B.10 ELECTRIFIED FILTER BED[13, 31, 32]

B.10.1 Background

Electrified filter beds (EFBs) are used to control particulate matter (PM), including fine dust and smoke particles from flue gas streams. Example applications include wood waste-fired boilers and wood products dryers. In an EFB, fine dust particles are charged in a corona formed by the ionizer, and are then deposited on an electrically polarized bed of pea gravel. The pea gravel is either periodically replaced, or is continuously removed from the filter bed, cleaned in a pneumatic conveyor, and returned to the filter bed; the dust removed from the gravel is sent to a fabric filter.

A typical EFB system can be divided into three sections: the ionizer (corona charger), the filter bed, and the gravel cleaning and recirculation system. As the gas stream passes through the ionizer system, dust particles are electrostatically charged. An ion flux is created in the gas stream by high voltage electrodes; the ions attach to the particles, giving them an electrical charge. The filter bed is formed by pea gravel held between two annular inner and outer louver sets. The louvers are electrically grounded. A cylindrical, metal sheet is suspended between the two louver sets and is held at a high direct current positive voltage. The voltage polarizes the gravel, inducing regions of positive and negative charge. As the gas flows through the filter bed, the negatively charged dust particles are attracted to the positively charged regions on the gravel and are transferred to the surface of the gravel. Cleaned gas collects in the outlet plenum and exits the system.

In some systems, to maintain a constant gas flow and pressure differential across the system, gravel is slowly and continuously removed from the filter bed. The purpose of the gravel cleaning and recirculation system is to clean the gravel and elevate it to the top of the filter bed for reuse. The gravel travels from the bottom of the filter bed, through an infeed pipe, and into the lift line. Agitation in the lift line, along with the loss of gravel charge, dislodges dust from the gravel. The lift line discharges into the disengagement chamber, which decreases the lift air velocity. The cleaned gravel falls into the gravel reserve hopper, and the dust is conveyed with the lift air to a fabric filter. Other systems require manual removal of spent gravel and addition of new gravel on a weekly basis.

A common problem with EFBs is buildup of a glaze on the ionizer or gravel. The combination of dust, condensed hydrocarbons, and condensed moisture in the gas stream forms a hard, powder-like material which settles on the ionizer and gravel. This glaze buildup interferes with the corona charging of the ionizer and the charging of the filter bed. Manufacturers recommend continuous blowdown with air to prevent buildup, and once buildup occurs, it can be removed with low-pressure sandblasting. The EFB has a relatively narrow temperature operating range. The temperature must be low enough to allow condensible hydrocarbons to form into liquid aerosol form for removal in the filter bed, and high enough to ensure that water condensation does not occur. Moisture condensation in the bed can result in an electrical short in the gravel bed, in addition to contributing to the hydrocarbon glaze described above.

Manufacturers recommend that EFBs operate at 30°F above the dew point temperature. The inlet gas stream may be heated in a preheater prior to the EFB to maintain the appropriate temperature.

B.10.2 Indicators of EFB Performance

The primary indicators of performance for EFBs are the ionizer voltage, ionizer current, filter bed voltage, filter bed current, filter bed temperature, and the inlet gas temperature. Other parameters that indicate EFB performance include pressure differential and gas flow rate. Outlet PM concentration and opacity may also be monitored for an EFB. Each of these indicators is described below. Table B-10 lists these indicators and illustrates potential monitoring options for EFBs.

Ionizer current and voltage. Both the voltage and the current are important monitoring parameters for the ionizer. The ionizer is held at high voltage to create the corona. The voltage is increased to a voltage value that corresponds to initiation of the corona; the current is zero until this corona voltage is reached. The voltage then is increased to a maximum voltage above which sparking or short-circuiting occurs, and the current continues to increase as well. In general, higher voltage indicates increased control efficiency, up to this critical sparking voltage. Because the current is zero until the corona voltage is reached and continues to increase along with voltage from this point, it is also an indicator of the amount of corona available for electrical charging of the PM. The current also gives an indication of the PM control efficiency of the EFB; higher current indicates increased control efficiency. The ionizer may become coated with PM and condensed hydrocarbon (hydrocarbon glazing); the ionizer may need frequent low-pressure sand-blasting to remove the coating or continuous air blowdown to prevent coating buildup. A decrease in ionizer current could indicate fouling or buildup of PM and condensed hydrocarbons on the ionizer or that the cleaning system may have malfunctioned. When the ionizer current increases suddenly with low or zero ionizer voltage, a short circuit or coated surfaces are likely.

If only one parameter for the ionizer is measured, the ionizer current should be monitored as it provides an indication of both current and voltage. One manufacturer recommends ionizer current at 2 to 4 milliamps (mA) for normal operation, with a minimum ionizer current of 1 mA; this manufacturer recommends ionizer voltage of 30 to 40 kilovolts (kV) for normal operation.

Filter bed current and voltage. Both current and voltage are important monitoring parameters for the filter bed. The filter bed voltage is an indicator of the PM control efficiency of the EFB; the voltage indicates the intensity of the electric field in the bed. A decrease in filter bed voltage could indicate an electrical short or a buildup of PM or condensed hydrocarbons on the gravel. The filter bed current is generally low and constant. If the bed current increases suddenly with no corresponding increase in bed voltage or a bed voltage at zero, there is a short in the filter bed (likely caused by moisture condensation and the flue gas temperature approaching the dew point of the gas stream). If only one parameter for the filter bed is to be monitored, it should be the filter bed voltage. One manufacturer recommends that the bed voltage be maintained at 5 to 10 kV and the bed current at 0.5 amps (A).

Filter bed temperature. Electrified filter beds are designed with a narrow operating range for temperature; the filter bed temperature must be maintained above the dew point of the gas stream to avoid water condensation but also maintained at a low enough temperature to allow the hydrocarbons to form into liquid aerosol. The temperature of the filter bed provides a good indication that condensation is not occurring; water condensation may cause an electrical short in the filter bed. Maintaining the filter bed temperature above the dew point also provides a good indication that hydrocarbon glaze is not occurring on the ionizer.

Inlet gas temperature. Electrified filter beds are designed with a narrow operating range for temperature; the temperature of the inlet gas stream must be maintained above the dew point of the stream to avoid moisture condensation and low enough to allow formation of liquid aerosols. To maintain this temperature, the inlet gas stream may be heated in a preheater. A decrease in the inlet gas temperature may cause condensation in the filter bed or hydrocarbon glaze in the ionizer.

Pressure differential. To maintain constant pressure differential across the filter bed, PM-coated gravel must be removed from the filter bed on a regular basis. An increase in pressure differential over the EFB may indicate excessive buildup of PM in the filter bed and indicate a need for an increased gravel removal rate, more frequent removal, or a need to replace the gravel bed. An increase in pressure differential indicates decreased gas flow rate through the filter bed. One EFB manufacturer indicates that a pressure differential of 3 to 5 in. H_2O gauge is appropriate for normal operation. This manufacturer also indicated that an increase in pressure differential of 10 percent each week can be expected.

Gas flow rate. The gas flow rate through an EFB is an indicator of residence time, and control efficiency is a function of residence time. An increase in the gas flow rate lowers the residence time in the filter bed and lowers the control efficiency.

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 placed into widespread use.

Opacity. As is the case for nearly 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 EFB performance. A continuous opacity monitor may be used, or the visual determination of opacity (Method 9) or visible emissions (modified Method 22) may be made by plant personnel. Condensibles in the outlet gas stream may be an issue if the inlet gas temperature is too high. One manufacturer indicates that inlet gas temperatures above 200°F result in opacity due to vaporization of condensibles that normally are collected on the bed with lower inlet temperatures.

B.10.3 Illustrations

The following illustrations present an example of compliance assurance monitoring for an EFB:

10a: Monitoring ionizer voltage, ionizer current, filter bed voltage, filter bed current, pressure differential, filter bed temperature, and inlet gas temperature.
10b: Monitoring ionizer current, filter bed voltage, and filter bed inlet and outlet temperatures.

B.10.4 Bibliography

TABLE B-10. SUMMARY OF PERFORMANCE INDICATORS FOR EFBs

		Approach No.	**1**	**2**	**3**
		Illustration No.	**10a**	**10b**	
		Example CAM Submittals			**A.11**
Parameters	**Performance indication**	**Comment**			
Primary Indicators of Performance					
Ionizer current	Partial indicator of power consumption of the corona. Want highest current/voltage without sparking or short-circuit. Decreased current can indicate fouling on the ionizer. Increased current with low or zero voltage indicates short-circuit.		X	X	X
Ionizer voltage	Partial indicator of power consumption of the corona. Want highest current/voltage without sparking or short-circuit. Increased voltage corresponds with increased control efficiency up to a maximum voltage above which sparking occurs. Decreased voltage indicates decreased control efficiency due to lower corona. Best if monitored in conjunction with ionizer current.		X		
Filter bed voltage	Partial indicator of power consumption of the bed. Decreased voltage can indicate fouling of the bed.		X	X	X
Filter bed current	Partial indicator of power consumption of the bed. Increased current with low or zero voltage indicates short-circuit. Best if monitored in conjunction with filter bed voltage.		X		
Filter bed temperature	Indicator of potential for condensation in the filter bed. Condensation can result in gravel coating and decreased control efficiency and can also cause an electrical short in the filter bed.		X	X	
Inlet gas temperature	Indicator of potential for condensation in the ionizer or filter bed. Condensation can result in ionizer coating or gravel coating, an electrical short in the filter bed, and decreased control efficiency.		X		X
Comments: • Opacity also may be used in conjunction with any of these approaches.					

CAM ILLUSTRATION
No. 10a. ELECTRIFIED FILTER BED FOR PM

1. APPLICABILITY

1.1 Control Technology: Electrified filter bed (EFB) [079]
1.2 Pollutants
Primary: Particulate matter (PM)
Other:
1.3 Process/Emission units: Kilns, coolers, wood products dryers

2. MONITORING APPROACH DESCRIPTION

2.1 Parameters to be Monitored: Ionizer current, ionizer voltage, filter bed voltage, filter bed current, filter bed temperature, and inlet gas temperature.
2.2 Rationale for Monitoring Approach
- Ionizer current: The current on the ionizer provides an indicator of the voltage. A decrease in current could indicate a malfunction, such as a buildup of PM or condensed hydrocarbons on the ionizer.
- Ionizer voltage: The voltage indicates that a corona is formed and is generating ions for charging particles.
- Filter bed voltage: The voltage on the gravel must be maintained so charged PM is attracted to the gravel. A decrease in voltage could indicate a malfunction, such as a short or a buildup of PM or condensed hydrocarbons on the gravel.
- Filter bed current: A sudden increase in bed current with no corresponding increase in bed voltage or a bed voltage at zero indicates a short in the filter bed.
- Filter bed temperature: An EFB is designed to operate within a relatively narrow temperature operating range. The temperature inside the unit should remain above the dew point of the gas stream being treated because condensation within the system could result in an electrical short in the gravel bed.
- Inlet gas temperature: An EFB is designed to operate within a relatively narrow temperature operating range. The temperature inside the unit should remain above the dew point of the gas stream being treated because condensation within the system could result in an electrical short in the gravel bed.

2.3 Monitoring Location
- Ionizer current: Measure current to ionizer electrode (after transformer-rectifier).
- Ionizer voltage: Measure voltage of ionizer electrode (after transformer-rectifier).
- Filter bed voltage: Measure voltage of filter bed electrode (after transformer-rectifier).
- Filter bed current: Measure current to filter bed electrode (after transformer-rectifier).
- Filter bed temperature: Measure at the outlet of the filter bed.
- Inlet gas temperature: Measure at the inlet duct to the EFB.

2.4 Analytical Devices Required

- Ionizer current: Ammeter.
- Ionizer voltage: Voltmeter.
- Filter bed voltage: Voltmeter.
- Filter bed current: Ammeter.
- Filter bed temperature: Thermocouple, RTD, or other temperature sensing device; see section 4.2 for additional information on devices.
- Inlet gas temperature: Thermocouple, RTD, or other temperature sensing device; see section 4.2 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:
  - Ionizer current: Milliamps.
  - Ionizer voltage: Kilovolts.
  - Filter bed voltage: Kilovolts.
  - Filter bed current: Amps.
  - Filter bed temperature: Degrees Fahrenheit or Celsius as appropriate.
  - Inlet gas temperature: Degrees Fahrenheit or Celsius as appropriate.
- Recording process: Operators log data manually, or automatically recorded on strip chart or data acquisition system.

2.6 Data Requirements

- Baseline ionizer voltage, ionizer current, filter bed voltage, filter bed current, inlet gas temperature, and filter bed temperature measurements concurrent with emissions test.
- Historical plant records of ionizer voltage, ionizer current, filter bed voltage, filter bed current, inlet gas temperature, and filter bed temperature measurements.

2.7 Specific QA/QC Procedures: Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.

2.8 References: 13, 31, 32.

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).

CAM ILLUSTRATION
No. 10b. ELECTRIFIED FILTER BED FOR PM

1. APPLICABILITY

1.1 Control Technology: Electrified filter bed (EFB) [079]
1.2 Pollutants
Primary: Particulate matter (PM)
Other:
1.3 Process/Emission units: Kilns, coolers, wood products dryers

2. MONITORING APPROACH DESCRIPTION

2.1 Parameters to be Monitored: Ionizer current, filter bed voltage, and filter bed temperature.

2.2 Rationale for Monitoring Approach

- Ionizer current: The current on the ionizer provides an indicator of the voltage. A decrease in current could indicate a malfunction, such as a buildup of PM or condensed hydrocarbons on the ionizer.
- Filter bed voltage: The voltage on the gravel must be maintained so charged PM are attracted to the gravel. A decrease in voltage could indicate a malfunction, such as a short or a buildup of PM or condensed hydrocarbons on the gravel.
- Filter bed temperature: An EFB is designed to operate within a relatively narrow temperature operating range. The temperature inside the unit should remain above the dew point of the gas stream being treated because condensation within the system could result in an electrical short in the gravel bed.

2.3 Monitoring Location

- Ionizer current: Measure current to ionizer electrode (after transformer-rectifier).
- Filter bed voltage: Measure voltage of filter bed electrode (after transformer-rectifier).
- Filter bed temperature: Measure at the outlet of the filter bed.

2.4 Analytical Devices Required

- Ionizer current: Ammeter.
- Filter bed voltage: Voltmeter.
- Filter bed temperature: Thermocouple, RTD, or other temperature sensing device; see section 4.2 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:
  - Ionizer current: Milliamps.
  - Filter bed voltage: Kilovolts.
  - Filter bed temperature: Degrees Fahrenheit or Celsius as appropriate.

- Recording process: Operators log data manually, or automatically recorded on strip chart or data acquisition system.

2.6 Data Requirements
- Baseline ionizer current, filter bed voltage, and filter bed temperature measurements concurrent with emissions test.
- Historical plant records of ionizer current, filter bed voltage, and filter bed temperature measurements.

2.7 Specific QA/QC Procedures: Calibrate, maintain, and operate instrumentation using procedures that take into account manufacturer's specifications.

2.8 References: 13, 31, 32.

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.)