

Given:

An ideal Diesel cycle with air as the working fluid has a compression ratio of 18 and a cutoff ratio of 2. At the beginning of the compression process, the working fluid is at 14.7 psia, 80°F, and 117 in³.

$$r := 18 \quad r_c := 2 \quad P_1 := 14.7 \text{ psi} \quad T_1 := 80^\circ \text{F} \quad V_1 := 117 \text{ in}^3$$

Required:

Utilizing the cold-air-standard assumptions, determine the temperature and pressure of air at the end of each process, the net work output and the thermal efficiency, and the mean effective

Solution:

Since the cold-air-standard assumption may be used, air may be treated as having constant specific heats at room temperature. Furthermore, the properties of air may be found from Table

$$A-2E \left(R_{\text{air}} := 0.06855 \frac{\text{Btu}}{\text{lbm} \cdot \text{R}} \quad c_p := 0.240 \frac{\text{Btu}}{\text{lbm} \cdot \text{R}} \quad c_v := 0.171 \frac{\text{Btu}}{\text{lbm} \cdot \text{R}} \quad k := 1.4 \right)$$

The volumes for each state may be determined using the compression ratio and cutoff ratio. This is shown below

$$r = \frac{V_1}{V_2} \quad V_2 := \frac{V_1}{r} = 6.5 \text{ in}^3$$

$$r_c = \frac{V_3}{V_2} \quad V_3 := r_c \cdot V_2 = 13 \text{ in}^3$$

$$V_4 := V_1 = 117 \text{ in}^3$$

Since the process from 1 to 2 is isentropic and has constant specific heats, the following is true.

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2} \right)^{k-1} \quad T_2 := T_1 \cdot \left(\frac{V_1}{V_2} \right)^{k-1} = 1714.9 \text{ R} \quad T_2 = 1255.2^\circ \text{F}$$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2} \right)^k \quad P_2 := P_1 \cdot \left(\frac{V_1}{V_2} \right)^k = 840.8 \text{ psi}$$

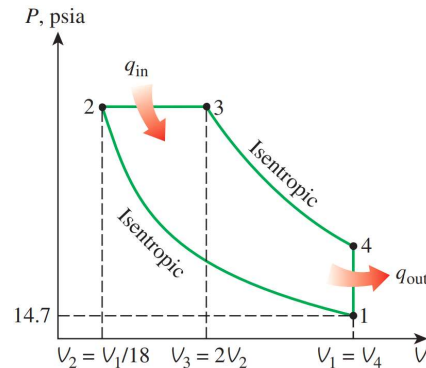
From state 2 to 3, the pressure is constant so

$$P_3 := P_2 = 840.8 \text{ psi}$$

The Ideal Gas Law may be used to determine the temperature at state 3.

$$P \cdot V = m \cdot R \cdot T$$

$$\frac{m \cdot R}{P} = c = \frac{V}{T} \quad \text{thus} \quad \frac{V_2}{T_2} = \frac{V_3}{T_3} \quad T_3 := T_2 \cdot \frac{V_3}{V_2} = 3429.8 \text{ R} \quad T_3 = 2970.1^\circ \text{F}$$



Solution (contd.):

Since the process from 3 to 4 is isentropic and has constant specific heats, the following is true.

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4} \right)^{k-1} \quad T_4 := T_3 \cdot \left(\frac{V_3}{V_4} \right)^{k-1} = 1424.2 \text{ R} \quad T_4 = 964.5^\circ\text{F}$$

$$\frac{P_4}{P_3} = \left(\frac{V_3}{V_4} \right)^k \quad P_4 := P_3 \cdot \left(\frac{V_3}{V_4} \right)^k = 38.8 \text{ psi}$$

The mass contained in the cycle may be determined by the Ideal Gas law at state 1.

$$P \cdot V = m \cdot R \cdot T \quad m := \frac{P_1 \cdot V_1}{R_{\text{air}} \cdot T_1} = 4.979 \times 10^{-3} \text{ lbm}$$

The process from state 2 to 3 is the heat addition stage of the cycle. Since there is boundary work that occurs during this process, the heat added is

$$Q_{\text{in}} = m \cdot (h_3 - h_2) = m \cdot c_p \cdot (T_3 - T_2)$$

$$Q_{\text{in}} := m \cdot c_p \cdot (T_3 - T_2) = 2.049 \text{ Btu}$$

The process from state 4 to 1 is the heat rejection stage of the cycle. Since the process is a constant volume process, the heat rejected is

$$Q_{\text{out}} = m \cdot (u_4 - u_1) = m \cdot c_v \cdot (T_4 - T_1)$$

$$Q_{\text{out}} := m \cdot c_v \cdot (T_4 - T_1) = 0.753 \text{ Btu}$$

The net work of the cycle is then

$$W_{\text{net}} := Q_{\text{in}} - Q_{\text{out}} = 1.296 \text{ Btu}$$

The thermal efficiency is given by

$$\eta_{\text{th}} := \frac{W_{\text{net}}}{Q_{\text{in}}} = 63.25\%$$