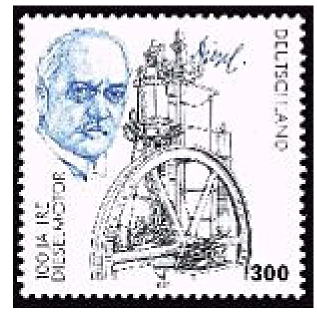
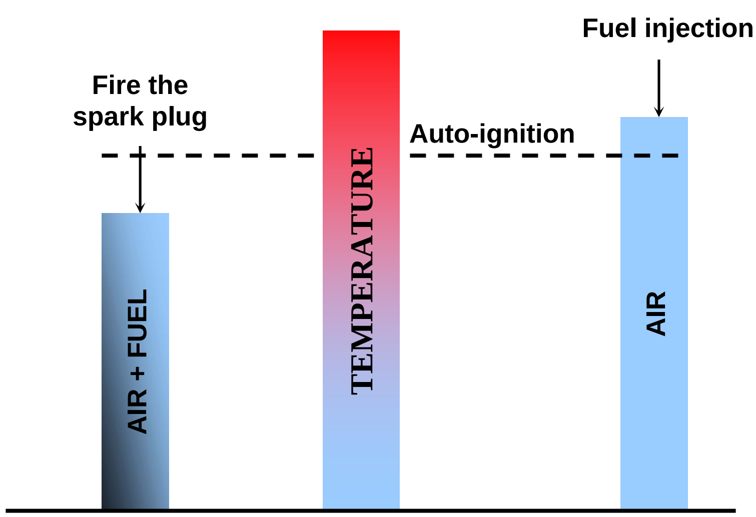
DIESEL Cycle

In July 1878, 19-year-old Rudolf Diesel sat in a classroom at the Polytechnic High School of Germany, the nation's top engineering college, while Professor Carl von Linde lectured on thermodynamics. Von Linde, one of the school's most distinguished scholars, was talking about steam engines, and the young Diesel was disturbed by the professor's statement that steam engines utilized only 10% of the fuel to perform useful work—the rest of the fuel produced useless heat. In the margin of his notebook, Diesel wrote: "Study the possibility of development of the isotherm." These words were the seed that germinated into one of the great inventions of our times: the diesel engine.



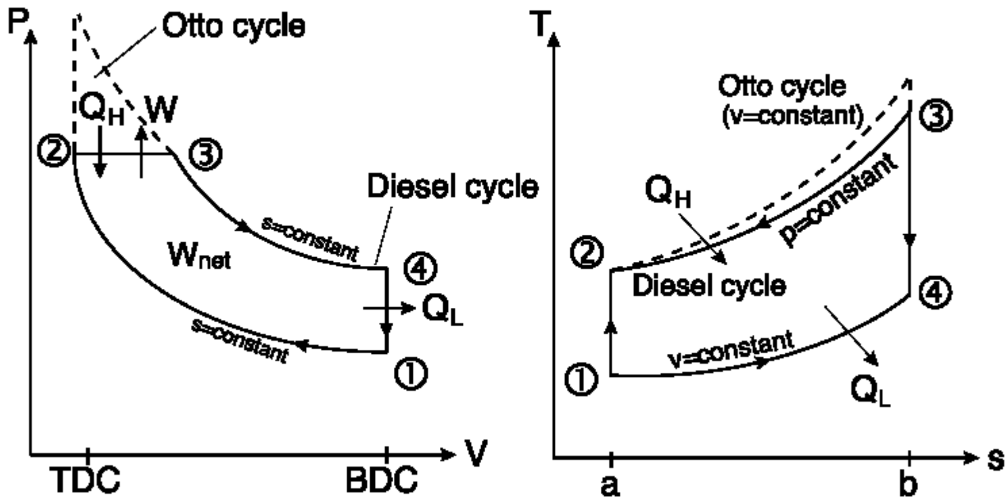
- Difference between Otto and Diesel cycles:

Otto cycle	Diesel cycle
Ignition engine [The combustion is initiated using a spark plug] Heat transfer at constant **VOLUME**	Compression engine [Auto-ignition due to compression] Heat transfer at constant **PRESSURE**



The main difference between Otto cycle and Diesel cycle is how the heat is supplied to initiate combustion.

- Diesel cycle thermal efficiency



we define:

the compression ratio: $r = \frac{v_1}{v_2} = \frac{v_4}{v_2} \neq \frac{v_4}{v_3}$

the cutoff ratio: $r_c = \frac{v_3}{v_2}$

$$\eta_{th} = \frac{W_{net}}{Q_H} = \frac{Q_H - Q_L}{Q_H} = 1 - \frac{Q_L}{Q_H}$$

but; $Q_L = \dot{m}\, C_v \left(T_4 - T_1\right)$ and $Q_H = \dot{m} \boxed{C_p} \left(T_3 - T_2\right)$

Therefore;

$$\eta_{th} = 1 - \frac{\dot{m}\, C_v \left(T_4 - T_1\right)}{\dot{m}\, C_p \left(T_3 - T_2\right)} = 1 - \frac{1}{k}\frac{\left(T_4 - T_1\right)}{\left(T_3 - T_2\right)} = 1 - \frac{1}{k}\frac{T_1\left(\frac{T_4}{T_1} - 1\right)}{T_2\left(\frac{T_3}{T_2} - 1\right)} \quad \text{(eq.8.2)}$$

$$\rightarrow \quad \frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{k-1} = r^{k-1} \Leftrightarrow \frac{T_1}{T_2} = \frac{1}{r^{k-1}}$$

$$\rightarrow \quad \frac{T_3}{T_2} = \frac{\dfrac{P_3 v_3}{R}}{\dfrac{P_2 v_2}{R}} = \frac{P_3 v_3}{P_2 v_2} = \frac{v_3}{v_2}\bigg|_{P_3 = P_2} = r_c \qquad \text{(eq.8.3)}$$

↑
For a Diesel engine

$\rightarrow$ and finally for the term $\frac{T_4}{T_1}$:

$$\frac{T_3}{T_4} = \left(\frac{v_4}{v_3}\right)^{k-1} ; \quad \frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{k-1}$$

therefore; $\frac{T_3 T_1}{T_4 T_2} = \left(\frac{v_4}{v_3}\right)^{k-1} \left(\frac{v_2}{v_1}\right)^{k-1} = \left(\frac{v_4 v_2}{v_3 v_1}\right)^{k-1} = \left(\frac{v_2}{v_3}\right)^{k-1} = r_c^{1-k}$

but from (eq.8.3): $\frac{T_3}{T_2} = r_c$

hence, $r_c \frac{T_1}{T_4} = r_c^{1-k} \Leftrightarrow \frac{T_1}{T_4} = r_c^{-k} \Leftrightarrow \frac{T_4}{T_1} = r_c^{k}$

Finally replacing in eq.8.2, gives

$$\eta_{th} = 1 - \frac{1}{r^{k-1}}\left[\frac{r_c^k - 1}{k\left(r_c - 1\right)}\right]$$

for the same compression ratio the Otto cycle (gasoline cycle) is more efficient than the Diesel cycle.
Example:
r=10; r_c=2
The Otto cycle efficiency is 60.2%
The Diesel cycle efficiency is 53.7%

However, in practice, a compression ratio of 20 can be achieved in a Diesel engine.
Therefore, the Diesel cycle efficiency rises up to 64.7%.

Because of the higher compression ratios, Diesel engines typically operate at a higher efficiency than gasoline engines.

- Some additional info

The Zeppelin Hindenburg was propelled by reversible diesel engine. From full power forward, the engine could be brought to a stop, changed over, and brought to full power in reverse in less than 60 seconds.

The first production Diesel cars were the Mercedes- Benz 260 D in 1936.

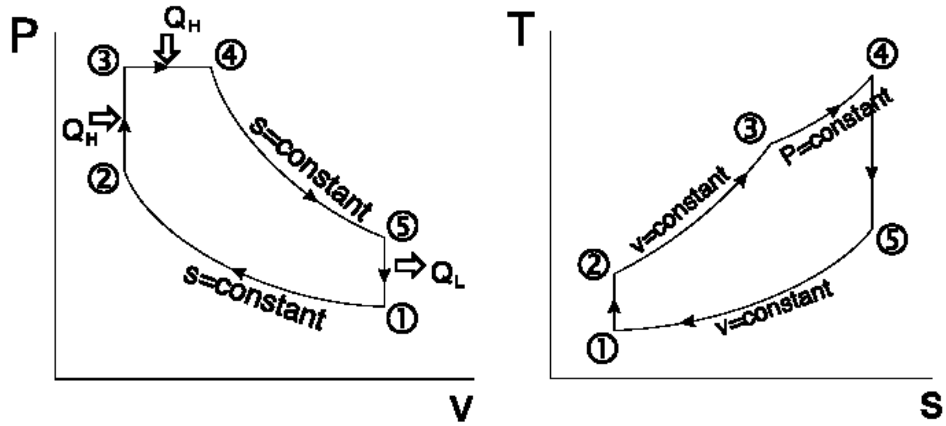
One anecdote tells of Formula One driver Jenson Button, who was arrested while driving a diesel-powered BMW 330cd Coupé at 230 km/h in France, where he was too young to have a gasoline-engined car hired to him. Button dryly observed in subsequent interviews that he had actually done BMW a public relations service, as nobody had believed a diesel could be driven that fast.

<u>Example</u>

A Diesel cycle operates on air with a low pressure of 0.1 MPa and a low temperature of 15°C. If the compression ratio is 16 and the heat supplied is 1800 kJ/kg; compute:

1- The pressure, the temperature and the specific volume for each state.
2- The cutoff ratio.
3- The thermal efficiency.
4- The mean effective pressure.

- DUAL cycle (Pressure limited cycle)



This is a more realistic process (combinaison of Otto (v=cte) and Diesel (P=cte) cycles), since the relative amount of heat transferred during each process can be adjusted to approximate the actual cycle closely.