Table 3. Input data for cyclone design or air pollution control.

Value of cyclone overall height, ft?	26.333
Value of cylindrical height of cyclone, ft?	8.552
Value of cyclone diameter, ft?	6.333
Value of cyclone dust-outlet diameter, ft?	2.533
Value of cyclone gas inlet length, ft?	4.500
Value of cyclone gas inlet width, ft?	1.896
Value of cyclone gas outlet length, ft?	3.448
OK to continue (Y/N)?	
Value of cyclone gas outlet diameter, ft?	3.792
Value of gas rate, ft³/s?	516.700
Value of particle density, lb/ft³?	62.430
Value of gas density, lb/ft³?	0.075
Value of gas viscosity, lb/ft-s?	0.00001280
Value of gas temperature, °F?	110.000
Value of particle size, ft?	0.00003281
OK to continue (Y/N)?	

Table 4. Cyclone design.

Cyclone Overall Height, ft	26.333
Cyclone Cylindrical Height, ft	8.552
Cyclone Diameter, ft	6.333
Cyclone Dust-Outlet Diameter, ft	2.533
Cyclone Gas Inlet Length, ft	4.500
Cyclone Gas Inlet Width, ft	1.896
Cyclone Gas Outlet Length, ft	3.448
Cyclone Gas Outlet Diameter, ft	3.792
Gas Rate, ft³/s	516.70
Particle Density, lb/ft³	62.430
Gas Density, lb/ft³	0.075
Gas Viscosity, lb/ft-s	0.128000×10^{-4}
Gas Temperature, °F	110.000
Particle Size Equivalent, ft	0.328100×10^{-4}
Relaxation Time, s	0.000292
Inlet Fluid Velocity, ft/s	60.560
Saltation Velocity, ft/s	22.108
Cyclone Configuration Factor	89.728
Cyclone Pressure Drop, in H_2O	7.834
Do You Want to Print the Results?	Y
Cyclone Efficiency, %	63.305
Effective Number of Turns	3.71
Critical Particle Diameter, ft	0.643700×10^{-4}
Critical Particle Diameter, microns	18.58
Ratio of Particle Diameter to Critical Diameter	0.510

Lieberman *(10)* has reviewed the causes of these maloperations, which often result in loss catalyst and reduced efficiency. A deficient cyclone reactor is identified by bottom sediment and water levels in the slurry oil products. For a regenerator cyclone, problems are visibly identified by the increased opacity of the regenerator flue gas or by reduced rates of spent catalyst withdrawal.

Cyclone collection efficiency

Many theories have been proposed to predict the performance of a cyclone, although no fundamental relationship has been accepted. Attempts have been made to predict the critical particle diameter, $(D_p)_{crit}$. This is the size of the smallest particle that is theoretically separated from the gas stream with 50% efficiency. The critical particle diameter is defined by Walas in Ref. 11.

$$(D_p)_{crit} = \left[\frac{9\mu D_c}{4\pi N_t v_i(\rho - \rho_g)}\right]^{0.5} \quad (18)$$

where N_t is the effective number of turns made by the gas stream in the cyclone, and is defined by

$$N_t = (v_i)\left[0.1079 - 0.00077V_i + 1.924\left(10^{-6}\right)v_i^2\right] \quad (19)$$

where v_i is the inlet linear velocity.

Figure 2 shows the percentage removal of particles in a cyclone as a function of the ratio of the particle to the critical diameter.

Cyclone design factors

Cyclones are designed to meet specified ΔP limitations. The factor that controls the collection efficiency is the cyclone diameter, and a smaller diameter cyclone at a fixed ΔP will have a higher efficiency. Therefore, small diameter cyclones require a multiple of units in parallel for a given capacity. Reducing the gas outlet diameter results in an increased collection efficiency and ΔP. High-efficiency cyclones have cone lengths in the range of 1.6 to 3.0 times the cyclone diameters.

Collection efficiency increases as the gas throughput increases. Kalen and Zenz *(9)* reported that collection efficiency increases with increasing gas inlet velocity to a minimum tangential velocity. This reaches the point where the dust is re-entrained or not deposited because of saltation. Koch and Licht *(7)* showed that saltation velocity is consistent with cyclone inlet velocities in the range of 50 to 90ft/s.

Design problem

Problem. Determine the efficiency and pressure drop (ΔP) based on cyclone dimensions and the gas flow rate at 516.7 ft³/s and density of 0.075 lb/ft³ containing particles with density of 62.43 lb/ft³. The dimensions and data required are shown in Table 2.

Solution. The computer program CYCLONE has been developed to calculate the efficiency and pressure drop of a cyclone using the cyclone geometry, fluid and particle specifications. Table 3 is the input data, and Table 4 gives the computer printouts of the program. The computed ratio of the particle diameter relative to the critical diameter is 0.54. Figure 2 shows that the percentage removal of the particle is 28%. CEP