B.2 ELECTROSTATIC PRECIPITATORS[1,2,7,8,9,22,23]

B.2.1 Background

Electrostatic precipitators (ESPs) use electrical energy to remove PM from exhaust gas streams. As the exhaust stream enters an ESP, PM in the gas encounters negatively charged ions, which apply a charge to the particles. The charged particles then are attracted to collector plates carrying the opposite charge. As the particles accumulate, they periodically are removed from the collector plates and collected in a hopper. Electrostatic precipitators can be broadly classified as either dry ESPs or wet ESPs; the primary difference between these two classifications is the method by which the collector plates are cleaned. In dry ESPs, the plates are cleaned by applying a mechanical impulse or vibration to the plates, thereby knocking loose the collected PM. This cleaning method is referred to as rapping. In wet ESPs, collector plates are cleaned by rinsing with water. This section focuses on dry ESPs, which hereafter are referred to simply as ESPs. Wet ESPs are discussed further in section B.3 of this Appendix. Examples of ESP applications include: coal-fired boilers; cement kilns; solid waste incinerators; paper mill recovery boilers; catalytic crackers; metallurgical furnaces; sulfuric acid plants; and iron and steel sinter plants.

The primary components of an ESP are the shell or housing, discharge electrodes, collection electrodes, high voltage equipment, rapping system, and collection hoppers. The shell encloses and supports the electrical components of the unit. A discharge electrode is the component that creates ions that collide with the particles and applies the electrical charge to PM in the incoming gas stream. An ESP typically has a series of discharge electrodes. The two basic discharge electrode designs are the weighted-wire and rigid-frame electrode. Weighted-wire electrodes consist of wires suspended from a frame at the top of the unit with weights attached to the ends to keep the wires in place. In rigid-frame systems, both ends of the electrode wires are attached to a frame. The weighted-wire design typically has higher maintenance costs (due to wire breakage), but closer spacing is allowed between the collection and discharge electrodes. The collection electrodes, which typically are called plates, provide the collection surfaces for the particulates. Although collection plates come in a variety of shapes, most consist of closely spaced sheets of carbon steel. High voltage equipment includes a transformer, rectifier, and several meters. Collectively, this equipment is called a T-R set. The transformer steps up the input voltage from between 400 and 480 volts to between 20,000 and 70,000 volts. The rectifier converts the input current from alternating to direct current. Metering generally includes a primary voltmeter, which measures the input voltage; primary ammeter, which measures the current drawn across the transformer; secondary voltmeter, which measures the voltage applied to the discharge electrodes; secondary ammeter, which measures the current supplied to the discharge electrodes; and sparkmeter, which measures the spark rate across the electrodes. The rapping system, which removes collected PM from the collection plates, may be an external roof-mounted rapper or an internal rotating hammer rapper. Collection hoppers are bins located directly below the collection plates to temporarily store the collected PM until it can be disposed.

To maximize control efficiency, most ESPs are designed with several bus sections or fields, each of which is equipped with separate, independent power supplies, controllers, and meters. Each of these fields acts as a separate ESP. The power supplied to the initial fields generally is higher because PM concentrations are highest at the inlet. Having multiple fields allows the operator flexibility in operating the ESP and reduces the likelihood of electrical failure shutting down the entire ESP.

B.2.2 Indicators of ESP Performance

The primary indicators of ESP performance are PM concentration, opacity, secondary corona power, secondary voltage (i.e., the voltage across the electrodes), and secondary current (i.e., the current to the electrodes). Other indicators of performance are the spark rate, primary current, primary voltage, inlet gas temperature, gas flow rate, rapper operation, and number of fields in operation. Each of these indicators is described below. Table B-2 lists these indicators and illustrates potential monitoring options for ESPs.

Outlet PM concentration. Particulate matter CEMS can be used to continuously monitor PM emission concentrations. These instruments are a fairly recent development and have yet to be put into widespread use.

Opacity. As is the case for all dry PM controls, opacity is an indicator of control device performance.

Secondary corona power. The secondary corona power is a measure of the energy consumed in the removal of PM from the gas stream. A decrease in power generally indicates a decrease in control efficiency. Secondary corona power is the product of the secondary voltage and the secondary current, and typically is monitored by measuring the secondary voltage and secondary current separately. Because each field is independent of the others, secondary voltage and current should be monitored in each field of the ESP.

Secondary current. Secondary current is a measure of the current supplied to the discharge electrodes and is a partial indicator of the energy or power consumed by the ESP. The secondary current is usually measured in conjunction with secondary voltage to calculate the power. A drop in current may indicate a loss of power. Current at too high a level indicates a short-circuit or sparking. Measuring the secondary current helps in identifying which fields are operating properly.

Secondary voltage. Secondary voltage is a measure of the voltage applied to the discharge electrodes and is a partial indicator of the energy or power consumed by the ESP. Increases in voltage result in increased corona, greater particle charging, and increased control efficiency up to a critical voltage, above which excessive spark occurs and control efficiency decreases. A decrease in voltage indicates lower particle charging. A decrease in voltage with a corresponding increase in current indicates a short circuit or sparking. Measuring the secondary voltage helps in identifying which fields are operating properly.

Spark rate. Under normal operation, electrical current repeatedly surges from the discharge electrodes to the collector plates in the form of sparks. Sparks result in an instantaneous termination of the electrical field (i.e., a short circuit in the field). As the secondary voltage increases, particle charging and sparking increase. As a result, there is an optimal range of spark rates within which there is a high degree of particle charging without excessive sparking. Spark rates outside this range generally indicate a decrease in control efficiency.

Primary current. Although secondary current is a better indicator of power consumption, the primary current is also an indicator of the power being consumed by the ESP. Low current levels indicate a potential problem with ESP operation.

Primary voltage. The primary voltage generally does not vary. However, this parameter can be used to identify a field that is not operating.

Inlet gas temperature. The control efficiency of an ESP depends partly on particle resistivity. Although particle resistivity is not typically monitored, resistivity decreases with increasing temperature. Therefore, changes in temperature can indicate changes in resistivity and the performance of the ESP. (Particles with low resistivity, i.e., less than 1×10^7 ohm-centimeters [℧-cm] are difficult to collect because they lose their charge quickly and are not retained on the collection plates. Particles with high resistivity, i.e., greater than 1×10^{10} ℧-cm, are difficult to charge.) The inlet gas temperature may also be important to avoid condensation of components of the gas stream. The temperature must be maintained above the dew point.

Gas flow rate. The rate of gas flow through an ESP is an indicator of residence time. Control efficiency is a function of residence time; longer residence times allow for higher control efficiency (i.e., increased gas flow rate lowers the control efficiency and decreased gas flow increases the control efficiency).

Rapper operation. Rapper operation is an indication that collector plates are being cleaned at regular intervals and with the appropriate intensity. The process of rapping re-entrains a small amount of PM in the exhaust stream. Therefore, if rapping is too frequent or too intense, control efficiency is lower. On the other hand, if rapping is either too infrequent or of insufficient intensity to jar collected material loose, the dust layer on the collection plates becomes too thick and collection efficiency again decreases.

Fields in operation. As explained previously, most ESPs are designed with multiple fields, each of which is operated independently of the others. If any of the fields fail, the overall performance of the ESP will decrease; that reduction in performance will be a function of which specific fields fail and which are still in operation.

B.2.3 Illustrations

The following illustration presents an example of compliance assurance monitoring for ESPs:

2a: Monitoring secondary voltage, secondary current, and spark rate.

B.2.4 Bibliography

TABLE B-2. SUMMARY OF PERFORMANCE INDICATORS FOR ESPs

Parameter	Performance indication	Approach No.	1	2	3	4	5
		Illustration No.	**2a**				
		Example CAM Submittals				**A?**	
		Comment	✔		✔	✔	✔
Primary Indicators of Performance							
PM concentration							X
Opacity	Increased opacity or VE denotes performance degradation. COMS, opacity observations, or visible/no visible emissions.				X	X	
Secondary corona power	Performance usually increases as power input increases; indicates work done by ESP to remove PM. Product of voltage and current; can help identify any fields that are not operating.		a	a	a	X	
Secondary current	Partial indicator of power consumption; too low indicates malfunction. Can help identify any fields that are not operating properly.		X	X	X		
Secondary voltage	Partial indicator of power consumption; too low indicates problem such as grounded electrodes. Can help identify any fields that are not operating properly.		X	X	X		
Other Performance Indicators							
Inlet gas temperature	Temperature affects resistivity of particulate. Temperature is also an important parameter when the exhaust stream includes condensible pollutants.			X			
Gas flow rate	Indication of residence time in ESP. Performance is a function of residence time; an increase in flow rate decreases control efficiency, and a decrease in flow rate increases efficiency.						X
Fields operating	Performance decreases when individual fields fail. Effect depends on which section goes out; need to test to determine effects of outages.					X	

TABLE B-2. (Continued)

Parameter	Performance indication	Approach No.	1	2	3	4	5
		Illustration No.	**2a**				
		Example CAM Submittals				**A?**	
		Comment	✔		✔	✔	✔

Comments:

- Approach No. 1 is required by some State and Federal rules; spark rate may also be required by some rules.
- Approach No. 3 corresponds to 40 CFR 63, Subpart LL (Primary Aluminum Production).
- 40 CFR 61, subpart K, uses Approach No. 4 along with primary current as an additional parameter.
- Approach No. 5 is an EPRI/UARG-type approach where opacity and power are the major indicators of performance. This is a tiered approach where opacity is monitored on a regular basis with a coms; but when opacity reaches a particular level, the facility begins to monitor secondary power (i.e., secondary voltage and secondary current) for input to a model. The model calculates PM emissions based on secondary voltage and secondary current.
- Approach No. 6 corresponds to 40 CFR 63, subpart LLL (Portland Cement); PM CEMS monitoring is deferred. ***[LLL also allows opacity via mg.] Where does it say "Gas flow rate/"***

[a] Monitoring both secondary current and voltage is essentially the same as monitoring secondary corona power. Monitoring of corona power is not appropriate for ESPs with a large number of fields.

CAM ILLUSTRATION
No. 2a. ESP FOR PM CONTROL

1. APPLICABILITY

1.1 Control Technology: Electrostatic precipitator (ESP) [010, 011, 012]
1.2 Pollutants
Primary: Particulate matter (PM)
Other:
1.3 Process/Emissions units: Furnaces, combustors

2. MONITORING APPROACH DESCRIPTION

2.1 Parameters to be Monitored: Secondary voltage and secondary current.
2.2 Rationale for Monitoring Approach
- Secondary current and voltage: Operating with these parameters outside of normal (design) specifications indicates a change in PM collection efficiency.

2.3 Monitoring Location
- Secondary current and Secondary voltage: Measure after each transformer/rectifier set prior to electrode.

2.4 Analytical Devices Required:
- Secondary current and Secondary voltage: Ammeters, voltmeters, other methods or instrumentation as appropriate; see section 4.6 for additional information on devices.

2.5 Data Acquisition and Measurement System Operation
- Frequency of measurement: Hourly, or recorded continuously on strip chart or data acquisition system.
- Reporting units:
  - Secondary current and Secondary voltage: Amps and volts
- Recording process: Operators log data manually, or automatically recorded on strip chart or data acquisition system.

2.6 Data Requirements
- Baseline secondary current and secondary voltage measurements concurrent with emissions test.
- Historical plant records of secondary current and secondary voltage 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, 3, 7, 8, 9, 10, 11, 12.

3. COMMENTS

3.1 Data Collection Frequency: For large emission units, a measurement frequency of once per hour would not be adequate; collection of four or more data points each hour is required. (See Section 3.3.1.2.)