Table 2. Dimensions and data for a typical design problem.

Cyclone Gas Inlet Height, ft	4.5
Cyclone Gas Inlet Width, ft	1.896
Cyclone Gas Outlet Length, ft	3.448
Cyclone Gas Outlet Diameter, ft	3.792
Cyclone Cylindrical Height, ft	8.552
Cyclone Diameter, ft	6.333
Gas Rate, ft³/s	516.7
Gas Density, lb/ft³	0.075
Particle Density, lb/ft³	62.430
Gas Viscosity, lb/ft-s	1.28×10^{-5}
Temperature, °F	110
Particle Size, ft	3.281×10^{-5}

$K = 16$ for no inlet vane; $K = 7.5$ with a neutral inlet vane. Pressure drop, ΔP, depends strongly on the inlet velocity, and high velocities can cause both reentrainment and high pressure drop. However, entrainment can be reduced to a minimum, if the cyclone has a small base angle.

Troubleshooting cyclone maloperations

In general, cyclones are used to separate particles from the gas stream, but recent developments have enabled cyclones to function as reactors. Some cyclone reactors can separate cracking catalyst from vaporized reaction products in the range of 950°F and 1,000°F, or can function as regenerators for flue gases between 1,250°F and 1,500°F. In both cases, the high particle velocities can cause rapid erosion of the cyclone material. This often results in poor performance of the cyclone. Other causes of poor cyclone performance are:

- a hole in a cyclone body;
- a cyclone volute plugged;
- a dip leg unsealed;
- a dip leg plugged; and
- dip leg failure.

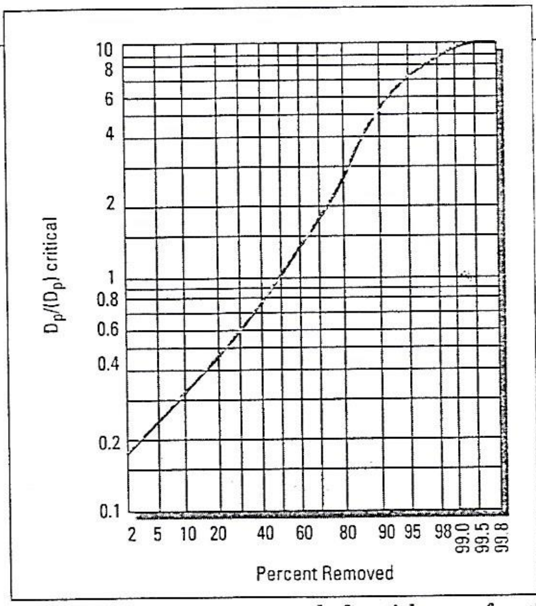

Figure 2. Percentage removal of particles as a functio of particle diameter relative to the critical diameter.

Nomenclature

- a = inlet height, ft
- b = inlet width, ft
- B = cyclone dust-outlet diameter, ft
- d = diameter of central core at a point where vortex turns, ft
- d_{pi} = diameter of particle in size range, i, ft
- D_c = cyclone diameter, ft
- D_e = cyclone gas-outlet diameter, ft
- $(D_p)_{crit}$ = critical particle diameter, ft
- g = acceleration due to gravity, 32.2. ft/s²
- G = cyclone configuration factor
- h = cylindrical configuration factor
- i = subscript denotes interval n particle size range
- K_a = a/D_c
- K_b = b/D_c
- K_c = cyclone volume constant
- l = natural length (distance below gas outlet where vortex turns), ft
- n = vortex component
- N_H = number of inlet velocity heads
- N_t = effective number of turns made by the gas stream in the cyclone
- ΔP = pressure drop, H_2O
- Q = total gas flow rate, actual ft³/s
- S = gas outlet length, ft
- T = temperature, °F
- v_i = inlet velocity, ft/s
- v_s = saltation velocity, ft/s
- V_H = volume below exit duct (excluding core), ft³
- V_{nl} = volume at natural length (excluding core), ft³
- V_s = annular volume above exit duct to middle of entrance duct, ft³

Greek Letters

- η_i = grade efficiency for particle size at mid-point of internal i, %
- μ = fluid viscosity, lb_m/ft-s
- ρ_f = fluid density, lb_m/ft^3
- ρ_p = particle density, lb_m/ft^3
- τ = relaxation time, s
- ω = angular velocity parameter corrected for gravity and densities (see also Eq. 14.)

Literature Cited

1. **Kelsall, M. A.**, "A Study of the Motion of Solid Particles in a Hydraulic Cyclone," *Trans IChemE*, **30**, p. 87-108 (1952).

2. **Coker, A. K., and G. V. Jeffreys**, "Flow Patterns and Residence Time Distribution In Nozzle-Type Reactors," *IChemE Symp. Ser.*, Fluid Mixing III, **108**, p. 105 (1987).

3. **Coker, A. K.**, "A Study of Fast Reactions in Nozzle Type Reactors," PhD Thesis, Aston University, U. K. (1985).

4. **Coker, A. K., G. V. Jeffreys, and C. J. Mumford**, "Mechanisms of Nozzle Type Reactor Operations With Gas Removal," *Scientific Res.*, **49**, pp. 67-81 (1992).

5. **Stairmand, C. J.**, "Design and Performance of Cyclone Separators, " *Trans. IChenE.*, **29**, p. 356 (1951).

6. **Strauss, N., "Industrial Gas Cleaning,"** Chapter 6, Pergamon Press, New York (1966).

7. **Koch, W. H., and W. L. Licht**, "New Design Approach Boosts Cyclone Efficiency," *Chem Eng.*, pp. 80-88 (Nov. 1977).

8. **Zenz, F. A.**, "Conveyability of Materials of Mixed Particle Size," *Ind. & Eng. Chem. Fund.*, **3**, p. 65 (1964).

9. **Kalen, B., and F. A. Zenz**, "Theoretical-Empirical Approach to Saltation Velocity in Cyclone Design," *AIChE Symposium Series.* **70**, 137, P. 388 (1974).

10. **Lieberman, N. P.**, "Troubleshooting Process Operations," 2nd ed., Pennwell Books, Tulsa, OK (1985).

11. **Walas, S. M.**, "Chemical Process Equipment—Selection and Design," Butterworth Series in Chemical Engineering. Butterworth Publishers, Stoneham, MA (1988

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