ME 201
Thermodynamics

Piston-Cylinder Cycles
(Internal Combustion Engine Cycles)

Most internal combustion engines can be modeled as one of three piston/cylinder cycles. At the start of these cycles, the piston is out as far as possible, so that we have the maximum or bottom dead center volume. When the piston is in as far as possible we have the minimum or top dead center volume. Two parameters are used to communicate the size of the engine,

$$\text{Compression ratio: } r = \frac{V_{BDC}}{V_{TDC}}$$

$$\text{Engine Displacement: } V_{disp} = \left(V_{BDC} - V_{TDC}\right) \times \text{number of cylinders}$$

$$\text{Piston Stroke: } L = \frac{\left(V_{disp}\right)_{cylinder}}{\pi D^2_{cylinder}/4}$$

An additional parameter used to characterize engine performance is the mean effective pressure (MEP) which is defined as the pressure required to produce the same work output as the engine if the process was isobaric, or

$$W_{net} = (MEP) \cdot V_{disp}$$

or

$$MEP = \frac{W_{net}}{V_{BDC} - V_{TDC}}$$

The power output of an engine can be calculated from

$$\dot{W}_{net} = (\#\text{ of cylinders})(W_{net}\text{ for one cylinder})(\text{rpm})(1/60\text{ min/s})(2/(\#\text{ of strokes}))$$

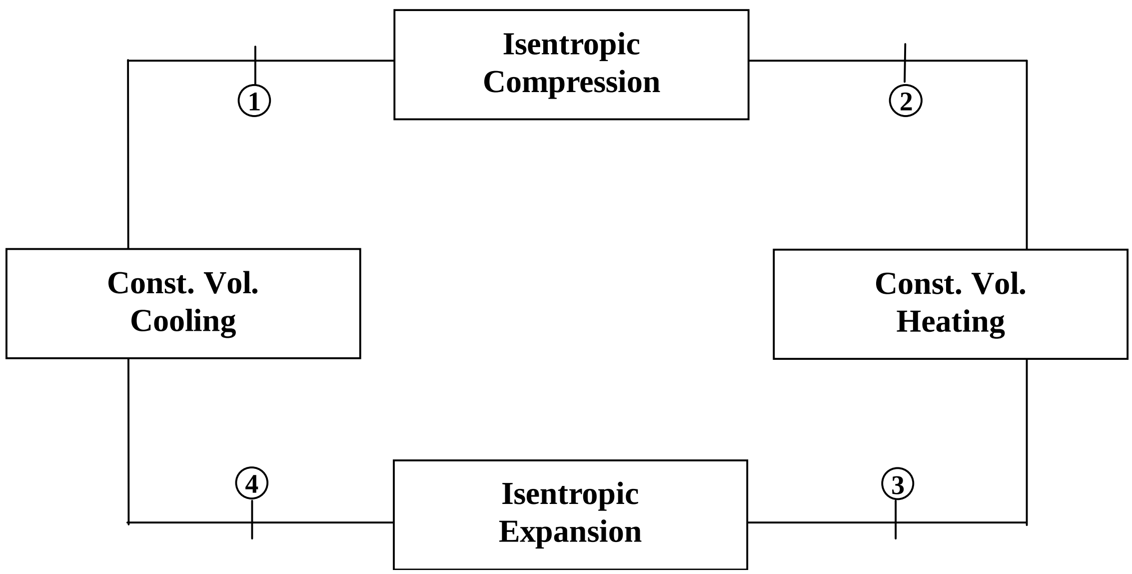
We now consider three of the most common piston/cylinder cycles.

1. Otto Cycle

The Otto Cycle is composed of the following four processes

Isentropic Compression
Constant Volume Heat Addition
Isentropic Expansion
Constant Volume Heat Rejection

The block diagram for this cycle is shown below



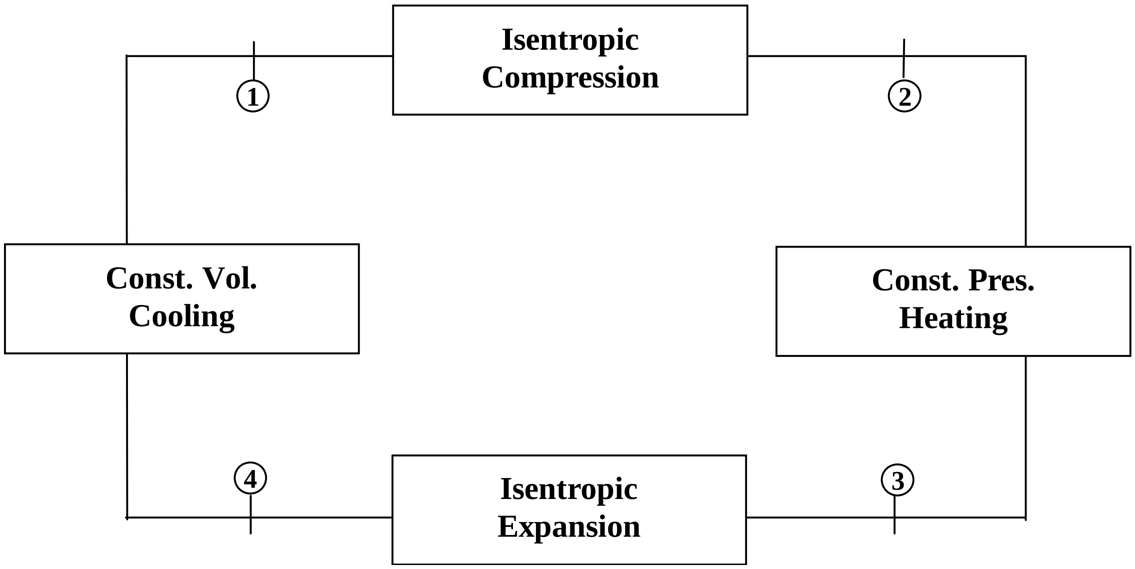
The cycle begins with the isentropic compression and the temperature and pressure prior to this process is normally given. The only other information required to work the problem are volume and compression ratio information and some information about the combustion process, heat added or final temperature.

2. Diesel Cycle

The Diesel cycle consists of the following four process

Isentropic Compression
Constant Pressure Heat Addition
Isentropic Expansion
Constant Volume Heat Rejection

The block diagram is shown below



In addition to initial temperature and pressure and volume and compression ratio data that must provided, we must also be given the cut-off ratio, given as

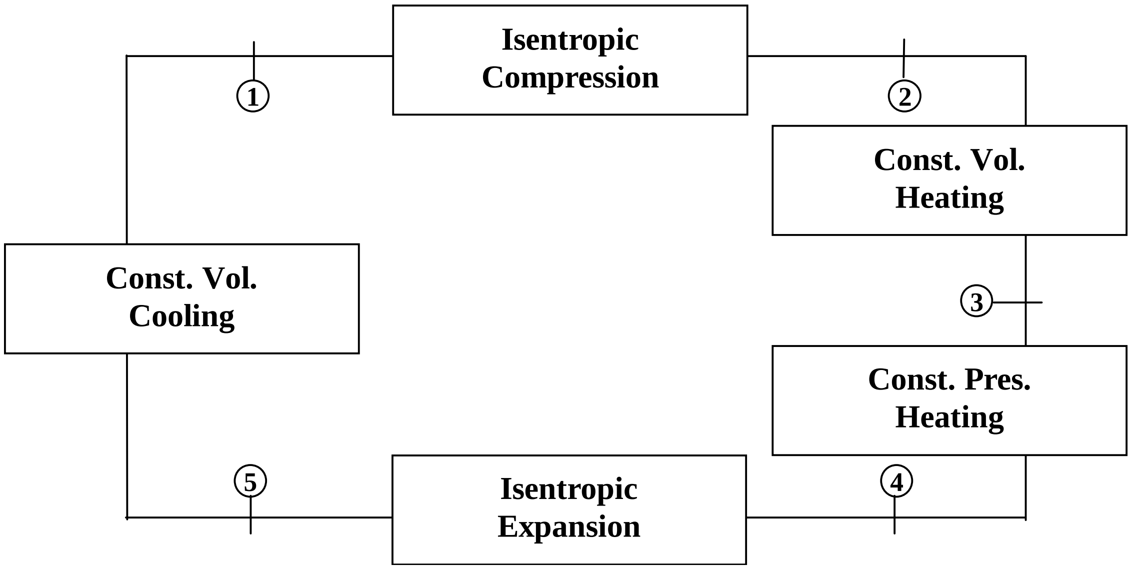
$$r_c = \frac{V_3}{V_{TDC}}$$

3. Dual Cycle

The Dual cycle consists of five processes and is a hybrid of the Otto and Diesel cycles

Isentropic Compression
Constant Volume Heat Addition
Constant Pressure Heat Addition
Isentropic Expansion
Constant Volume Heat Rejection

The block diagram for the cycle is shown below



Required operating data includes

Initial Temperature and Pressure
Volumes and/or compression ratio
Cutoff Ratio
Pressure Ratio or Maximum Operating Temperature

The pressure ratio is given as

$$r_P = \frac{P_3}{P_2}$$

The maximum operating temperature must be

$$T_4 = T_{max}$$

which will allow us to determine the pressure at 4 from the ideal gas law, which is also the pressure at 3.