EPA-452/F-03-010

Air Pollution Control Technology Fact Sheet

Name of Technology: Condensation Scrubber

This type of technology is a part of the group of air pollution controls collectively referred to as "wet scrubbers."

Type of Technology: Removal of air pollutants by use of condensation to increase pollutant particle size, followed by inertial interception.

Applicable Pollutants: Condensation scrubbers are typically intended to control fine particulate matter (PM) with an aerodynamic diameter of between approximately 0.25 and 1.0 micrometers (µm) (Sun, 1994).

Achievable Emission Limits/Reductions: Collection efficiencies of greater than 99 percent have been reported for particulate emissions, based on study results (Sun, 1994).

Applicable Source Type: Point

Typical Industrial Applications:

Condensation scrubbers are intended for use in controlling fine PM-containing waste-gas streams, and are designed specifically to capture fine PM which has escaped a primary PM control device. The technology is suitable for both new and retrofit installations. Condensation scrubbing systems are a relatively new technology and are not yet generally commercially available (Sun, 1994; EPA, 1998; McMurry, 1999).

Emission Stream Characteristics:

- **a. Air Flow:** Typical air flows are on the order of 10 standard cubic meters per second (sm^3/sec) or 21,000 standard cubic feet per minute (scfm) (Sun, 1994).
- **b. Temperature:** The waste gas entering a condensation scrubber is generally cooled to saturation conditions, approximately 20 to 26°C (68 to 78°F) (Sun, 1994).
- **c. Pollutant Loading:** Pollutant loading is dependent upon the control effectiveness for fine PM of the primary PM control system. Fine PM may, in some cases, comprise up to 90 percent of the total mass of PM emissions from a combustion source, and many primary control technologies have relatively low collection efficiencies for fine PM (Sun, 1994).
- **d. Other Considerations:** The fine fraction of PM emissions from a combustion source often contains cadmium and other metals. Use of a condensation scrubber to capture fine PM may provide an effective method of reducing the emission of metals (Sun, 1994).

Emission Stream Pretreatment Requirements:

For PM control from combustion sources, the flue gas enters a coagulation area (e.g., ductwork, a chamber, or a cyclone) to reduce the number of ultrafine particles, and then a gas conditioner to cool the gas to a suitable temperature and saturation state. This is generally accomplished by means of a waste heat recovery heat exchanger to reduce the temperature of the flue gas or by spraying water directly into the hot flue gas stream. It is usually not practical or cost effective to cool flue gases to temperatures below ambient values. Condensation scrubbers are generally intended to be used downstream of another scrubber (e.g., a venturi scrubber) which has already removed PM >1.0 μm aerodynamic diameter (Sun, 1994).

Cost Information:

The following provides cost information (expressed in fourth quarter 1993 dollars) for retrofitting an existing scrubber system with a condensation scrubber under typical operating conditions, adapted from EPA cost-estimating spreadsheets (EPA, 1996) and referenced to the volumetric flow rate of the waste stream treated. For purposes of calculating the example cost effectiveness, the pollutant is PM at a loading of approximately 7 grams per standard cubic meter (g/sm^3) or 3 grains per standard cubic foot (gr/scf). The costs do not include costs for post-treatment or disposal of used solvent or waste (Sun, 1994).

a. **Capital Cost:** $13,000 per sm^3/sec, ($6.00 per scfm)

b. **O & M Cost:** $5,300 per sm^3/sec ($2.50 per scfm), annually

c. **Annualized Cost:** $7,000 per sm^3/sec ($3.40 per scfm), annually

d. **Cost Effectiveness:** $65 per metric ton ($59 per short ton), annualized cost per ton per year of pollutant controlled

Theory of Operation:

Condensation scrubbing is a relatively recent development in wet scrubber technology. Most conventional scrubbers rely on the mechanisms of impaction and diffusion to achieve contact between the PM and liquid droplets. In a condensation scrubber, the PM act as condensation nuclei for the formation of droplets. Generally, condensation scrubbing depends on first establishing saturation conditions in the gas stream. Once saturation is achieved, steam is injected into the gas stream. The steam creates a condition of supersaturation and leads to condensation of water on the fine PM in the gas stream. The large condensed droplets are then removed by one of several conventional devices, such as a high efficiency mist eliminator (EPA, 1998).

Advantages:

Advantages of condensation scrubbers include (Cooper, 1994):

1. Can handle flammable and explosive dusts with little risk;
2. Can handle fine PM;
3. Collection efficiency can be varied; and
4. Corrosive gases and dusts can be neutralized.

Disadvantages:

Disadvantages of condensation scrubbers include (Perry, 1984, Cooper, 1994):

1. Effluent liquid can create water pollution problems;
2. Waste product collected wet;
3. High potential for corrosion problems;

4. Protection against freezing required;
5. Off-gas may require reheating to avoid visible plume;
6. Collected particulate may be contaminated, and may not be recyclable; and
7. Disposal of waste sludge may be very expensive.

Other Considerations:

For PM applications, wet scrubbers generate waste in the form of a slurry. This creates the need for both wastewater treatment and solid waste disposal. Initially, the slurry is treated to separate the solid waste from the water. The treated water can then be reused or discharged. Once the water is removed, the remaining waste will be in the form of a solid or sludge. If the solid waste is inert and nontoxic, it can generally be landfilled. Hazardous wastes will have more stringent procedures for disposal. In some cases, the solid waste may have value and can be sold or recycled (EPA, 1998).

References:

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