EPA-452/F-03-012

# Air Pollution Control Technology Fact Sheet

**Name of Technology**: Impingement-Plate/Tray-Tower Scrubber

This type of technology is a part of the group of air pollution controls collectively referred to as "wet scrubbers." When used to control inorganic gases, they may also be referred to as "acid gas scrubbers." When used to specifically control sulfur dioxide ($SO_2$), the term flue-gas desulfurization (FGD) may also be used.

**Type of Technology:** Removal of air pollutants by inertial or diffusional impaction, reaction with a sorbent or reagent slurry, or absorption into liquid solvent.

**Applicable Pollutants:**

Primarily 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 (HAP) in particulate form ($PM_{HAP}$); and inorganic fumes, vapors, and gases (e.g., chromic acid, hydrogen sulfide, ammonia, chlorides, fluorides, and $SO_2$). These types of scrubbers may also occasionally be used to control volatile organic compounds (VOC). Hydrophilic VOC may be controlled with and aqueous fluid, and hydrophobic VOC may be controlled with an amphiphilic block copolymer in the water. However, since very little data exist for this application, VOC data are not presented. When using absorption as the primary control technique, the spent solvent must be easily regenerated or disposed of in an environmentally acceptable manner (EPA, 1991).

**Achievable Emission Limits/Reductions:**

PM: Impingement-plate tower collection efficiencies range from 50 to 99 percent, depending upon the application. This type of scrubber relies almost exclusively on inertial impaction for PM collection. Therefore, collection efficiency decreases as particle size decreases. Short residence times will also lower scrubber efficiency for small particles. Collection efficiencies for small particles (< 1 µm in aerodynamic diameter) are low for these scrubbers, hence, they are not recommended for fine PM control (EPA, 1998).

Inorganic Gases: Control device vendors estimate that removal efficiencies range from 95 to 99 percent (EPA, 1993). For $SO_2$ control, removal efficiencies vary from 80 to greater than 99 percent, depending upon the type of reagent used and the plate tower design. Most current applications have an $SO_2$ removal efficiency greater than 90 percent (Sondreal, 1993; Soud, et al., 1993).

**Applicable Source Type:** Point

**Typical Industrial Applications:**

The suitability of gas absorption as a pollution control method is generally dependent on the following factors: 1) availability of suitable solvent; 2) required removal efficiency; 3) pollutant concentration in the inlet vapor; 4) capacity required for handling waste gas; and, 5) recovery value of the pollutant(s) or the disposal cost of the unrecoverable solvent (EPA, 1996).

Impingement plate scrubbers are typically used in the food and agriculture industry, and at gray iron foundries (EPA, 1998).

FGD is used to control $SO_2$ emissions from coal and oil combustion from electric utilities and industrial sources. Impingement scrubbers are one wet scrubber configuration used to bring exhaust gases into contact with a sorbent designed to remove the $SO_2$. On occasion, wet scrubbers have been applied to $SO_2$ emissions from processes in the primary nonferrous metals industries (e.g., copper, lead, and aluminum), but sulfuric acid or elemental sulfur plants are more popular control devices for controlling the high $SO_2$ concentrations associated with these processes (Soud, et al., 1993).

When absorption is used for VOC control, packed towers are usually more cost effective than impingement-plate towers. However, in certain cases, the impingement-plate design is preferred over packed-tower columns when either internal cooling is desired, or where low liquid flow rates would inadequately wet the packing (EPA, 1992).

**Emission Stream Characteristics:**

- **a. Air Flow:** Typical gas flow rates for a single impingement-plate scrubber unit are 0.47 to 35 standard cubic meters per second ($sm^3$/sec) (1,000 to 75,000 standard cubic feet per minute (scfm)) (EPA, 1998).

- **b. Temperature:** Inlet gas temperature is limited to 4 to 370°C (40 to 700°F) for PM control. For gaseous pollutant control, the gas temperature ranges between 4 to 38°C (40 to 100°F). In general, the higher the gas temperature, the lower the absorption rate, and vice-versa. Higher temperatures can lead to loss of scrubbing liquid or solvent through evaporation (EPA, 1996; Avallone, 1996).

- **c. Pollutant Loading:** Impingement-plate scrubbers are easy to clean and maintain and are not subject to fouling as packed-bed wet scrubbers are, hence they are more suited to PM control and there are no practical limits to inlet PM concentrations (EPA, 1998).

- **d. Other Considerations:** For organic vapor HAP control, low outlet concentrations will typically be required, leading to impractically tall absorption towers, long contact times, and high liquid-gas ratios that may not be cost-effective. Wet scrubbers will generally be effective for HAP control when they are used in combination with other control devices such as incinerators or carbon adsorbers (EPA, 1991).

**Emission Stream Pretreatment Requirements:**

For gas absorption applications, precoolers (e.g., spray chambers) may be needed to reduce the inlet air temperature to acceptable levels to avoid solvent evaporation or reduced absorption rates (EPA, 1996).

**Cost Information:**

The following are cost ranges (expressed in 2002 dollars) for impingement-plate wet scrubbers of conventional design under typical operating conditions, developed using 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 assumed to be PM at an inlet loading of approximately 7 grams per standard cubic meter ($g/sm^3$), or 3 grains per standard cubic foot (gr/scf). The cost estimates do not include costs for post-treatment or disposal of used solvent or 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:** \$8,500 to \$23,000 per $sm^3$/sec (\$4 to \$11 per scfm)

b. **O & M Cost:** \$6,500 to \$93,000 per $sm^3$/sec (\$3.10 to \$44 per scfm), annually

c. **Annualized Cost:** \$11,000 to \$150,000 per $sm^3$/sec (\$5.10 to \$71 per scfm), annually

d. **Cost Effectiveness:** \$104 to \$1,400 per metric ton (\$94 to \$1,300 per short ton), annualized cost per ton per year of pollutant controlled

**Theory of Operation:**

PM Control:

An impingement-plate scrubber is a vertical chamber with plates mounted horizontally inside a hollow shell. Impingement-plate scrubbers operate as countercurrent PM collection devices. The scrubbing liquid flows down the tower while the gas stream flows upward. Contact between the liquid and the particle-laden gas occurs on the plates. The plates are equipped with openings that allow the gas to pass through. Some plates are perforated or slotted, while more complex plates have valve-like openings (EPA, 1998).

The simplest impingement-plate scrubber is the sieve plate, which has round perforations. In this type of scrubber, the scrubbing liquid flows over the plates and the gas flows up through the holes. The gas velocity prevents the liquid from flowing down through the perforations. Gas-liquid-particle contact is achieved within the froth generated by the gas passing through the liquid layer. Complex plates, such as bubble cap or baffle plates, introduce an additional means of collecting PM. The bubble caps and baffles placed above the plate perforations force the gas to turn before escaping the layer of liquid. While the gas turns to avoid the obstacles, most PM cannot and is collected by impaction on the caps or baffles. Bubble caps and the like also prevent liquid from flowing down the perforations if the gas flow is reduced (EPA, 1998).

In all types of impingement-plate scrubbers, the scrubbing liquid flows across each plate and down the inside of the tower onto the plate below. After the bottom plate, the liquid and collected PM flow out of the bottom of the tower. Impingement-plate scrubbers are usually designed to provide operator access to each tray, making them relatively easy to clean and maintain. Consequently, impingement-plate scrubbers are more suitable for PM collection than packed-bed scrubbers. Particles greater than 1 μm in aerodynamic diameter can be collected effectively by impingement-plate scrubbers, but many particles $<1$ μm in aerodynamic diameter will penetrate these devices (EPA, 1998).

Inorganic Gases Control:

Water is the most common solvent used to remove inorganic contaminants, though as caustic for is used for acid-gas absorption (EPA, 1996). Amphiphilic block copolymers can be used to absorb hydrophobic VOC.

When used as part of an FGD system, an impingement-plate scrubber promotes contact between the flue gas and the sorbent slurry in a vertical column with transversely mounted perforated trays. The $SO_2$-laden gas enters at the bottom of the column and travels upward through the perforations in the trays; the reagent slurry is fed at the top and flows over the plates toward the bottom. In most cases the sorbent is an alkaline slurry, commonly limestone, slaked lime, or a mixture of slaked lime and alkaline fly ash, though many other sorbent processes exist. Absorption of $SO_2$ is accomplished by countercurrent contact between the gas reagent slurry. The sulfur oxides react with the sorbent, forming a wet mixture of calcium sulfite and sulfate (EPA, 1981; Soud, et al., 1993).

**Advantages:** Advantages of impingement plate scrubbers include (Cooper, 1994):

1. Can handle flammable and explosive dusts with little risk;
2. Provides gas absorption and dust collection in a single unit;
3. Can handle mists;
4. Collection efficiency can be varied;
5. Provides cooling for hot gases;
6. Corrosive gases and dusts can be neutralized; and
7. Improves gas-slurry contact for $SO_2$ removal.

**Disadvantages:** Disadvantages of impingement plate scrubbers include (AWMA, 1992, 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 (steam) 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. 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).

For gas absorption, the water or other solvent must be treated to remove the captured pollutant from the solution. The effluent from the column may be recycled into the system and used again. This is usually the case if the solvent is costly (e.g., hydrocarbon oils, caustic solutions). Initially, the recycle stream may go to a waste treatment system to remove the pollutants or the reaction product. Make-up solvent may then be added before the liquid stream reenters the column (EPA, 1996).

For FGD applications, the slurry combines with the $SO_2$-laden waste gas to form a waste slurry in the bottom of the scrubber. The sludge is removed from the scrubber and, depending upon the reagent or sorbent used to react with the $SO_2$, the waste reacted sludge is disposed of, recycled or regenerated, or, in some cases, a salable product. For slurries which produce calcium sulfate and sulfite, oxidizing the waste sludge results in gypsum. Gypsum is a preferred product because it can be marketed and also because of its superior dewatering characteristics. Most scrubbers are operated without the oxidizing step and the waste sludge must be dewatered and disposed of properly. Some slurries can be regenerated and used again, but few such systems are in use due to high energy costs associated with the regeneration of the reagent (Sondreal, 1993; Soud, et al., 1993; Merrick, 1989).

Configuring a control device that optimizes control of more than one pollutant often does not achieve the highest control possible for any of the pollutants controlled alone. For this reason, waste gas flows which contain multiple pollutants (e.g., PM and $SO_2$, or PM and inorganic gases) are generally controlled with multiple control devices, occasionally more than one type of wet scrubber (EC/R, 1996).

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