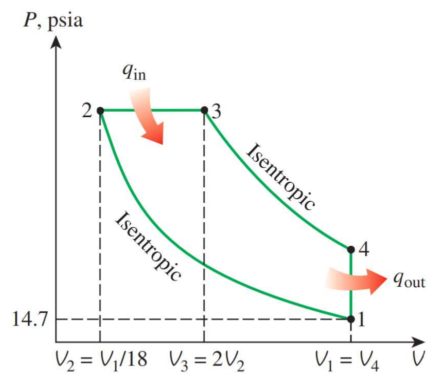
Given:

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 in^3.

$r := 18 \quad r_c := 2 \quad P_1 := 14.7psi \quad T_1 := 80\,°F \quad V_1 := 117in^3$



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 pressure.

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($R_{air} := 0.06855\frac{Btu}{lbm\cdot R} \quad c_p := 0.240\frac{Btu}{lbm\cdot R} \quad c_v := 0.171\frac{Btu}{lbm\cdot R} \quad k := 1.4$

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

$$r = \frac{V_1}{V_2} \qquad V_2 := \frac{V_1}{r} = 6.5\cdot in^3$$

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

$$V_4 := V_1 = 117\cdot in^3$$

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

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

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

From state 2 to 3, the pressure is constant so

$$\boxed{P_3 := P_2 = 840.8\cdot psi}$$

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

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

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

Solution (contd.):

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

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

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

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

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

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

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

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

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

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

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

The net work of the cycle is then

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

The thermal efficiency is given by

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

The mean effective pressure is given by

$$\boxed{MEP := \frac{W_{net}}{V_1 - V_2} = 109.5 \, psi}$$