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Revision Memo

11/03	Minor revision to the December 1998 issue. Added information on the CycloFines™ technology.
12/98	This is a minor revision to the December, 1993 issue. The section on FINES HOPPER AND COLLECTION DEVICE has been expanded. Minor editorial changes have also been made.

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SCOPE

This section discusses the use of dry cyclone systems for air pollution control applications. The material presented here compliments and supplements [Section VI-C, Fluid Solids - Particle Collection](#).

REFERENCES

DESIGN PRACTICES

[Section VI-B](#) Fluid Solids - Pneumatic Conveying of Solids

[Section VI-C](#) Fluid Solids - Particle Collection

OTHER REFERENCES

1. Hoke, R.C., *Fluids Solids Design Guide*, EE.1E-X.89 (June 1989).
2. Tao, L.L. and Hoke, R.C., Revised Program T3575, *Fluidization and Particulate Emissions*, EE.1FF.85 (March 1985).
3. Theodore, Louis, *Air Pollution Control Equipment: Selection, Design, Operation and Maintenance*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1982.

BACKGROUND

A cyclone is a static device which removes particulates by centrifugal force. It converts the velocity of the inflowing gas stream into a confined vortex. The centrifugal forces generated tend to drive the suspended particles to the wall of the cyclone body where they collect and move by gravitational forces to the bottom of the cyclone. Three elements are required in order for a device to be a cyclone. They are:

- A gas inlet which can produce a vortex.
- An axial outlet for the clean gas.
- A dust discharge.

Since centrifugal forces are limited by practical aspects (e.g., pressure drop, erosion, etc.), the overall collection efficiency of cyclones is limited. Thus, cyclones in environmental applications are generally used to meet relatively lenient particulate regulations or as a precleaner to reduce dust loadings to devices having a higher collection efficiency on fine particles.

CYCLONE TYPE / DESIGNATIONS

Cyclone types are classified by the design of the gas inlet (tangential, scroll, or axial) and the design of the dust discharge (axial or peripheral). Two common types, depicted in [Figure 1](#), are:

- Tangential inlet with axial dust discharge. (Flow pattern shown in [Figure 2](#).)
- Axial inlet trough vanes with axial dust discharge.

Cyclones which have tangential or scroll inlets and an axial dust discharge are generally called conventional cyclones or, simply, cyclones. Conventional cyclones generally have large diameters [> 24 in. (61 cm)] but some vendors have designed conventional cyclones with diameters as small as 9 in. (23 cm). Cyclones which have axial inlets through vanes with axial dust discharge typically have diameters < 12 in. (30 cm). Since a large number of these smaller cyclones are typically required to handle most gas flows, they have traditionally been clustered together in a parallel array and are called multiclones.

ExxonMobil and Kellogg have jointly developed a new Fluid Catalytic Cracker (FCC) Multi-Cyclonic Third Stage Separator (TSS), which is called CycloFines™. ([Figure 6](#)) This new TSS has achieved higher removal efficiency of small particles compared to existing commercial TSS. CycloFines™ has a 10 in. barrel diameter and a 10 ft barrel length. The majority of the improved particle collection efficiency is due to the proprietary dust outlet termination device.

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Advantages of the CycloFines™ design include:

- + May achieve less than 50 mg/Nm³ particulates in the flue gas stack
- + Captures particles as small as 5 microns
- + Lowers flue gas stack opacity
- + Extends power recovery turbine blade life with higher average turbine efficiency

CycloFines™ can be incorporated as a:

- + Grassroots unit for optimum particle collection efficiency
- + Retrofit, with key aspects incorporated into most existing TSS units

Cyclones have also been designated by the number of cyclones in series. If a single-cyclone stage is used, the cyclones are called primary cyclones or just cyclones. For additional mass and/or smaller particle removal, a secondary and a tertiary stage can be installed. For environmental control, a tertiary stage for one application (e.g., fluid solids processes) may be meeting a similar particulate emission target as a primary stage for another application (e.g., an incinerator).

Cyclones should be given initial consideration for particulate removal due to their low cost and compact size. However, cyclones have disadvantages, such as low collection efficiency. The following is a list of their advantages and disadvantages in air pollution control applications.

ADVANTAGES

- Compactness. Cyclones have a high capacity to size ratio.
- Low capital and maintenance costs.
- Design flexibility. Cyclones can operate at high dust loading, temperature, and pressure, limited only by materials considerations.
- Mechanical reliability, typically.

DISADVANTAGES

- Cyclones have limited collection capabilities of small particles because they are a grade efficient device.
- Cyclones generally are not able to meet most of the current more stringent environmental regulations by themselves.
- Cyclone operation and performance cannot be modified except by changes in the upstream processes or by mechanical modification of the cyclone.

CYCLONE APPLICATIONS

APPLICATIONS

In air pollution control, cyclones, multiclones, and tertiary cyclone systems have the following typical applications:

- Petroleum refining fluid solids unit (Fluid Catalytic Cracker, Fluid Coker, Flexicoker) gas cleanup.
- Incinerator stack gas cleanup.
- Pneumatic transfer system product disengagement.
- Coal/Coke fired heaters.

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EFFECTS OF OPERATING VARIABLES ON CYCLONE PERFORMANCE

The following is a qualitative summary of the effect of a single change of variable on cyclone performance. The key variables are inlet velocity and dust properties.

INLET VELOCITY

1. Increasing inlet velocity increases pressure drop.
2. Increasing inlet velocity increases efficiency up to a maximum value. Further increases in velocity will cause efficiency to decrease due to increased turbulence. Thus, the optimum design point for a cyclone is just below the point of maximum efficiency, usually limited by erosion. The loss of performance at higher inlet velocities is poorly defined and is generally not included in performance equations.
3. Higher inlet velocities rapidly increase erosion.

DUST PROPERTIES

1. Larger particles are collected more efficiently than smaller particles, since these have greater separation forces. The critical particle diameter, d_c , is the diameter of the particle that is collected with 50% efficiency in a given cyclone. [Section VI-C, Eq. \(1\)](#), provides an easy way of hand calculating d_c . Computer Program T-3575 provides a rigorous efficiency calculation.
2. Collection efficiency increases with increasing particle density. This is because centrifugal force separates solids from fluids by their density difference.

GAS PROPERTIES

1. Increasing density increases pressure drop. This usually has negligible effect on efficiency.
2. Increasing gas viscosity reduces collection efficiency since it increases the drag on the particles which hinders settling.

DUST LOADING

1. Increased dust loading increases efficiency due to increased particle interaction which aids solids settling. However, due to low loading, tertiary cyclones do not experience this effect, but fines hopper cyclones do. See [Section VI-C, Figure 12](#) for the effect of dust loading on efficiency.
2. Experience suggests that increased dust loading reduces internal pressure drop and increases entrance pressure drop, but these effects are poorly defined.

NOISE

There is some evidence that some cyclone systems can generate pure tone noise which may lead to community complaints. Presently, the cause of the pure tone noise generation is not well-understood nor can it be predicted. Therefore, a noise specialist should be consulted during the cyclone design. The noise specialist can conduct a risk assessment and suggest if a silencer should be installed as a precaution.