EPA-452/F-03-027

Air Pollution Control Technology Fact Sheet

Name of Technology: Dry Electrostatic Precipitator (ESP)- Wire-Pipe 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.

Applicable Source Type: Point

Typical Industrial Applications:

Many older ESPs are of the wire-pipe design, consisting of a single tube placed on top of a smokestack (EPA, 1998). Dry pipe-type ESPs are occasionally used by the textile industry, pulp and paper facilities, the metallurgical industry, including coke ovens, hazardous waste incinerators, and sulfuric acid manufacturing plants, among others, though other ESP types are employed as well. Wet wire-pipe ESPs are used much more frequently than dry wire-pipe ESPs, which are used only in cases in which wet cleaning is undesirable, such as high temperature streams or wastewater restrictions (EPA, 1998; Flynn, 1999).

Emission Stream Characteristics:

a. Air Flow: Typical gas flow rates for dry wire-pipe ESPs are 0.5 to 50 standard cubic meters per second (sm^3/sec) (1,000 to 100,000 standard cubic feet per minute (scfm)) (Flynn, 1999).

b. Temperature: Dry wire-pipe 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-pipe ESP are 1 to 10 g/m^3 (0.5 to 5 gr/scf). It is common to pretreat a waste stream, usually with a wet spray or scrubber, to bring the stream temperature and pollutant loading into a manageable range. Highly toxic flows with concentrations well below 1 g/m^3 (0.5 gr/scf) are also sometimes controlled with ESPs (Flynn, 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 dry wire-pipe 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:** \$42,000 to \$260,000 per sm^3/sec (\$20 to \$125 per scfm)

b. **O & M Cost:** \$8,500 to \$19,000 per sm^3/sec (\$4 to \$9 per scfm), annually

c. **Annualized Cost:** \$19,000 to \$55,000 per sm^3/sec (\$9 to \$26 per scfm), annually

d. **Cost Effectiveness:** \$47 to \$710 per metric ton (\$43 to \$640 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 collection surfaces. 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. Recently, dry wire-pipe ESPs are being cleaned acoustically with sonic horns (Flynn, 1999). The horns, typically cast metal horn bells, are usually powered by compressed air, and acoustic vibration is introduced by a vibrating metal plate that periodically interrupts the airflow (AWMA, 1992). As with a rapping system, the collected particulate slides downward into the hopper. 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 a wire-pipe ESP, also called a tubular ESP, the exhaust gas flows vertically through conductive tubes, generally with many tubes operating in parallel. The tubes may be formed as a circular, square, or hexagonal honeycomb. Square and hexagonal pipes can be packed closer together than cylindrical pipes, reducing wasted space. Pipes are generally 7 to 30 cm (3 to 12 inches (in.)) in diameter and 1 to 4 meters (3 to 12 feet) in length. The high voltage electrodes are long wires or rigid "masts" suspended from a frame in the upper part of the ESP that run through the axis of each tube. Rigid electrodes are generally supported by both an upper and lower frame. In modern designs, sharp points are added to the electrodes, either at the entrance to a tube or along the entire length in the form of stars, to provide additional ionization sites (EPA, 1998; Flynn, 1999).

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 electrode to the collection surfaces. Therefore, each electrode-pipe combination 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).

Due to necessary clearances needed for nonelectrified internal components at the top of wire-plate ESPs, part of the gas is able to flow around the charging zones. This is called "sneakage" and places an upper limit on the collection efficiency. Wire-pipe ESPs provide no sneakage paths around the collecting region, but field nonuniformities may allow some particles to avoid charging for a considerable fraction of the tube length. Dry wire-pipe ESPs are, however, subject to reentrainment of the collected material after cleaning the collectors with a rapping or acoustic mechanism, though the closed nature of the pipes increases chances for recollection (AWMA, 1992).

Another major factor in the performance is the resistivity of the collected material. Because the particles form a continuous layer on the ESP pipes, all the ion current must pass through the layer to reach the ground. 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-pipe 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 collecting surface so loosely that general reentrainment, as well as that associated with collector cleaning, 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).

Advantages:

Dry wire-pipe 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 millimeters (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, though are uncommon in wire-pipe ESPs (AWMA, 1992).

Disadvantages:

ESPs generally have high capital costs. 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 pipe, causing increased sparking and wear. Newer ESP designs are tending toward rigid electrodes, or “masts” which largely eliminate the drawbacks of using wire electrodes (Cooper and Alley, 1994; Flynn, 1999).

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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