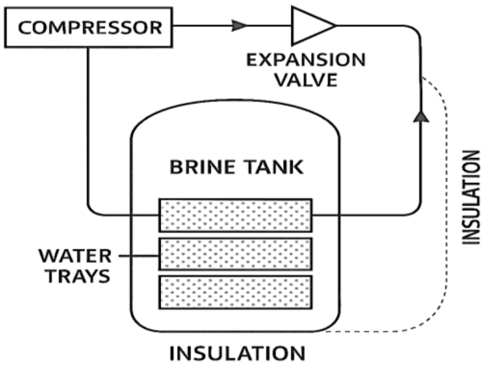
- Window AC
- Split AC
- Central AC
- HVAC (Heating, Ventilation, Air Conditioning)

Functions

- Cooling air
- Dehumidification
- Air purification
- Air circulation

ICE PLANTS

Ice plants are used to produce ice commercially. They use the vapour compression refrigeration system with brine and ammonia as refrigerants.



Process

- Water is placed in trays and submerged in chilled brine.
- Brine is cooled using refrigerant.
- Heat is extracted till water freezes into ice.