Problem 7.6.1: A flue gas flows through a cyclone separator at a rate of 4520 acfm having a particulate loading (C_1) of 5 gr/ft^3 at 1600 °F. The cyclone is 3 ft in diameter (D_c) and its inlet duct is rectangular in shape having width (B_c) of 0.75 ft and height (H_c) of 1.5 ft. The flue gas contains particulate matter having three distinct sizes (d_1 = 5, d_2 = 25, and d_3 = 60 μm). The corresponding weight fractions (X) of particulates are 0.25, 0.5, and 0.25, respectively. The particle density (ρ_p) is found to be 181.05 lb/ft^3. The gas viscosity (μ) is found to be 3.11×10^{-5} lb/(ft.s). The effective number of turns (N) is 6. What is the particulate concentration (C_2) at the outlet of the cyclone?

Solution:

$$Q_g = 4520\frac{ft^3}{\text{min}} = 75.33\frac{\text{ft}^3}{\text{s}}$$

$$V_i = \frac{Q_g}{HW} = 66.96\frac{\text{ft}}{\text{s}}$$

$$d_c = \sqrt{\frac{9\mu.B_c}{2\pi.N.V_i.(\rho_p - \rho_g)}} = = 2.14\times10^{-5}\text{ ft} = 6.5\,\mu\text{m}$$

where d_c = particle diameter collected with 50 percent efficiency, ft
V_i = gas inlet velocity, ft/s

$$\eta = \frac{1}{1+\left(\frac{d_c}{d}\right)^2}$$

$$\eta_1 = 0.369,\ \eta_2 = 0.936,\ \eta_3 = 0.988$$

$$Removal = R = \Sigma\eta_i.X_i = 0.807$$

$$C_2 = C_1.(1 - R) = 0.963\frac{gr}{ft^3}$$