# Theory of Rankine and Brayton Cycles

## Introduction

Power cycles are used to convert heat energy into useful work. Most of the electricity we use today is generated using these cycles. In this report, the Rankine cycle and the Brayton cycle are explained.

The Rankine cycle is used in steam power plants, while the Brayton cycle is commonly used in gas turbine power plants. By studying these cycles, we can get the idea of how real plants operate and understand the basic principles behind them.

## Rankine Cycle

The Rankine cycle is an ideal cycle representing the working of a steam power plant. In this cycle, water is used as the working fluid, which undergoes phase change during the process.

### Main Components

- Boiler
- Turbine
- Condenser
- Pump

### Basic Processes of the Rankine Cycle

**1. Isentropic Compression (Pump)**

Water is pumped from low pressure to high pressure using a pump. Since water is incompressible, the work required by the pump is relatively small.

**2. Constant Pressure Heat Addition (Boiler)**

The high-pressure water enters the boiler where heat is supplied at constant pressure. The water converts into steam during this process.

**3. Isentropic Expansion (Turbine)**

The high-pressure steam expands in the turbine and produces work. This is the main power-producing step of the cycle.

**4. Constant Pressure Heat Rejection (Condenser)**

After expansion, the steam enters the condenser where heat is rejected to the surroundings and the steam condenses back into water.

## T–S Diagram of Rankine Cycle

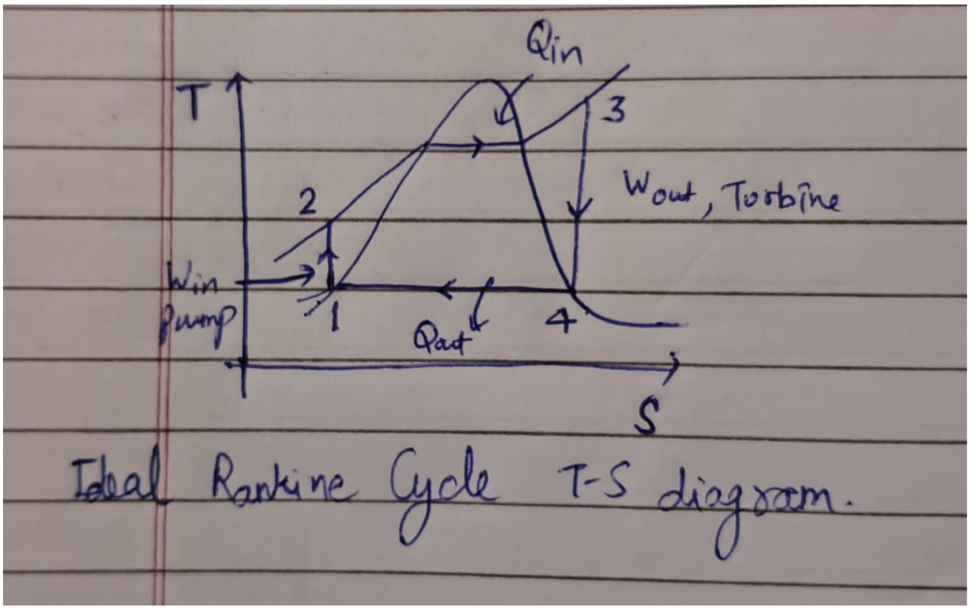


Figure 1: Ideal Rankine Cycle on T–S Diagram

### Layout of Rankine Cycle

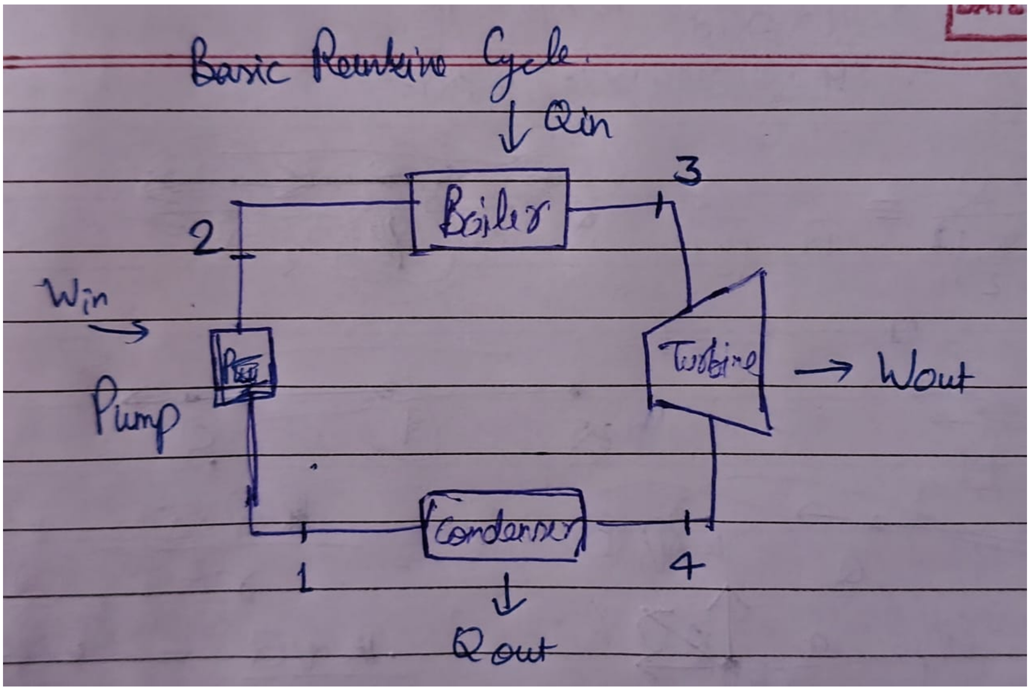


Figure 2: Basic Rankine Cycle Layout

### Thermal Efficiency

The thermal efficiency of the Rankine cycle is the ratio of net work output to the heat supplied in the boiler.

$$\eta_{th} = \frac{W_{net}}{Q_{in}}$$

## Brayton Cycle

The Brayton cycle is an ideal cycle that represents the working of a gas turbine power plant. Air is generally used as the working fluid. There is no phase change as compared to the Rankine cycle.

### Main Components

- Compressor
- Combustion chamber
- Turbine

## Basic Processes of the Brayton Cycle

1. **Isentropic Compression (Compressor)**

   Air is compressed in the compressor, which increases its pressure and temperature.

2. **Constant Pressure Heat Addition (Combustion Chamber)**

   Heat is added to the compressed air at constant pressure, usually by burning fuel.

3. **Isentropic Expansion (Turbine)**

   The high-temperature gases expand through the turbine and produce work.

4. **Constant Pressure Heat Rejection**

   Heat is rejected to the atmosphere through the exhaust gases.

## T–S Diagram of Brayton Cycle

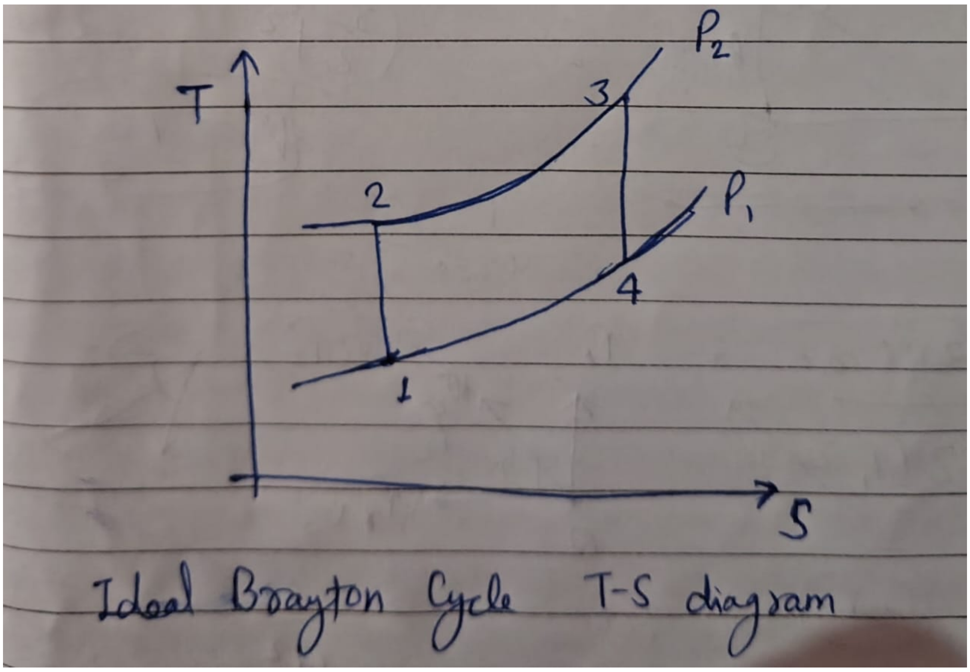


Figure 3: Ideal Brayton Cycle on T–S Diagram

### Layout of Brayton Cycle

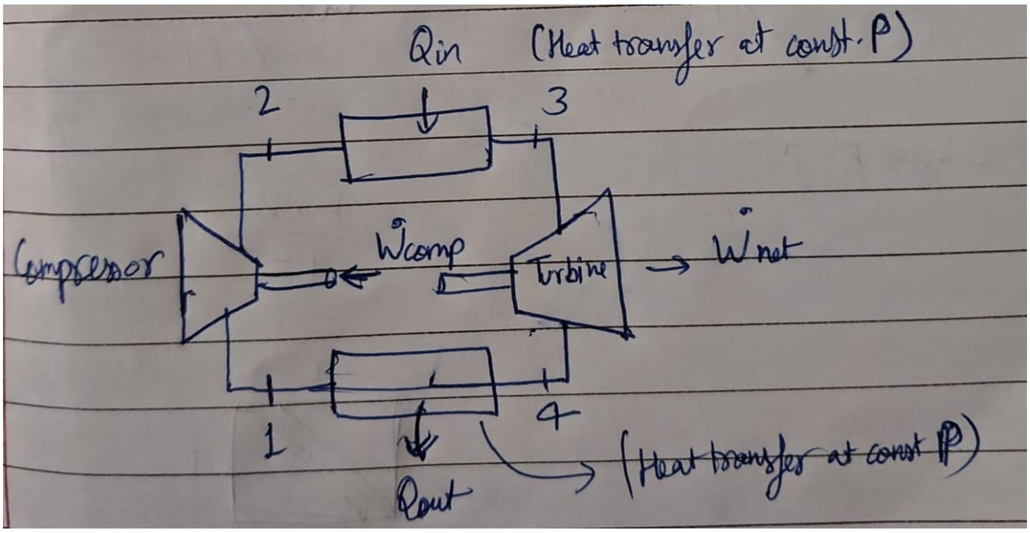


Figure 4: Basic Brayton Cycle Layout

### Thermal Efficiency

The efficiency of the Brayton cycle mainly depends on the pressure ratio of the compressor.

$$\eta_{th} = \frac{W_{net}}{Q_{in}}$$

$$\eta_{th} = 1 - \frac{1}{r_p^{(\gamma-1)/\gamma}}$$

where $r_p$ is the pressure ratio.

## Final Conclusion

The report provides a basic understanding of both the Rankine and Brayton cycles, their processes, and their applications along with their thermal efficiencies. It also makes it clear that ideal cycles are only theoretical models. In real life, perfectly isentropic processes, zero losses, and constant-pressure heat transfer are not possible due to friction, heat losses, pressure drops, and material limitations.

The comparison between the two cycles highlights why different power plants use different cycles. The Rankine cycle is better suited for large-scale, steady power generation where phase change allows efficient heat transfer. The Brayton cycle is ideal for gas turbines and aircraft engines, where compactness and high power-to-weight ratio matter more than maximum efficiency.