EPA-452/F-03-029

Air Pollution Control Technology Fact Sheet

Name of Technology: Wet 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). Wet ESPs are often used to control acid mists and can provide incidental control of volatile organic compounds.

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 to some extent by dust resistivity, gas temperature, chemical composition (of the dust and the gas), and particle size distribution.

Applicable Source Type: Point

Typical Industrial Applications:

Wet ESPs are used in situations for which dry ESPs are not suited, such as when the material to be collected is wet, sticky, flammable, explosive, or has a high resistivity. Also, as higher collection efficiencies have become more desirable, wet ESP applications have been increasing. Many older ESPs are of the wire-pipe design, consisting of a single tube placed on top of a smokestack (EPA, 1998). Wet pipe-type ESPs are commonly used by the textile industry, pulp and paper facilities, the metalurgical industry, including coke ovens, hazardous waste incinerators, and sulfuric acid manufacturing plants, among others, though other ESP types are employed as well (EPA, 1998; Flynn, 1999).

Emission Stream Characteristics:

a. **Air Flow:** Typical gas flow rates for wet 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:** Wet wire-pipe ESPs are limited to operating at temperatures lower than approximately 80 to 90 C (170 to 190 F) (EPA, 1998; Flynn, 1999).

c. **Pollutant Loading:** Typical inlet concentrations to a wire-pipe ESP are 1 to 10 grams per cubic meter (g/m^3) (0.5 to 5 gr/ft^3). 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/ft^3) are also sometimes controlled with ESPs (Flynn, 1999).

d. **Other Considerations:** Dust resistivity is not a factor for wet ESPs, because of the high humidity atmosphere which lowers the resistivity of most materials. Particle size is much less of a factor for wet ESPs, compared to dry ESPs. Much smaller particles can be efficiently collected by wet ESPs due to the lack of resistivity concerns and the reduced reentrainment (Flynn, 1999).

Emission Stream Pretreatment Requirements:

When the pollutant loading is exceptionally high or consists of relatively large particles (> 2 :m), venturi scrubbers or spray chambers may be used to reduce the load on the ESP. Much larger particles (> 10 :m), are controlled with mechanical collectors such as cyclones. Gas conditioning equipment to reduce both inlet concentration and gas temperature is occasionally used as part of the original design of a wet ESPs (AWMA, 1992; Flynn, 1999).

Cost Information:

The following are cost ranges (expressed in 2002 dollars) for wire-pipe ESPs of conventional design under typical operating conditions, developed using EPA cost-estimating spreadsheets for dry wire-plate ESPs with adjustments made to reflect wet wire-pipe ESPs (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 titanium. Capital and operating costs are generally higher due to noncorrosive materials requirements, increased water usage, and treatment and disposal of wet effluent. In most cases, smaller units controlling a low concentration waste stream will not be as cost effective as a large unit cleaning a high pollutant load flow (EPA, 1998).

a. **Capital Cost:** \$85,000 to \$424,000 per sm^3/sec (\$40 to \$200 per scfm)

b. **O & M Cost:** \$12,000 to \$21,000 per sm^3/sec (\$6 to \$10 per scfm), annually

c. **Annualized Cost:** \$25,000 to \$97,000 per sm^3/s (\$12 to \$46 per scfm), annually

d. **Cost Effectiveness:** \$73 to \$720 per metric ton (\$65 to \$660 per 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 wet ESPs, the collectors are either intermittently or continuously washed by a spray of liquid, usually water. The collection hoppers used by dry ESPs are replaced with a drainage system. The wet effluent is collected, and often treated on-site (EPA, 1998).

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 m (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 collecting pipe. Therefore, each electrode-pipe combination establishes a charging zone through which the particles must pass. As larger particles (>10 :m diameter) absorb many times more ions than small particles (>1 :m 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 (AWMA, 1992).

Wet ESPs require a source of wash water to be injected or sprayed near the top of the collector pipes either continuously or at timed intervals. This wash system replaces the rapping mechanism usually used by dry ESPs. The water flows with the collected particles into a sump from which the fluid is pumped or drained. A portion of the fluid may be recycled to reduce the total amount of water required. The remainder is pumped into a settling pond or passed through a dewatering stage, with subsequent disposal of the sludge (AWMA, 1992).

Unlike dry ESPs, resistivity of the collected material is generally not a major factor in performance. Because of the high humidity in a wet ESP, the resistivity of particles is lowered, eliminating the "back corona" condition. The frequent washing of the pipes also limits particle buildup on the collectors (EPA, 1998).

Advantages:

Wet 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. Operating costs are relatively low. ESPs are capable of operating under high pressure (to 1,030 kPa (150 psi)) or vacuum conditions, and relatively large gas flow rates can be effectively handled (AWMA, 1992).

Wet ESPs can collect sticky particles and mists, as well as highly resistive or explosive dusts. The continuous or intermittent washing with a liquid eliminates the reentrainment of particles due to rapping which dry ESPs are subject to. The humid atmosphere that results from the washing in a wet ESP enables them to collect high resistivity particles, absorb gases or cause pollutants to condense, and cools and conditions the gas stream. Liquid particles or aerosols present in the gas stream are collected along with particles and provide another means of rinsing the collection electrodes (EPA, 1998). Wet wire-pipe ESPs have the additional advantages of reducing "sneakage" by passing the entire gas stream through the collection field, and the ability to be tightly sealed to prevent leaks of materia, especially valuable or hazardous materials (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). Relatively sophisticated maintenance personnel are required, as well as special precautions to safeguard personnel from the high voltage. Ozone is produced by the negatively charged electrode during gas ionization (AWMA, 1992). Wet ESPs add the complexity of a wash system, and the fact that the resulting slurry must be handled more carefully than a dry product, and in many cases requires treatment, especially if the dust can be sold or recycled. Wet ESPs are limited to operating at stream temperatures under approximately 80 to 90 C (170 to 190 F), and generally must be constructed of noncorrosive materials (EPA, 1998; Flynn, 1999).

Other Considerations:

For wet ESPs, consideration must be given to handling wastewaters. For simple systems with innocuous dusts, water with particles collected by the ESP may be discharged from the ESP system to a solids-removing clarifier (either dedicated to the ESP or part of the plant wastewater treatment system) and then to final disposal. More complicated systems may require skimming and sludge removal, clarification in dedicated wequipment, pH adjustment, and/or treatment to remove dissolved solids. Spray water from an ESP preconditioner may be treated separately from the water used to wash the ESP collecting pipes so that the cleaner of the two treated water streams may be returned to the ESP. Recirculation of treated water to the ESP may approach 100 percent (AWMA, 1992).

References:

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