



AIR & WASTE MANAGEMENT  
ASSOCIATION

Fact Sheet:

# Air Pollution Emission Control Devices for Stationary Sources



## INTRODUCTION

Stationary sources of air pollution emissions, such as power plants, steel mills, smelters, cement plants, refineries, and other industrial processes, release contaminants into the atmosphere as particulates, aerosols, vapors, or gases. These emissions are typically controlled to high efficiencies using a wide range of air pollution control devices. The selection of the appropriate control technology is determined by the pollutant collected, the stationary source conditions, and the control efficiency required. In some cases, pollutant emissions can be reduced significantly through process modifications and combustion controls. However, in most instances, some form of add-on pollution control equipment is installed in the ductwork (or flues) leading to the smoke stack to meet current allowable emission limits.

Common methods for eliminating or reducing gaseous pollutants include:

- destroying pollutants by thermal or catalytic combustion, such as by use of a flare stack, a high temperature incinerator, or a catalytic combustion reactor;
- changing pollutants to less harmful forms through chemical reactions, such as converting nitrogen oxides (NO<sub>x</sub>) to nitrogen and water through the addition of ammonia to the flue gas in front of a selective catalytic reactor; and
- collecting pollutants using air pollution control systems before they reach the atmosphere.

The most commonly used devices for controlling particulate emissions include:

- electrostatic precipitators (wet and dry types),
- fabric filters (also called bag houses),
- wet scrubbers, and
- cyclones (or multiclones).

In many cases, more than one of these devices are used in series to obtain desired removal efficiencies for the contaminants of concern. For example, a cyclone may be used to remove large particles before a pollutant stream enters a wet scrubber.

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## Air Pollution Emission Control Devices for Stationary Sources



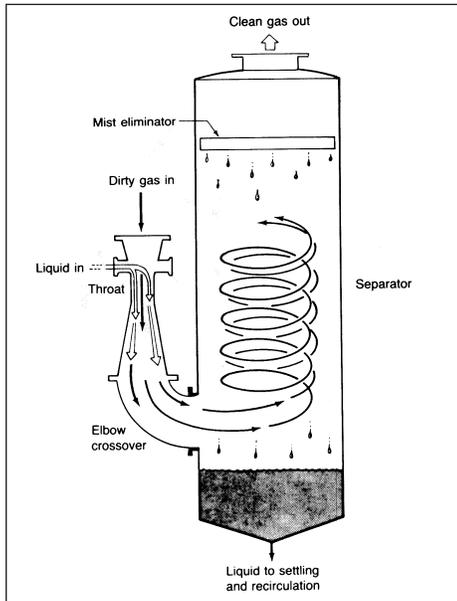
Common control devices for gaseous and vapor pollutants include:

- thermal oxidizers,
- catalytic reactors,
- carbon adsorbers,
- absorption towers, and
- biofilters.

The following table presents a list of common control devices, the typical contaminants they control, and examples of where these control devices might be used.

Common Control Devices	Pollutants	Examples Where Used
Packed towers, spray chambers, venturi scrubbers	Gases, vapors, sulfur oxides, corrosive acidic or basic gas streams, solid particles, liquid droplets	Asphalt and concrete batch plants; coal-burning power plants; facilities that emit sulfur oxides, hydrogen sulfide, hydrogen chloride, ammonia, and other gases that can be absorbed into water and neutralized with the appropriate reagent
Carbon adsorbers	Vapor-phase volatile organic compounds (VOCs), hazardous air pollutants (HAPs)	Soil remediation facilities, oil refineries, steel mills, printers, wastewater treatment plants
Fabric filters or bag houses	Particulate matter (PM)	Asphalt batch plants, concrete batch kilns, steel mills, foundries, fertilizer plants, and other industrial processes
Catalytic reactors, catalysts	VOCs, gases	Landfills, oil refineries, printing or paint shops
Cyclones	Large PM	Woodworking shops, pharmaceutical manufacturers, cotton gins, rock crushers, cement plants
Electrostatic precipitators (ESPs)	PM	Power plants, steel and paper mills, smelters, cement plants, oil refineries
Incinerators, thermal oxidizers, afterburners	VOCs, gases, fumes, hazardous organics, odors, PM	Soil contaminated with gasoline, landfills, crematories, inks from graphic arts production and printing, can and coil plants, hazardous waste disposal
Biofilters	VOCs, odors, hydrogen sulfide (H <sub>2</sub> S), mercaptans (organic sulfides)	Wastewater treatment plants, industrial processes

The following describes applications of these various pollution control devices in more detail. Additional information can be obtained from the “Air Pollution Engineering Manual, Second Edition” available through the Air & Waste Management Association.<sup>1</sup>



## ABSORPTION & WET SCRUBBING EQUIPMENT

Scrubbing is a physical process whereby particulates, vapors, and gases are controlled by either passing a gas stream through a liquid solution or spraying a liquid into a gas stream. Water is the most commonly used absorbent liquid. As the gas stream contacts the liquid, the liquid absorbs the pollutants, in much the same way that rain droplets wash away strong odors on hot summer days.

Gas absorption is commonly used to recover products or to purify gas streams that have high concentrations of water-soluble compounds. Absorption equipment is designed to get as much mixing between the gas and liquid as possible.

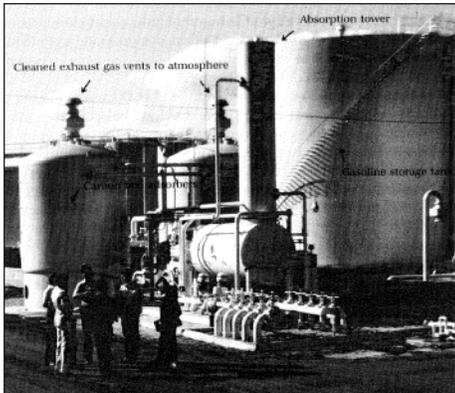
Common types of gas absorption equipment include spray towers, packed towers, tray towers, and spray chambers. Packed towers are by far the most commonly used control equipment for the absorption of gaseous pollutants. However, when used with heavy, particulate-laden gas, they can be plugged by particulate matter (PM). Wet collection devices used for PM control include venturi scrubbers, bubbling scrubbers, spray towers, and in some instances, wet electrostatic precipitators (ESPs).

Scrubbers use a liquid stream to remove solid particles from a gas stream by impacting these particles with water droplets either through water spraying into the gas or through violent mixing of water with the gas stream. For example, in a venturi scrubber, gas that is laden with PM passes through a constricted section of the scrubber (venture throat) where water and gas reach high velocities, resulting in high turbulence in the water and gas streams, which causes water droplet-particle contact.

Water is directed into the gas stream either immediately before or at the venture throat. The difference in velocity and pressure resulting from the constriction causes many small and larger water droplets to form. These droplets then collide with the particulates and essentially stick to them. The reduced velocity at the expanded end of the venture throat allows droplets of water containing the particles to coalesce into larger droplets, which then drop out of the gas stream. Often a large cyclonic section is placed after the venture to improve fallout of PM-laden water.

Wet scrubbers can be highly effective in removing particles, with removal efficiencies of up to 99%; however, their efficiency for very small particles can be much lower. Wet scrubbers produce a wastewater stream that will likely require treatment before reuse or discharge. When possible, collected PM is separated from the water, and the water is reused, but this is often difficult; disposal of a wet sludge by-product is often required.

Scrubbers are used in coal-burning power plants, asphalt/concrete plants, and can be very useful at facilities that emit particulates along with sulfur oxides, hydrogen sulfide, and other gases with high water solubility. In these cases, they can be used to collect multiple types of pollutants. Wet scrubbers are often used for corrosive acidic or basic gas streams.



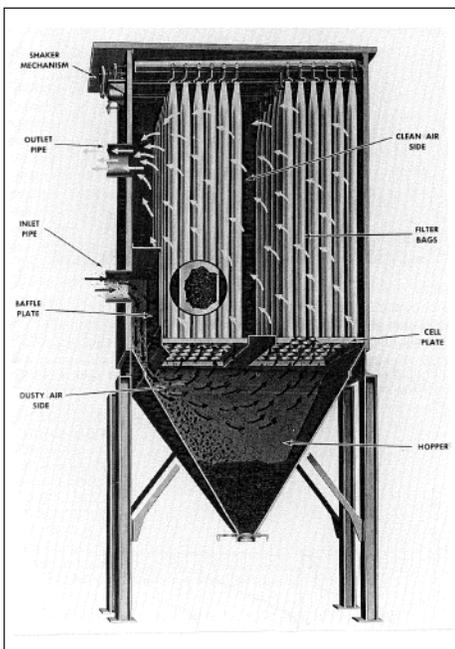
## ADSORPTION

The process of adsorption involves the molecular attraction of gases or vapors (usually volatile organic compounds (VOCs)) onto the surface of certain solids (usually carbon, molecular sieves, and/or catalysts). This attraction may be chemical or physical in nature and is predominantly a surface effect. Activated carbon (charcoal), which possesses the large internal surface area needed to adsorb large quantities of gases within its structure, is often used to remove VOCs from flue gases. After the activated carbon is saturated with VOCs, it is often treated (by heat and/or steam) to strip off the collected VOCs. The VOCs are then sent for further treatment, and the carbon is reused in the adsorption reactor. Adsorption is affected by the temperature, flowrate, concentration, and molecular structure of the gas.

Adsorption is commonly used for removing gases from contaminated soil, oil refineries, municipal wastewater treatment plants, industrial paint shops, and steel mills.

## FABRIC FILTERS OR BAG HOUSES

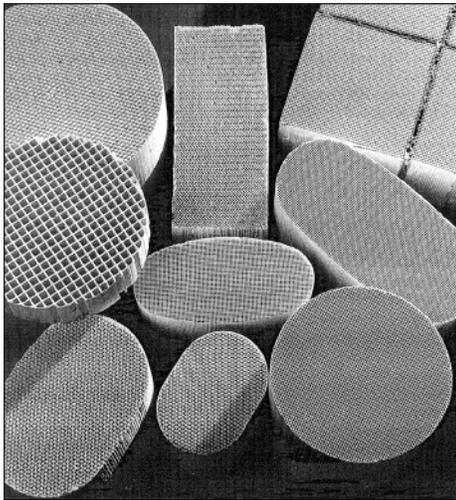
Fabric filters, also commonly referred to as bag houses, are used in many industrial applications. They operate in a manner similar to a household vacuum cleaner. Dust-laden gases pass through fabric bags where the dry particulates are captured on the fabric surface. After enough dust has built up on the filters, as indicated by a build up in pressure across the fabric, dust is periodically removed by blowing air back through the fabric, pulsing the fabric with a blast of air, or shaking the fabric. Dust from the fabric then falls to a collection hopper where it is removed. As dust builds up on the fabric, the dust layer itself can act as a filter aid improving the removal efficiency of the device.



Fabrics used in bag houses can be made of a number of different materials, selected for the particular application. Common materials for these filters include paper, cotton, Nomex, polyester, fiberglass, Teflon, and even spun stainless steels.

Bag houses maximize the filtration area by configuring the fabric filter media into a series of long small-diameter fabric tubes referred to as “bags”. The bags are tightly packed into one or more filter compartments with one compartment normally off-line for cleaning. Most bag houses contain as many as ten or more compartments with several hundred bags per compartment.

Bag houses are used to control air pollutants from coal-fired power plants, steel mills, foundries, and other industrial processes. Fabric filters can collect over 99.9% of the entering particulates, even fine PM. Bag houses also are sometimes used as part of a multistage gas cleaning system where they are used as a reactor as well as a particulate removal device, such as in semi-dry flue gas desulphurization systems. Recently some bag houses are being equipped with catalytic bags where they also act as a chemical reactor while they are collecting particulate.



## CATALYTIC REACTORS

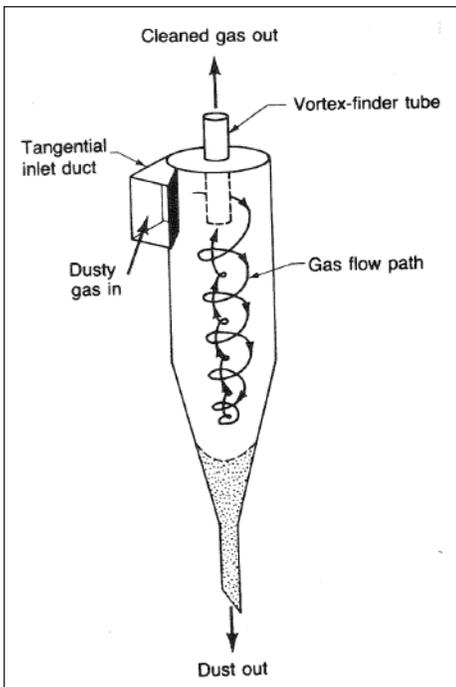
Catalytic reactors, referred to as selective catalytic reduction (SCR) systems, are used extensively to control NO<sub>x</sub> emissions arising from the burning of fossil fuels in industrial processes. Ammonia is injected and mixed with the flue gases upstream of the SCR reactor. In the SCR reactor, ammonia and NO<sub>x</sub> react to form nitrogen and water. Greater than 90% NO<sub>x</sub> removal is possible with these systems.

Catalytic reactors also perform thermal destruction functions like incinerators, but at lower temperatures and for selected waste gases only. They incorporate beds of solid catalytic material that the unwanted gases pass through, typically for oxidation or reduction purposes.

Catalytic reactors have the advantage of lowering the thermal energy requirements. Destruction efficiencies of 99.99% are possible with significantly reduced energy and operating costs as compared to an incinerator.

Problems with catalytic reactors may include the flow short-circuiting through the bed, poisoning of the catalysts, and excessive oxidation followed by thermal failure. Poisoning or contamination of the catalyst can cause a severe drop in performance over time.

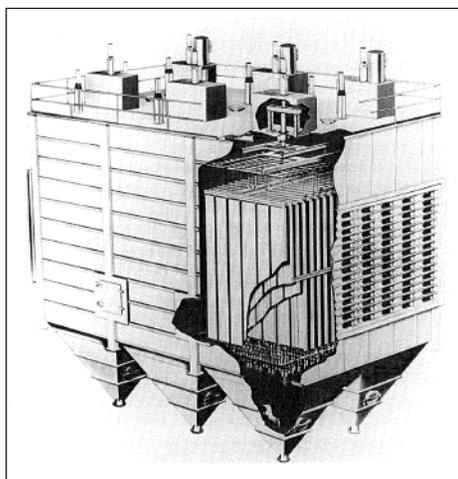
A very common example of a catalytic reactor is the three-way catalytic converter used in modern automobiles to simultaneously reduce emissions of NO<sub>x</sub>, VOCs, and carbon monoxide.



## CYCLONES

Dust-laden gas is whirled rapidly inside a collector shaped like a cylinder (or cyclone). The swirling motion creates centrifugal forces that cause the particles to be thrown against the walls of the cylinder and drop into a hopper below. The gas left in the middle of the cylinder after the dust particles have been removed moves upward and exits the cylinder. Cyclones operate to collect relatively large size PM from a gaseous stream, and can operate at elevated temperatures. Cyclones are typically used for the removal of particles 50 microns (μm) or larger. Efficiencies greater than 90% for particle sizes of 10 μm or greater are possible, and efficiency increases exponentially with particle diameter and with increased pressure drop through the cyclone.

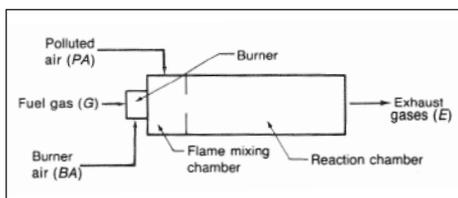
Cyclones are widely used; they control pollutants from cotton gins, rock crushers, and many other industrial processes that contain relatively large particulate in the gas stream. They can be used to remove either solid particles or liquid droplets. Cyclones can experience a number of problems including particles recirculating from the hopper, and erosion and corrosion of the cyclone internals due to the nature of the material being collected (corrosive and/or abrasive). Heavy dust at the inlet of the cyclone can also lead to plugging of the cyclone hopper.



## ELECTROSTATIC PRECIPITATORS (ESPs)

ESPs are relatively large, low velocity dust collection devices that remove particles in much the same way that static electricity in clothing picks up small pieces of lint. Transformers are used to develop extremely high voltage drops between charging electrodes and collecting plates. The electrical field produced in the gas stream as it passes through the high voltage discharge introduces a charge on the particles, which is then attracted to the collecting plates. Periodically the collected dust is removed from the collecting plates by a hammer device striking the top of the plates (rapping) dislodging the particulate, which falls to a bottom hopper for removal.

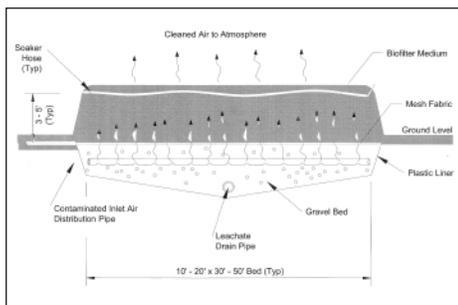
Electrostatic precipitators are often configured as a series of collecting plates to improve overall collection efficiency. Efficiencies exceeding 99% can be achieved, and ESPs are used in many of the same applications as bag houses, including power plants, steel and paper mills, smelters, cement plants, and petroleum refineries. In some applications water is used to remove the collected particulates. ESPs using this cleaning mechanism are referred to as “wet ESPs” and are often used to remove fumes such as sulfuric acid mist.



## INCINERATORS

Incineration involves the high efficiency combustion of certain solid, liquid, or gaseous wastes. The reactions may be self-sustaining based on the combustibility of the waste, or may require the addition of auxiliary fuels, such as natural gas or propane. They may be batch operations or continuous as with flares used to burn off methane from landfills. When not burning solids, they are also called thermal oxidizers, and these devices can operate at efficiencies of 99.99% (as with hazardous waste incinerators).

Thermal oxidizers are used to destroy odorous or toxic VOCs. Achieving the required temperatures (up to 2000°F) requires a large fuel usage, and costs can be high. Regenerative thermal oxidizers, though, can achieve very high heat recoveries (up to 95%), greatly reducing fuel costs.



## BIOFILTERS

Biofilters operate to destroy VOCs and odors by microbial oxidation of these problem compounds. They are most effective on water-soluble materials. The polluted air is passed through a wetted bed, which supports a biomass of bacteria that absorb and metabolize pollutants. Efficiencies over 98% are possible with this application.