

# Diesel Cycle Ideal vs Real Operation Analysis

An Online Continuing Education Course for Engineers

**Course Number: M-1039**

**Credit: 1 Hour / 1 PDH / 1 CPD**

# Diesel Cycle Ideal vs Real Operation Analysis

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## Course Description

In this one hour course, the open, simple Diesel Cycle used for stationary power generation is considered.

The Diesel Cycle thermal efficiency is presented only for the air as the working fluid. The thermal efficiency derivation is presented with a simple mathematical approach. The Diesel Cycle is presented in the  $p - V$  and  $T - s$  diagrams and its major performance trends (thermal efficiency and power output) are plotted in a few figures as a function of compression and cut off ratio values, combustor outlet temperature, some fixed cylinder geometry and both isentropic compression and expansion efficiency. It should be noted that this online course does not deal with costs (capital, operational or maintenance).

In this course, the student gets familiar with the Diesel Cycle, its components,  $p - V$  and  $T - s$  diagrams, ideal and operation and major performance trends.

This course includes a multiple-choice quiz at the end.

## Performance Objectives

At the conclusion of this course, the student will:

- Understand basic energy conversion engineering assumptions and equations
- Know basic components of the Diesel Cycle and its  $p - V$  and  $T - s$  diagrams
- Be familiar with the Diesel Cycle ideal and real operation
- Understand general Diesel Cycle performance trends

## Introduction

Over the years, diesel engine has become the premier transportation system for intermediate and high loads. Diesel engines are compact, lightweight, easy to operate and come in sizes ranging from several kilowatts to a few megawatts. Diesel engines require relatively low capital investment, have high operating flexibility, high thermal efficiency and can be used for various transportation and industrial applications. Diesel engines can help provide reliable power to meet the future demand using both high and low heat content fuels, with low emissions.

## Diesel Cycle

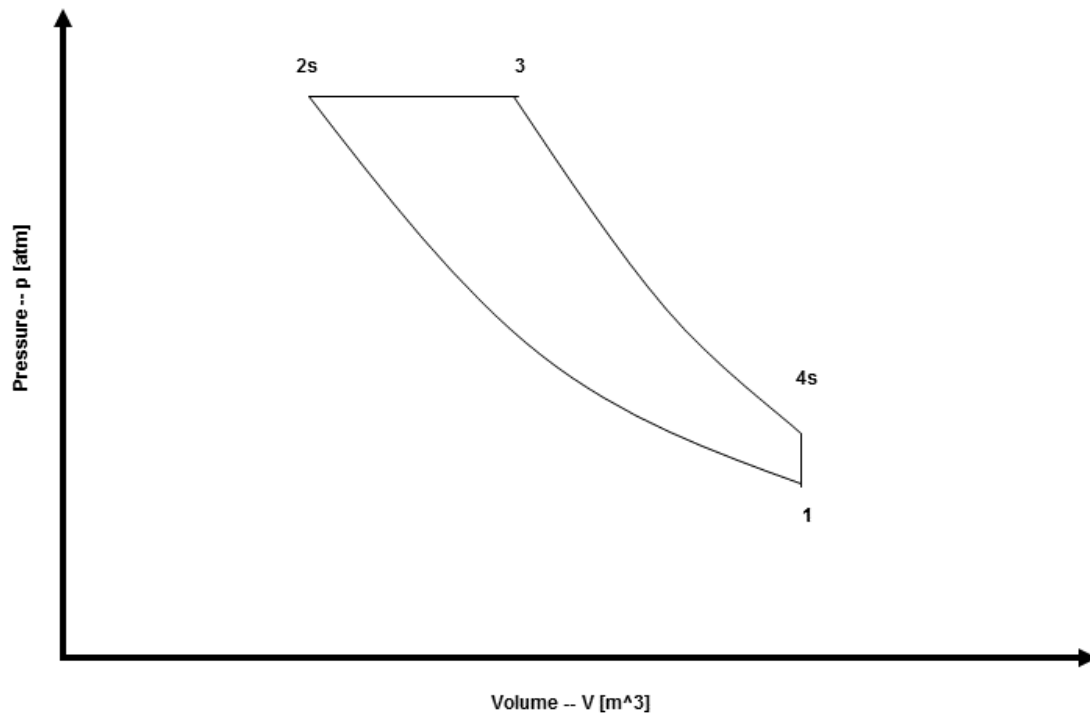
This section provides a Diesel Cycle analysis when the working fluid is air.

### Analysis

In the presented Diesel Cycle analysis, only air is considered as the working fluid behaving as a perfect gas -- specific heat has a constant value. Ideal gas state equation is valid --  $pV = RT$ .

Air enters a cylinder at point 1 when compression starts and it ends at point 2. Heat addition starts at point 2 and it ends at point 3. At a constant pressure, combustion takes place (fuel is added to the cylinder and the air temperature raises) and/or heat gets added to air. Expansion starts at point 3 and it ends at point 4. Air heat rejection starts at point 4 and it ends at point 1. At a constant volume, air gets cooled and the working fluid temperature decreases. It should be mentioned that air at point 1 enters the compression process again and the cycle is repeated.

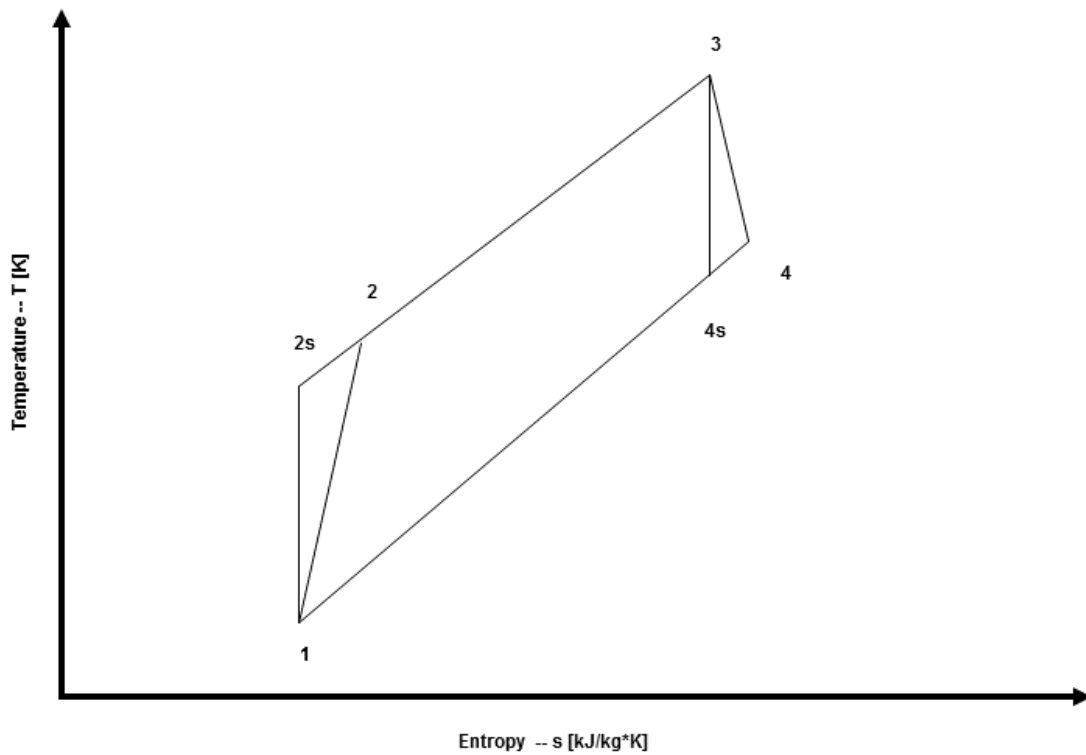
Figure 1 presents a Diesel Cycle pressure vs volume diagram.



**Diesel Cycle p - V Diagram**

**Figure 1 - Diesel Cycle Pressure vs Volume Diagram**

Figure 2 presents a Diesel Cycle temperature vs entropy diagram.



**Diesel Cycle T - s Diagram**

**Figure 2 - Diesel Cycle Temperature vs Entropy Diagram**

The thermal cycle efficiency can be given as a function of specific external work (specific net power output) and heat added to the working fluid as follows:

$$\eta = w/q_h = (w_e - w_c)/q_h = (q_h - q_l)/q_h$$

or

$$\eta = 1 - q_l/q_h = 1 - (c_v(T_4 - T_1))/(c_p(T_3 - T_2))$$

or

$$\eta = 1 - (c_v(T_4 - T_1))/(c_p(T_3 - T_2))$$

where

$\eta$  - thermal efficiency [/]

$\eta_c$  - isentropic compression efficiency [/]

$\eta_e$  - isentropic expansion efficiency [/]

$w$  - specific external work (specific net power output) [kJ/kg]

$w_e$  - expansion specific power output [kJ/kg]

$w_c$  - compression specific power input [kJ/kg]

$W$  - external work (net power output) [kW]

$W_e$  - expansion power output [kW]

$W_c$  - compression power input [kW]

$q_h$  - heat added to the working fluid [kJ/kg]

$q_l$  - heat rejected from the working fluid [kJ/kg]

$c_p$  - specific heat at constant pressure [kJ/kg\*K]

$c_v$  - specific heat at constant volume [kJ/kg\*K]

$m$  - working fluid mass flow rate [kg/s]

$\varepsilon$  - compression ratio [/]

$\phi$  - cut off ratio [/]

For isentropic compression and expansion:

$$T_{2S}/T_1 = (p_2/p_1)^{(\kappa-1)/\kappa} = (V_1/V_2)^{(\kappa-1)}$$

$$T_{4S}/T_3 = (p_4/p_3)^{(\kappa-1)/\kappa} = (V_3/V_4)^{(\kappa-1)}$$

where

$$\kappa = c_p/c_v - \text{for air } \kappa = 1.4 \text{ [/]}$$

$V_1, V_2, V_3, V_4$  - volume values at points 1, 2, 3 and 4 [m<sup>3</sup>]

$p_1, p_2, p_3, p_4$  - pressure values at points 1, 2, 3 and 4 [atm]

$T_1, T_{2s}, T_2, T_3, T_{4s}, T_4$  - temperature values at points 1, 2s, 2, 3, 4s and 4 [K]

$$\eta_c = (T_{2s} - T_1)/(T_2 - T_1)$$

$$T_2 = T_1 + (T_{2s} - T_1)/\eta_c$$

$$\eta_e = (T_3 - T_4)/(T_3 - T_{4s})$$

$$T_4 = T_3 - (T_3 - T_{4s})\eta_e$$

Knowing that

$$s_3 - s_{2s} = s_{4s} - s_1$$

and

$$s_3 - s_2 = c_p \ln(T_3/T_{2s})$$

$$s_4 - s_1 = c_v \ln(T_{4s}/T_1)$$

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where

1, 2, 3 and 4 [kJ/kg\*K]

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

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