EPA-452/F-03-028

Air Pollution Control Technology Fact Sheet

Name of Technology: Dry Electrostatic Precipitator (ESP) - Wire-Plate Type

Type of Technology: Control Device - Capture/Disposal

Applicable Pollutants: Particulate Matter (PM), including particulate matter less than or equal to 10 micrometers (µm) in aerodynamic diameter (PM_{10}), particulate matter less than or equal to 2.5 µm in aerodynamic diameter ($PM_{2.5}$), and hazardous air pollutants (HAPs) that are in particulate form, such as most metals (mercury is the notable exception, as a significant portion of emissions are in the form of elemental vapor).

Achievable Emission Limits/Reductions:

Typical new equipment design efficiencies are between 99 and 99.9%. Older existing equipment have a range of actual operating efficiencies of 90 to 99.9%. While several factors determine ESP collection efficiency, ESP size is most important. Size determines treatment time; the longer a particle spends in the ESP, the greater its chance of being collected. Maximizing electric field strength will maximize ESP collection efficiency (STAPPA/ALAPCO, 1996). Collection efficiency is also affected by dust resistivity, gas temperature, chemical composition (of the dust and the gas), and particle size distribution. Cumulative collection efficiencies of PM, PM_{10}, and $PM_{2.5}$ for actual operating ESPs in various types of applications are presented in Table 1.

Table 1. Cumulative PM, PM_{10}, and $PM_{2.5}$ Collection Efficiencies for Dry ESPs (EPA, 1998; EPA, 1997)

Application	Collection Efficiency (%)		
	Total PM (EPA, 1997)	PM_{10} (EPA, 1998)	$PM_{2.5}$ (EPA, 1998)
Coal-Fired Boilers			
Dry bottom (bituminous)	99.2	97.7	96.0
Spreader stoker (bituminous)	99.2	99.4	97.7
Primary Copper Production			
Multiple hearth roaster	99.0	99.0	99.1
Reverbatory smelter	99.0	97.1	97.4
Iron and Steel Production			
Open hearth furnace	99.2	99.2	99.2

Applicable Source Type: Point

Typical Industrial Applications:

Approximately 80% of all ESPs in the U.S. are used in the electric utility industry. ESPs are also used in pulp and paper (7%), cement and other minerals (3%), and nonferrous metals industries (1%) (EPA, 1998). Common applications of dry wire-plate ESPs are presented in Table 2.

Table 2. Typical Industrial Applications of Dry Wire-Plate ESPs (EPA, 1998)

Application	Source Category Code (SCC)	Are Other ESP Types Also Typically Used for this Application?
Utility Boilers (Coal, Oil)	1-01-002...004	No
Industrial Boilers (Coal, Oil, Wood, Liquid Waste)	1-02-001...005 1-02-009,-013	No
Commercial/Institutional Boilers (Coal, Oil, Wood)	1-03-001...005 1-03-009	No
Chemical Manufacture	Site specific	Yes
Non-Ferrous Metals Processing (Primary and Secondary):		
Copper	3-03-005 3-04-002	Yes
Lead	3-03-010 3-04-004	Yes
Zinc	3-03-030 3-04-008	Yes
Aluminum	3-03-000...002 3-04-001	Yes
Other metals production	3-03-011...014 3-04-005...006 3-04-010...022	Yes
Ferrous Metals Processing:		
Ferroalloy Production	3-03-006...007	No
Iron and Steel Production	3-03-008...009	Yes
Gray Iron Foundries	3-04-003	No
Steel Foundries	3-04-007,-009	Yes
Petroleum Refineries and Related Industries	3-06-001...999	No
Mineral Products:		
Cement Manufacturing	3-05-006...007	No
Stone Quarrying and Processing	3-05-020	Yes
Other	3-05-003...999	Yes
Wood, Pulp, and Paper	3-07-001	Yes
Incineration (Municipal Waste)	5-01-001	Yes

Emission Stream Characteristics:

a. Air Flow: Typical gas flow rates for wire-plate ESPs are 100 to 500 standard cubic meters per second (sm^3/sec) (200,000 to 1,000,000 standard cubic feet per minute (scfm)). Most smaller plate-type ESPs (50 sm^3/sec to 100 sm^3/sec, or 100,000 to 200,000 scfm) use flat plates instead of wires for the high-voltage electrodes (AWMA, 1992).

b. Temperature: Wire-plate ESPs can operate at very high temperatures, up to 700°C (1300°F) (AWMA, 1992). Operating gas temperature and chemical composition of the dust are key factors influencing dust resistivity and must be carefully considered in the design of an ESP.

c. Pollutant Loading: Typical inlet concentrations to a wire-plate ESP are 2 to 110 g/m^3 (1 to 50 grains per cubic foot (gr/ft^3)). It is common to pretreat a waste stream, usually with a mechanical collector or cyclone, to bring the pollutant loading into this range. Highly toxic flows with concentrations below 1 g/m^3 (0.5 gr/ft^3) are also sometimes controlled with ESPs (Bradburn, 1999; Boyer, 1999; Brown, 1999).

d. Other Considerations: In general, dry ESPs operate most efficiently with dust resistivities between 5×10^3 and 2×10^{10} ohm-cm. In general, the most difficult particles to collect are those with aerodynamic diameters between 0.1 and 1.0 µm. Particles between 0.2 and 0.4 µm usually show the most penetration. This is most likely a result of the transition region between field and diffusion charging (EPA, 1998).

Emission Stream Pretreatment Requirements:

When much of the pollutant loading consists of relatively large particles, mechanical collectors such as cyclones or spray coolers may be used to reduce the load on the ESP, especially at high inlet concentrations. Gas conditioning equipment to improve ESP performance by changing dust resistivity is occasionally used as part of the original design, but more frequently it is used to upgrade existing ESPs. The equipment injects an agent into the gas stream ahead of the ESP. Usually, the agent mixes with the particles and alters their resistivity to promote higher migration velocity, and thus higher collection efficiency. Conditioning agents that are used include SO_3, H_2SO_4, sodium compounds, ammonia, and water; the conditioning agent most used is SO_3 (AWMA, 1992).

Cost Information:

The following are cost ranges (expressed in 2002 dollars) for wire-plate ESPs of conventional design under typical operating conditions, developed using EPA cost-estimating spreadsheets (EPA, 1996). Costs can be substantially higher than in the ranges shown for pollutants which require an unusually high level of control, or which require the ESP to be constructed of special materials such as stainless steel or titanium. In general, smaller units controlling a low concentration waste stream will not be as cost effective as a large unit cleaning a high pollutant load flow.

a. Capital Cost: \$21,000 to \$70,000 per sm^3/sec (\$10 to \$33 per scfm)

b. O & M Cost: \$6,400 to \$74,000 per sm^3/sec (\$3 to \$35 per scfm), annually

c. Annualized Cost: \$9,100 to \$81,000 per sm^3/sec (\$4 to \$38 per scfm), annually

d. Cost Effectiveness: \$38 to \$260 per metric ton (\$35 to \$236 per short ton)

Theory of Operation:

An ESP is a particulate control device that uses electrical forces to move particles entrained within an exhaust stream onto collector plates. The entrained particles are given an electrical charge when they pass through a corona, a region where gaseous ions flow. Electrodes in the center of the flow lane are maintained at high voltage and generate the electrical field that forces the particles to the collector walls. In dry ESPs, the collectors are knocked, or "rapped", by various mechanical means to dislodge the particulate, which slides downward into a hopper where they are collected. The hopper is evacuated periodically, as it becomes full. Dust is removed through a valve into a dust-handling system, such as a pneumatic conveyor, and is then disposed of in an appropriate manner.

In the wire-plate ESP, the exhaust gas flows horizontally and parallel to vertical plates of sheet metal. Plate spacing is typically between 19 to 38 cm (9 in. and 18 in.) (AWMA, 1992). The high voltage electrodes are long wires that are weighted and hang between the plates. Some later designs use rigid electrodes (hollow pipes approximately 25 mm to 40 mm in diameter) in place of wire (Cooper and Alley, 1994). Within each flow path, gas flow must pass each wire in sequence as it flows through the unit. The flow areas between the plates are called ducts. Duct heights are typically 6 to 14 m (20 to 45 feet) (EPA, 1998).

The power supplies for the ESP convert the industrial AC voltage (220 to 480 volts) to pulsating DC voltage in the range of 20,000 to 100,000 volts as needed. The voltage applied to the electrodes causes the gas between the electrodes to break down electrically, an action known as a "corona." The electrodes are usually given a negative polarity because a negative corona supports a higher voltage than does a positive corona before sparking occurs. The ions generated in the corona follow electric field lines from the wires to the collecting plates. Therefore, each wire establishes a charging zone through which the particles must pass. As larger particles (>10 µm diameter) absorb many times more ions than small particles (>1 µm diameter), the electrical forces are much stronger on the large particles (EPA, 1996).

Certain types of losses affect control efficiency. The rapping that dislodges the accumulated layer also project some of the particles (typically 12% for coal fly ash) back into the gas stream. These reentrained particles are then processed again by later sections, but the particles reentrained in the last section of the ESP have no chance to be recaptured and so escape the unit. Due to necessary clearances needed for nonelectrified internal components at the top of the ESP, part of the gas may flow around the charging zones. This is called "sneakage" and places an upper limit on the collection efficiency. Anti-sneakage baffles are placed to force the sneakage flow to mix with the main gas stream for collection in later sections (EPA, 1998).

Another major factor in the performance is the resistivity of the collected material. Because the particles form a continuous layer on the ESP plates, all the ion current must pass through the layer to reach the ground plates. This current creates an electric field in the layer, and it can become large enough to cause local electrical breakdown. When this occurs, new ions of the wrong polarity are injected into the wire-plate gap where they reduce the charge on the particles and may cause sparking. This breakdown condition is called "back corona." Back corona is prevalent when the resistivity of the layer is high, usually above 2×10^{11} ohm-cm. Above this level, the collection ability of the unit is reduced considerably because the sever back corona causes difficulties in charging the particles. Low resistivities will also cause problems. At resistivities below 10^8 ohm-cm, the particles are held on the plates so loosely that rapping and nonrapping reentrainment become much more severe. Hence, care must be taken in measuring or estimating resistivity because it is strongly affected by such variables as temperature, moisture, gas composition, particle composition, and surface characteristics (AWMA, 1992).

Precipitator size is related to many design parameters. One of the main parameters is the specific collection area (SCA), which is defined as the ratio of the surface area of the collection electrodes to the gas flow. Higher collection areas lead to better removal efficiencies. Collection areas normally are in the range of 40 to 160 m^2 per sm^3/second of gas flow (200-800 ft^2/1000 scfm), with typical values of 80 (400) (AWMA, 1992).

Advantages:

Dry wire-plate ESPs and other ESPs in general, because they act only on the particulate to be removed, and only minimally hinder flue gas flow, have very low pressure drops (typically less than 13 mm (0.5 in.) water column). As a result, energy requirements and operating costs tend to be low. They are capable of very high efficiencies, even for very small particles. They can be designed for a wide range of gas temperatures, and can handle high temperatures, up to 700°C (1300°F). Dry collection and disposal allows for easier handling. Operating costs are relatively low. ESPs are capable of operating under high pressure (to 1,030 kPa (150 psi)) or vacuum conditions. Relatively large gas flow rates can be effectively handled. (AWMA, 1992)

Disadvantages:

ESPs generally have high capital costs. The wire discharge electrodes (approximately 2.5 mm (0.01 in.) in diameter) are high-maintenance items. Corrosion can occur near the top of the wires because of air leakage and acid condensation. Also, long weighted wires tend to oscillate - the middle of the wire can approach the plate, causing increased sparking and wear. Newer ESP designs are tending toward rigid electrodes (Cooper and Alley, 1994).

ESPs in general are not suited for use in processes which are highly variable because they are very sensitive to fluctuations in gas stream conditions (flow rates, temperatures, particulate and gas composition, and particulate loadings). ESPs are also difficult to install in sites which have limited space since ESPs must be relatively large to obtain the low gas velocities necessary for efficient PM collection (Cooper and Alley, 1994). Certain particulates are difficult to collect due to extremely high or low resistivity characteristics. There can be an explosion hazard when treating combustible gases and/or collecting combustible particulates. Relatively sophisticated maintenance personnel are required, as well as special precautions to safeguard personnel from the high voltage. Dry ESPs are not recommended for removing sticky or moist particles. Ozone is produced by the negatively charged electrode during gas ionization (AWMA, 1992).

Other Considerations:

Dusts with very high resistivities (greater than 10^{10} ohm-cm) are also not well-suited for collection in dry ESPs. These particles are not easily charged, and thus are not easily collected. High-resistivity particles also form ash layers with very high voltage gradients on the collecting electrodes. Electrical breakdowns in these ash layers lead to injection of positively charged ions into the space between the discharge and collecting electrodes (back corona), thus reducing the charge on particles in this space and lowering collection efficiency. Fly ash from the combustion of low-sulfur coal typically has a high resistivity, and thus is difficult to collect (ICAC, 1999).

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