XV: Standard Cycles

1: Introduction

1.1: What are thermodynamic cycles

- A series of thermodynamic processes
- Arranged sequentially to from a cycle.
- The working fluid undergoes a series of changes in state and is returned to the initial conditions at the end of the cycles.
- Usually idealised.
- Cycles are arranged in specific configuration to achieve particular purposes:
  - Converting Heat to Work.
  - Move heat energy form low to high temperature regions (**refrigeration**)
  - Work done to sore potential or pressure energy. (compressing gases)

1.2: What are standard cycles

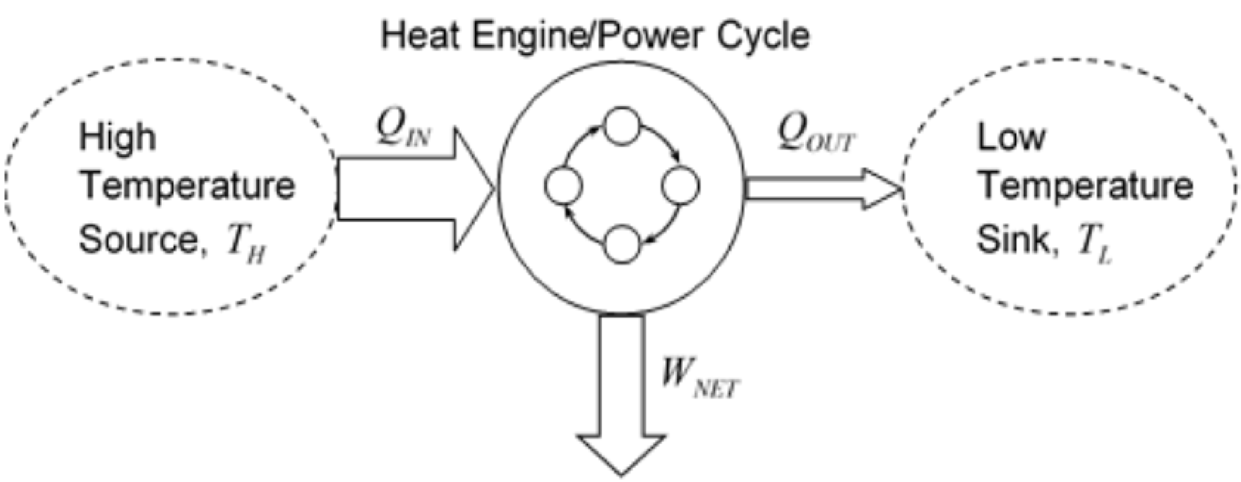
- Standard cycles:
  - Generally agreed cycle configurations.
  - Generally accepted as applicable to specific tasks and machines.
  - Often named after particular individuals to honour their contribution.
- What are standard cycles used for:
  - Provide the idealised basis of thermodynamic machines.
  - Theoretical limits / feasibility.
  - Provide guidelines & a basis of calculation of cycle operating conditions

1.3: Thermodynamic Machines and Machine Cycles versus Theoretical (Standard) Thermodynamic Cycles

- **Thermodynamic Machines**: are the physical and practical hardware operating in machine cycles.
- **Machine Cycles**: Are a repeating sequence of events subjects to all applicable laws of physics.
- **Theoretical Thermodynamics Cycles**: are idealised and conceptual and make no attampt to model much of the detail indicate of actual mechanical devices.

2: General approach to performing analysis

- Applied to systems modelled as:
  - **Closed systems (reciprocating internal combustion engines)**: Energy exchangedd calculated with Non-Flow Energy Equation (NFEE).
  - **Open systems (gas turbines)**:
    - Generally assumed to be operating in a steady state.
    - Energy Exchanges calculated with Steady Flow Energy Equation (SFEE)
    - Only enthalpy changes need to be considered.
- Basic metrics of cycle performance:
  - **Ratio of relevant energy exchanges involved**
    - Efficiency (heat engine cycles)
    - Coefficient of performance (refrigeration cycles)
  - **Mass (Mass flow rate) of working fluid required to achieve particular energy exchanges**
    - This can be useful as a proxy for system size or weight.
    - Power-to-weight ratio.
    - Power-to -volume ratio.
    - Indicated mean effective pressure.
    - The more working fluid mass, or mass flow rate per unit output ,then generally the larger the system will be required.
- Circle Efficiency Calculations:



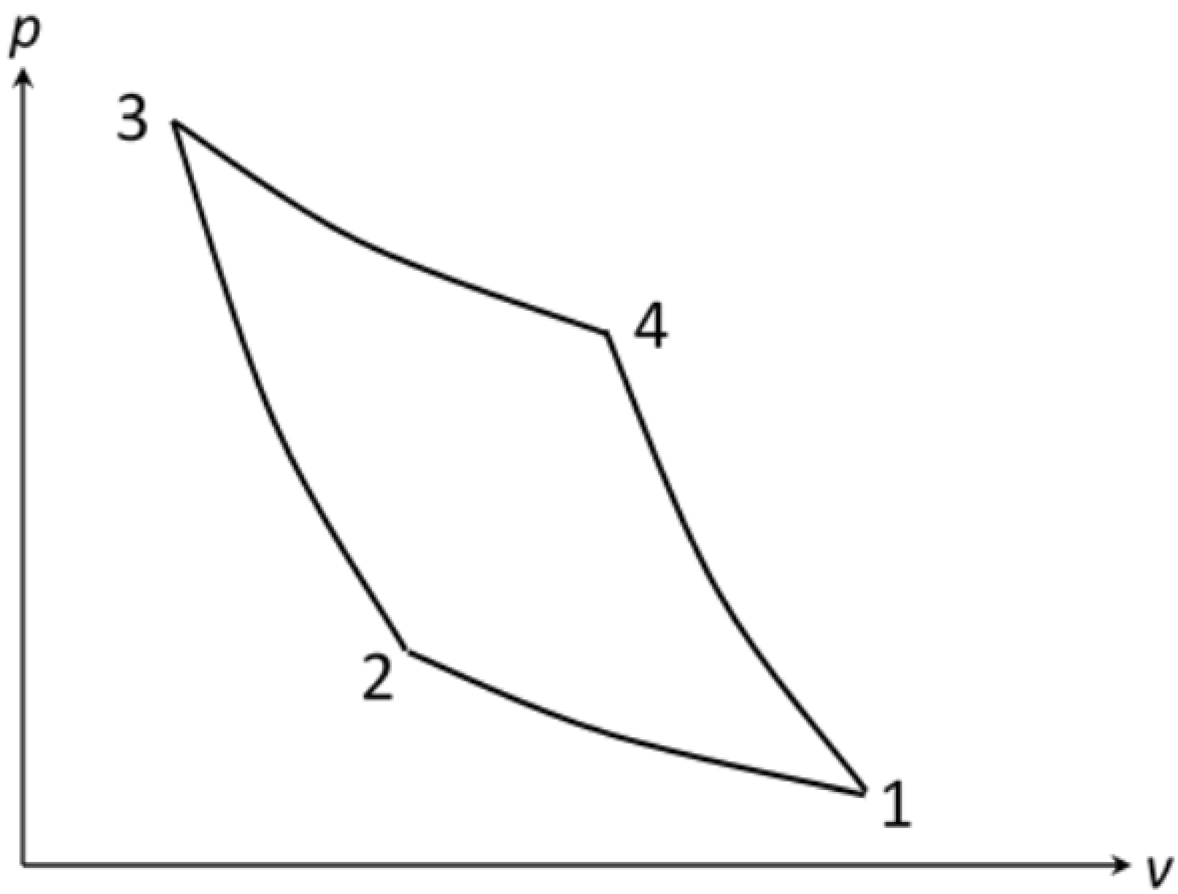
- First Law:

$$W_{NET} = Q_{IN} - Q_{OUT}$$

- Efficiency:

$$\eta = \frac{W_{NET}}{Q_{IN}}$$
$$= 1 - \frac{Q_{OUT}}{Q_{IN}}$$

2: Standard Cycles: The Carnot Cycles



- Carnot's work is recognized as laying the foundations of thermodynamics.
- 1-2: Isothermal (Low Temperature, T_L)
- 2-3: Reversible Adiabatic Compression
- 3-4: Isothermal Heat Addition (High Temperature, T_H)
- 4-1: Reversible Adiabatic Expansion
- Carnot demonstrated that the max efficiency is between T_H and T_L:

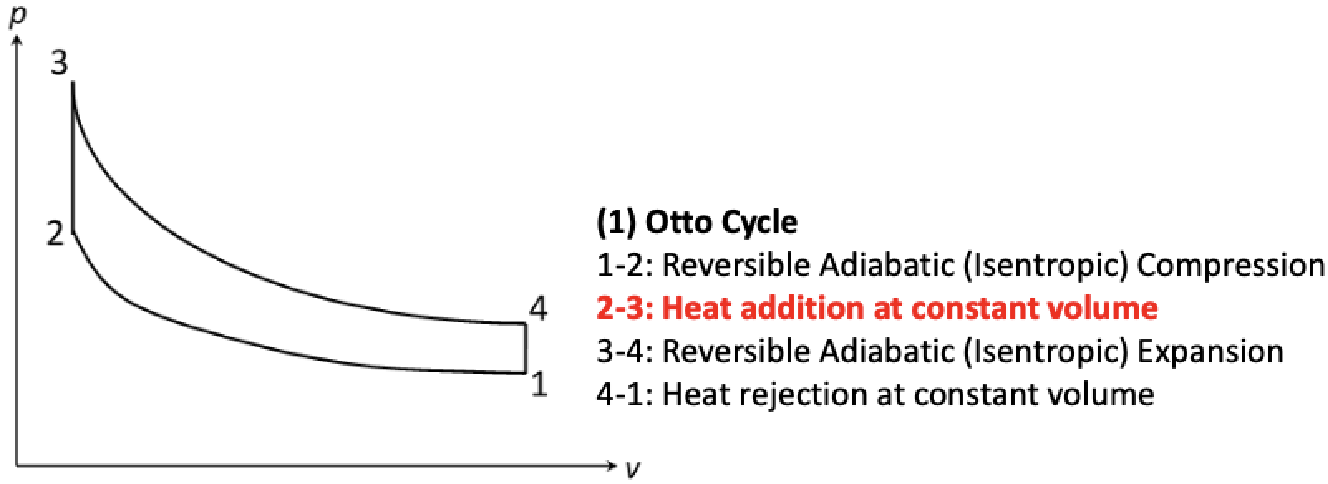
$$\eta_{Carnot} = 1 - \frac{T_L}{T_H}$$

- This also leads to the idea which means the larger the value of T_H, the higher the cycle efficiency in his cycle.

3: Standard Cycles: Otto - Diesel - Dual

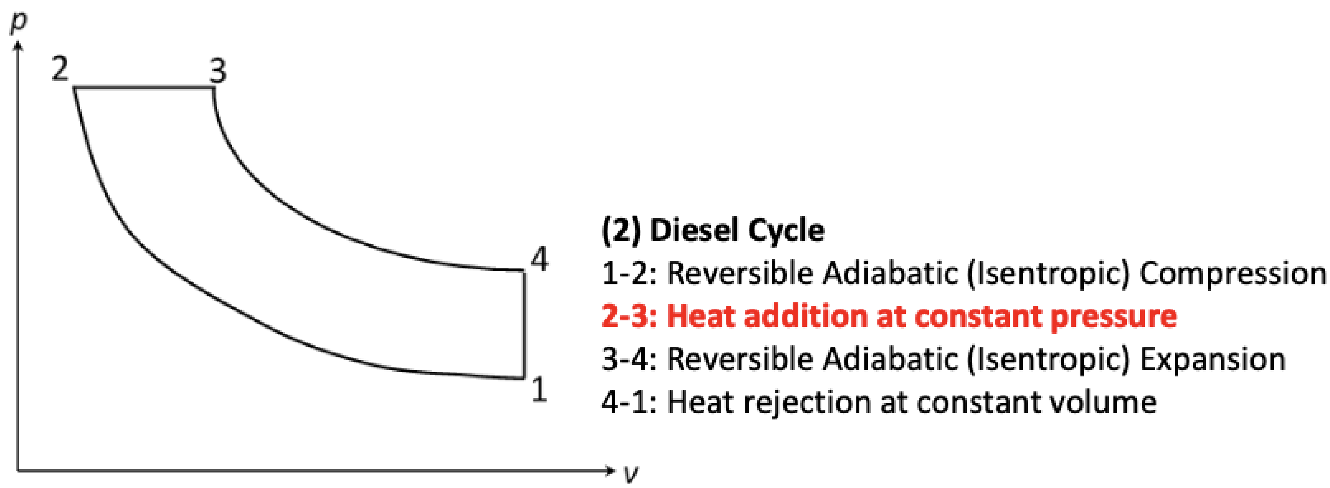
3.1: Otto Cycles

- Spark ignition reciprocating engine (the basis of Petrol Engine or Gas Engine)



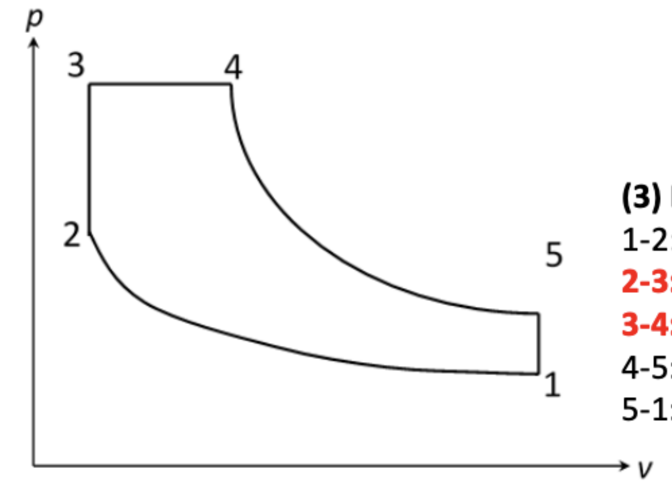
3.2: Diesel Cycles

- Compression ignition reciprocating engine.



3.3: Dual Cycles

- To more accurately model real internal combustion engine operation than constant volume heat and constant pressure heat.



(3) Dual Cycle
1-2: Reversible Adiabatic (Isentropic) Compression
2-3: Heat addition at constant volume
3-4: Heat addition at constant pressure
4-5: Reversible Adiabatic (Isentropic) Expansion
5-1: Heat rejection at constant volume

4: Standard Cycles analysis

- Treated as a closed system and NFEE can be used for the basis .
- Assume as perfect gas with constant specific heat capacities
- **Definition**: (volumetric) Compression Ratio, r_v

$$r_v = \frac{v_1}{v_2} = \frac{V_1}{V_2}$$

- i.e. ratio of maximum to minimum volume

Cycle Efficiency base on Dual Cycle

$$\boxed{\eta = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{C_v(T_5 - T_1)}{C_v(T_3 - T_2) + C_p(T_4 - T_3)}}$$

- For Otto or Diesel just omit the relevant heat addition.