

B.12 CYCLONES^{1,2,9,22}

B.12.1 Background

A cyclone is a mechanically aided collector that uses inertia to separate PM from the gas stream as it spirals through the cyclone. The collection efficiency of a cyclone improves as the number of revolutions made by the gas and the gas velocity increase. Ultimately, however, the overall performance depends on the particle size distribution of the incoming gas stream. Cyclones are generally used for collection of medium-sized and coarse particles.

Cyclone designs can be classified according to the manner by which the gas stream enters and exits the cyclone as: tangential inlet, axial dust outlet; tangential inlet, peripheral dust outlet; axial inlet, axial dust outlet; and axial inlet, peripheral dust outlet. In general, a vortex is created in the cylinder by injecting gas tangentially or using a spin vane. In the cyclone, the gas makes one or more revolutions, spiraling toward the bottom or end of the cyclone. Because of inertia, the particles resist the direction change as the gas turns, and they migrate toward the cylinder walls. Near the bottom of the cylinder, the gas changes direction and turns back toward the outlet duct, flowing through the center of the spiral; the particles are discharged downward or tangentially and are collected in a hopper.

Cyclones have a relatively simple construction and generally have no moving parts. Simple cyclones consist of an inlet cylindrical section, conical section, outlet gas duct, outlet dust tube, and collection hopper; a cyclone uses an induced draft fan to move the gas stream through the device. They are sized to provide the maximum inlet velocity possible for high separation without excessive turbulence. Multiclones (or multicyclones) consist of multiple small-diameter tubes in parallel, each of which acts like a small cyclone. This configuration combines the high efficiency of a small diameter with the ability to treat large gas volumes. Multiclone collection efficiency can be further improved by slip-streaming, in which a small portion of the gas is drawn through the collection hopper to create suction on the dust outlet tube and reduce dust re-entrainment into the multiclone tubes. Multiclones are sized to include the minimum number of tubes needed to treat the required gas volume without exceeding the maximum flow per tube.

Common operational problems experienced with cyclones and multiclones include erosion of cyclone components that come into contact with high velocity particles; plugging of the dust outlet or the gas inlet vanes; corrosion from contact with acid gases in the inlet gas stream; and air leakage that affects the inlet velocity and control efficiency of the cyclone.

B.12.2 Indicators of Cyclone Performance

The primary indicators of the performance of cyclones are the outlet opacity and inlet velocity. Other indicators of cyclone performance are the pressure differential across the cyclone and inlet gas temperature. Each of these indicators is described below. Table B-12 lists these indicators and illustrates potential monitoring options for cyclones.

Opacity. As is the case for all dry PM controls, opacity is an indicator of control device performance. An increase in opacity or visible emissions generally corresponds to a decrease in cyclone performance.

Inlet velocity or Inlet gas flow rate. Among other factors, cyclone control efficiency is a function of inlet velocity. As velocity increases, the inertial forces acting on particles in the gas stream increase, as does the likelihood that particles will impact the cyclone wall and be transported to the collection hopper. However, as velocity increases, turbulence forms in the gas stream and disrupts gas flow. Beyond a critical velocity, control efficiency decreases with increasing velocity. Below this critical velocity, decreases in velocity result in reductions in control efficiency.

Pressure differential. Because pressure differential across a cyclone is primarily a function of velocity, it can be used as a surrogate for velocity measurements. Therefore, up to the pressure differential that corresponds to the critical velocity, control efficiency increases with increasing pressure differential.

Inlet temperature. As temperature increases, gas density decreases, which can result in a decrease in collection efficiency. A change in gas temperature and density affects the inlet velocity. Monitoring inlet temperature applies to control of thermal processes only. However, the other parameters listed above are more reliable indicators of cyclone performance.

B.12.3 Illustrations

The following illustrations present examples of compliance assurance monitoring for cyclones:

- 12a: Monitoring cyclone inlet gas velocity (inlet gas flow rate).
- 12b: Monitoring pressure differential across cyclone.

B.12.4 Bibliography

TABLE B-12. SUMMARY OF PERFORMANCE INDICATORS AND MONITORING OPTIONS FOR CYCLONES

Parameters	Performance indication	Approach No.	1	2	3
		Illustration No.	12a	12b	
		Example CAM Submittals			
		Comment			
Primary Indicators of Performance					
Opacity/visible emissions	Increased opacity or VE denotes performance degradation. COMS, opacity observations, or visible/no visible emissions.				X
Inlet gas velocity or Inlet gas flow rate	Collection efficiency varies with inlet velocity. Efficiency increases with increasing velocity up to a critical velocity, beyond which turbulence disrupts flow patterns and control efficiency begins to decrease.		X		
Pressure differential	Indicator of gas velocity through cyclone. Increase in pressure differential generally indicates an increase in control efficiency, up to a critical pressure differential.			X	
Comments: None.					

CAM ILLUSTRATION
No. 12a. CYCLONE FOR PM CONTROL

1. APPLICABILITY

- 1.1 Control Technology: Cyclone [075]; also applicable to multiclones with or without fly ash reinjection [076, 077], centrifugal collectors [007, 008, 009], and other types of mechanical collectors and dry inertial separators
- 1.2 Pollutants
 - Primary: Particulate matter (PM)
 - Other: Heavy metals
- 1.3 Process/Emissions Unit: Combustors, mineral processing units, furnaces, kilns

2. MONITORING APPROACH DESCRIPTION

- 2.1 Indicators Monitored: Inlet gas velocity (Inlet gas flow rate).
- 2.2 Rationale for Monitoring Approach: Control efficiency increases with increased velocity; if inlet velocity exceeds a specific value, turbulence becomes excessive and control efficiency begins to decrease.
- 2.3 Monitoring Location: Inlet gas duct.
- 2.4 Analytical Devices Required: Differential pressure flow meter, anemometer, or other type of device that measures gas velocity or gas flow rate; see section 4.3 for information on specific types of instruments.
- 2.5 Data Acquisition and Measurement System Operation
 - Frequency of measurement: Once per shift, or recorded continuously on strip chart or data acquisition system.
 - Reporting units: Feet per minute (ft/min).
 - Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.
- 2.6 Data Requirements
 - Baseline inlet gas velocity measurements concurrent with emission test.
 - Historical plant records of inlet gas velocity measurements.
 - Manufacturer's design specifications and efficiency curve/equation for inlet gas velocity or pressure differential.
- 2.7 Specific QA/QC Procedures
 - Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.
- 2.8 References: 1, 2, 22.

3. COMMENTS

- 3.1 Because this illustration applies to a PM source, visible emissions or opacity monitoring is also an appropriate performance indicator.
- 3.2 Data Collection Frequency: For large emission units, a measurement frequency of once per shift or once per hour would not be adequate; collection of four or more data points each hour is required. (See Section 3.3.1.2.)

CAM ILLUSTRATION
No. 12b. CYCLONE FOR PM CONTROL

1. APPLICABILITY

- 1.1 Control Technology: Cyclone [075]; also applicable to multiclones with or without fly ash reinjection [076, 077], centrifugal collectors [007, 008, 009], and other types of mechanical collectors and dry inertial separators
- 1.2 Pollutants
 - Primary: Particulate matter (PM)
 - Other: Heavy metals
- 1.3 Process/Emissions Unit: Combustors, mineral processing units, furnaces, kilns

2. MONITORING APPROACH DESCRIPTION

- 2.1 Indicators Monitored: Pressure differential.
- 2.2 Rationale for Monitoring Approach: Control efficiency increases with increasing pressure differential; however, if the pressure differential exceeds a specific value, turbulence becomes excessive and control efficiency decreases. (Pressure differential is a function of inlet gas velocity, and changes in velocity result in changes in pressure differential across device.)
- 2.3 Monitoring Location: Gas inlet and outlet ducts.
- 2.4 Analytical Devices Required: Differential pressure transducer, differential pressure gauge, manometers, or alternative methods/instrumentation; see section 4.3 for information on specific types of instruments.
- 2.5 Data Acquisition and Measurement System Operation
 - Frequency of measurement: Once per shift, or recorded continuously on strip chart or data acquisition system.
 - Reporting units: Inches of water column (in. w.c.).
 - Recording process: Operators log data manually, or recorded automatically on strip chart or data acquisition system.
- 2.6 Data Requirements
 - Manufacturer's design specifications and efficiency curve/equation for inlet velocity and pressure differential.
 - Baseline pressure differential measurements concurrent with emission test.
 - Historical plant records of pressure differential measurements.
- 2.7 Specific QA/QC Procedures
 - Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.
- 2.8 References: 1, 2, 22.

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