EPA-452/F-03-017

Air Pollution Control Technology Fact Sheet

Name of Technology: Venturi Scrubber

This type of technology is a part of the group of air pollution controls collectively referred to as "wet scrubbers." Venturi scrubbers are also known as venturi jet scrubbers, gas-atomizing spray scrubbers, and ejector-venturi scrubbers.

Type of Technology: Removal of air pollutants by inertial and diffusional interception.

Applicable Pollutants:

Venturi scrubbers are primarily used to control particulate matter (PM), including PM less than or equal to 10 micrometers (μm) in aerodynamic diameter (PM_{10}), and PM less than or equal to 2.5 μm in aerodynamic diameter ($PM_{2.5}$). Though capable of some incidental control of volatile organic compounds (VOC), generally venturi scrubbers are limited to control PM and high solubility gases (EPA, 1992; EPA, 1996).

Achievable Emission Limits/Reductions:

Venturi scrubbers PM collection efficiencies range from 70 to greater than 99 percent, depending upon the application. Collection efficiencies are generally higher for PM with aerodynamic diameters of approximately 0.5 to 5 μm. Some venturi scrubbers are designed with an adjustable throat to control the velocity of the gas stream and the pressure drop. Increasing the venturi scrubber efficiency requires increasing the pressure drop which, in turn, increases the energy consumption (Corbitt, 1990; EPA, 1998).

Applicable Source Type: Point

Typical Industrial Applications:

Venturi scrubbers have been applied to control PM emissions from utility, industrial, commercial, and institutional boilers fired with coal, oil, wood, and liquid waste. They have also been applied to control emission sources in the chemical, mineral products, wood, pulp and paper, rock products, and asphalt manufacturing industries; lead, aluminum, iron and steel, and gray iron production industries; and to municipal solid waste incinerators. Typically, venturi scrubbers are applied where it is necessary to obtain high collection efficiencies for fine PM. Thus, they are applicable to controlling emission sources with high concentrations of submicron PM (EPA, 1995; Turner, 1999).

Emission Stream Characteristics:

a. **Air Flow:** Typical gas flow rates for a single-throat venturi scrubber unit are 0.2 to 478 standard cubic meters per second (sm^3/sec) (500 to 100,000 standard cubic feet per minute (scfm)). Flows higher then this range use either multiple venturi scrubbers in parallel or a multiple throated venturi (EPA, 2001).

b. **Temperature:** Inlet gas temperatures are usually in the range of 4 to 400 C (40 to 750 F) (EPA 2002).

c. **Pollutant Loading:** Waste gas pollutant loadings can range from 1 to 115 grams per standard cubic meter (g/sm^3) (0.1 to 50 grains per standard cubic foot (gr/scf)) (Turner, 1999; Dixit, 1999).

d. **Other Considerations:** In situations where waste gas contains both particulates and gases to be controlled, venturi scrubbers are sometimes used as a pretreatment device, removing PM to prevent clogging of a downstream device, such as a packed bed scrubber, which is designed to collect primarily gaseous pollutants.

Emission Stream Pretreatment Requirements:

Generally, no pretreatment is required for venturi scrubbers, though in some cases the waste gas is quenched to reduce the temperature for scrubbers made of materials affected by high temperatures (Dixit, 1999)

Cost Information:

The following are cost ranges (expressed in 2002 dollars) for venturi wet scrubbers of conventional design under typical operating conditions, developed using the *EPA Air Pollution Control Cost Manual*. For purposes of calculating the example cost effectiveness, the pollutant is assumed to be PM at an inlet loading of approximately 7 g/sm^3 (3 gr/scf) and the control efficiency is 99%. The costs do not include costs for fans and pumps or costs for treatment/disposal of used solvent and waste. Actual costs can be substantially higher than in the ranges shown for applications which require expensive materials, solvents, or treatment methods. As a rule, smaller units controlling a low concentration waste stream will be much more expensive (per unit volumetric flow rate) than a large unit cleaning a high pollutant load flow.

a. **Capital Cost:** $5,300 to $45,000 per sm^3/sec ($2.5 to $21 per scfm)

b. **O & M Cost:** $9,300 to $254,000 per sm^3/sec ($4.4 to $120 per scfm), annually

c. **Annualized Cost:** $12,000 to $409,000 per sm^3/sec ($5.7 to $193 per scfm), annually

d. **Cost Effectiveness:** $77 to $2,600 per metric ton ($70 to $2,400 per short ton), annualized cost per ton per year of pollutant controlled

Theory of Operation:

A venturi scrubber accelerates the waste gas stream to atomize the scrubbing liquid and to improve gas-liquid contact. In a venturi scrubber, a “throat” section is built into the duct that forces the gas stream to accelerate as the duct narrows and then expands. As the gas enters the venturi throat, both gas velocity and turbulence increase. Depending upon the scrubber design, the scrubbing liquid is sprayed into the gas stream before the gas encounters the venturi throat, or in the throat, or upwards against the gas flow in the throat. The scrubbing liquid is then atomized into small droplets by the turbulence in the throat and droplet-particle interaction is increased. Some designs use supplemental hydraulically or pneumatically atomized sprays to augment droplet creation. The disadvantage of these designs is that clean liquid feed is required to avoid clogging (EPA, 1998; AWMA, 1992; Corbitt, 1990).

After the throat section, the mixture decelerates, and further impacts occur causing the droplets to agglomerate. Once the particles have been captured by the liquid, the wetted PM and excess liquid droplets are separated from the gas stream by an entrainment section which usually consists of a cyclonic separator and/or a mist eliminator (EPA, 1998; Corbitt, 1990).

Current designs for venturi scrubbers generally use the vertical downflow of gas through the venturi throat and incorporate three features: (1) a “wet-approach” or “flooded-wall” entry section to avoid a dust buildup at a wet-dry junction; (2) an adjustable throat for the venturi throat to provide for adjustment of the gas velocity and the pressure drop; and (3) a “flooded” elbow located below the venturi and ahead of the entrainment separator, to reduce wear by abrasive particles. The venturi throat is sometimes fitted with a refractory lining to resist abrasion by dust particles (Perry, 1984).

Advantages:

Advantages of venturi scrubbers include (Cooper, 1994):

1. Can handle flammable and explosive dusts with little risk;
2. Can handle mists;
3. Relatively low maintenance;
4. Simple in design and easy to install;
5. Collection efficiency can be varied;
6. Provides cooling for hot gases; and
7. Corrosive gases and dusts can be neutralized.

Disadvantages:

Disadvantages of impingement plate 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 PM 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 or wet sludge. 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).

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