A Process Combustion Corporation Company

An Introduction to Air Pollution Control Technologies

An eBook generated to provide the reader with a generic overview of the common technologies utilized to control Industrial and Municipal air pollution. PCC continues to provide educational material in support of Industry and the need to utilize properly designed and configured Air Pollution Control equipment.

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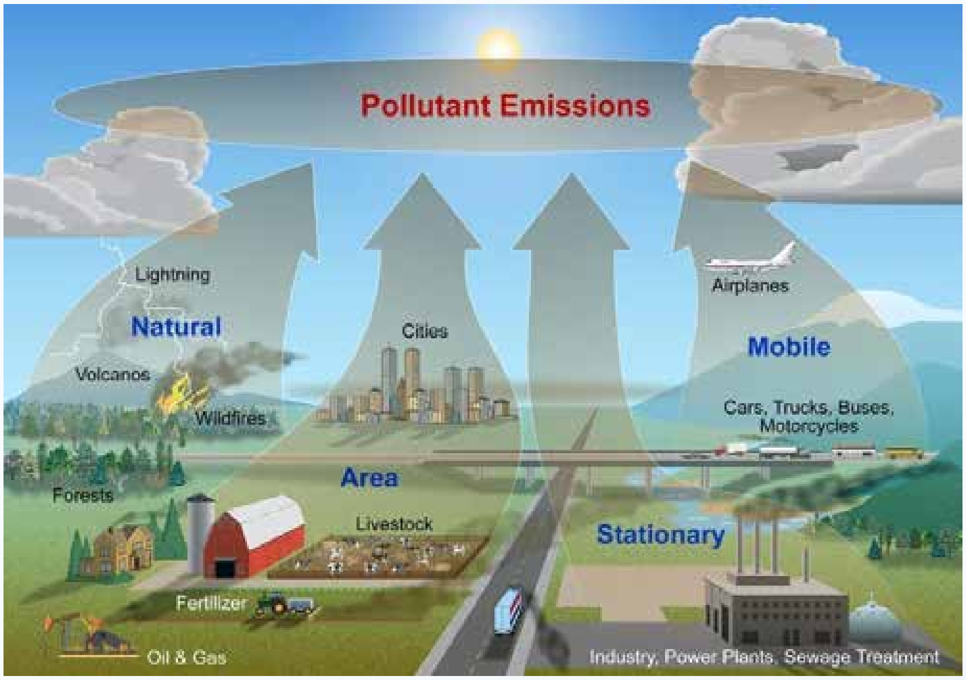
Introduction:

What is an Air Pollutant?

Answer: Any substance in the air that can cause harm to humans and the environment. Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may be natural or man-made.



Pollutants can be classified as primary or secondary. Usually, primary pollutants are directly emitted from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulfur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. An important example of a secondary pollutant is ground level ozone — one of the many secondary pollutants that make up photochemical smog. Some pollutants may be both primary and secondary: that is, they are both emitted directly and formed from other primary pollutants.

Air pollution is controlled to protect the environment from the harmful effects of industrial and municipal pollutants. We must eliminate the impact air pollution has on humans, animals, plants and all other life supporting systems.

Air Pollution Control (APC) can be described as a "separation" technology. The pollutants, whether they are gaseous, aerosol, or solid particulate, are separated from a carrier gas which is usually air. The pollutants are categorized as follows:

- Gaseous pollutants are compounds that exist as a gas at normal conditions.
- Aerosols are finely divided solid and liquid particles that are typically under 0.5 microns in diameter. They often result from the sudden cooling of a gaseous pollutant.
- Solid particulates can be evolved through combustion or through common processing operations such as grinding, roasting, drying, coating, forming or metalizing

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Pollutants are commonly referred to as Volatile Organic Compounds (VOC's) or Hazardous Air Pollutants (HAPs). As defined by the US EPA, "Volatile organic compounds (VOC) means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions." On the other side of the equation, APC defines HAPs, also known as toxic air pollutants or air toxics, as those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects.

The following industries commonly employ Air Pollution Control (APC devices as an integral part of their manufacturing process.

- Paint and Coatings Manufacturers
- Wood Products Manufacturing
- Petroleum Refining
- Chemical/Petro-Chemical Manufacturing
- Pharmaceutical Manufacturing
- Semi-Conductor and Solar
- Food and Beverage Industry
- Industrial and Municipal Waste Water

Typical industrial and municipal air streams contain a very diverse and wide range of compound pollutants. As a result, numerous technologies have been developed to address the specific control needs as determined by local, regional, state and national regulatory agencies.

APC systems can be very specific relative to their treatment capability, broad based and can effectively treat a wide range of compounds. APC is broken into two functional categories, Particulate Control and Gaseous (Waste gas) Pollutant Control

The information presented in this overview is intended to provide the reader with a general understanding of the current technologies available for the control of air pollution. The technologies presented are currently being utilized by Industrial and Municipal companies globally. Control is specific to the compounds found in the air stream, the loadings associated with each compound and the level of removal that must be achieved. As such, each system must be configured to meet the desired results based on the specifics associated with the air stream.

The following technologies are typically used to control VOCs and HAPs emissions:

- Wet Scrubbers
- Incineration
- Bio Scrubbers/Bio trickling Filters
- Carbon Adsorption

Our goal is to provide the reader with a generic knowledge of the basic, most common technologies utilized to treat waste gas emissions from industrial and municipal applications.

Wet Scrubbers

Wet Scrubbers

In wet scrubbing processes, liquid or solid particles are removed from a gas stream by transferring them to a liquid. That liquid is usually water; however, if gaseous pollutants are also being removed, it may be an aqueous solution that contains chemicals selected to react with the absorbed contaminants. Most wet scrubbing systems operate with particulate collection efficiencies over 95 percent.

Wet scrubbers for particulates are classified by energy usage levels which include:

- Low energy usage,
- Medium energy usage, and
- High energy usage.

The common types of air pollution control wet scrubber systems for particulates are:

- Spray Tower wet scrubbers,
- Tray Tower wet scrubbers,
- Packed Bed wet scrubbers,
- Fiber Bed wet scrubbers, and
- Venturi wet scrubbers.

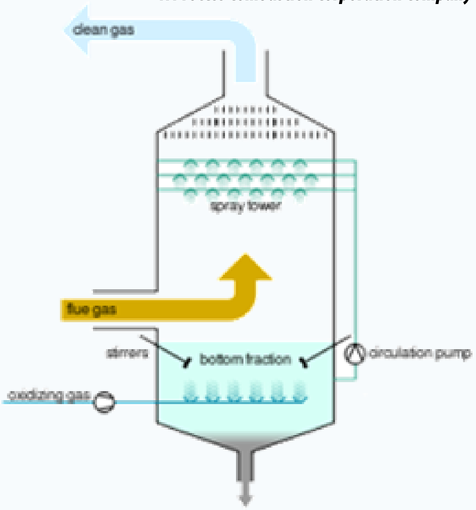
All of which are followed by Mist Eliminators or Entrainment Separation methods that remove final or exit droplets. This is done with Chevrons, Mesh Pads, and Cyclones.

Wet scrubber types by energy use:

There are many equipment designs for contacting the liquid with the contaminated gas stream. The capability of a particular design can be approximated from the gas stream pressure drop across the unit scrubber. In general, higher pressure drops indicate more aggressive contact between the liquid and the gas stream, causing smaller particles to be collected with greater efficiency. Collectors Scrubbers with pressure drops less than about 5 inches of water are capable of efficiently removing particles greater than about 5-10 micrometers in diameter. These are referred to as low energy wet scrubbers. Medium energy wet scrubbers have pressure drops from 5 to 25 inches of water. These collectors are capable of removing micrometer-sized particles, but are not very efficient on sub-micrometer particles. Removal of sub micrometer particles requires significant energy input, ranging from 25 to over 100 inches of water, depending on the particle size. These collectors are referred to as high energy wet scrubbers. Not all scrubber designs will conform to these generalized categories.

Collectors that may collect smaller particles than their pressure drop would indicate include electro-statically enhanced scrubbers and condensation growth scrubbers.

Spray Towers:

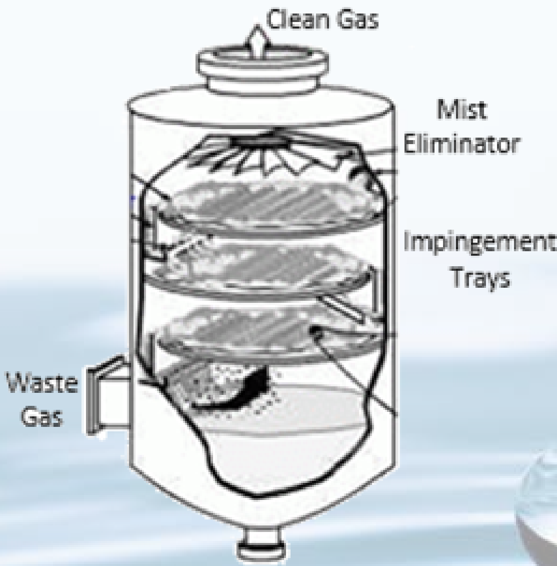


The spray tower is a low energy device and is the simplest wet scrubber used for particle collection. It consists of an open vessel with one or more sets of spray nozzles to distribute the scrubbing liquid. Typically, the gas stream enters at the bottom and passes upward through the sprays. The particles are collected when they impact the droplets. This is referred to as counter-current operation. Spray towers can also be operated in a cross-current arrangement. In cross-current scrubbers, the gas flow is horizontal and the liquid sprays flow downward. Cross-current spray towers are not usually as efficient as counter-current units.

Tray Towers:

The tray tower is a medium energy scrubber and consists of a vertical column with one or more trays mounted horizontally inside. The simplest tray is a perforated plate that is referred to as a sieve tray.

Other tray designs include:



1. Impingement trays that have small impingement targets above each perforation to enhance gas-liquid contact,

2. Bubble cap trays that can operate over a wide range of gas and liquid flow rates without adversely affecting collection efficiency.

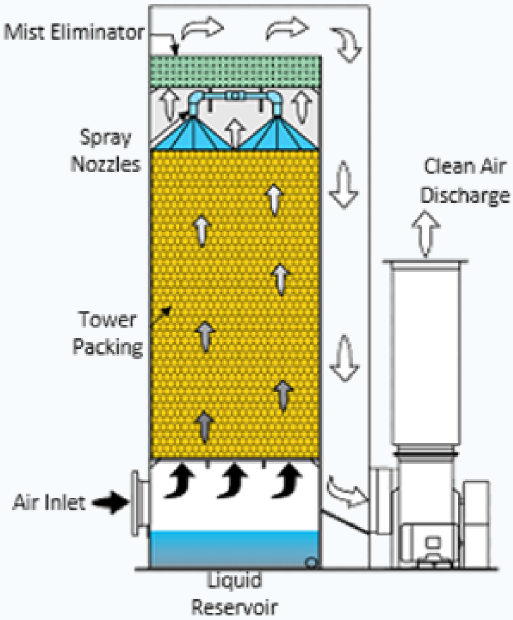
3. Valve trays that have liftable valves or caps that improve gas-liquid contact when the gas flow rate varies. Tray scrubbers are vulnerable to solids accumulation and plugging problems.

How do tray towers work?

Regardless of the tray design, all of these units operate in a similar manner. The contaminated gas stream enters at the bottom and flows upward through the holes in the plates. The liquid enters at the top of the tower, flows across the tray and then through a down comer to the tray below until it reaches the bottom of the tower. The function of the trays is to disperse the liquid into droplets and the gas stream into bubbles, creating the gas-liquid contact necessary for particle collection.

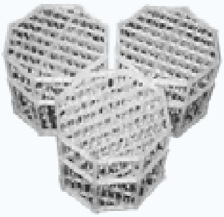
Packed Bed Scrubbers:

Packed bed scrubbers are another type of medium energy collector. Packed bed collectors spread the liquid over packing material in order to provide a large surface area for particle impaction. There are many designs for the packing materials, but they all have large surface area while maintaining open areas for the gas flow. Although they are usually made of plastic, metal and ceramic packing's are available when plastic cannot be used.



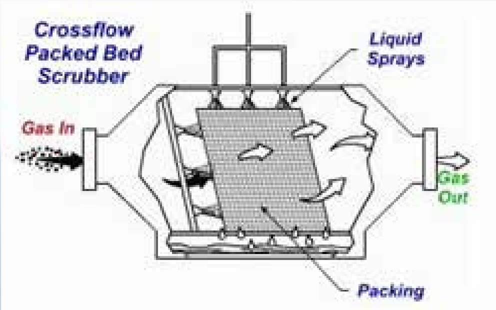
Like spray towers, packed beds are classified according to the relative direction of the gas and liquid flows. In the counter-current design, the liquid is introduced at the tope of the tower using sprays or weirs and flows downward over the packing material.

The contaminated gas stream enters at the bottom of the tower and flows upward through the packing. Because of limitations in the amount of liquid that will move downward against the upward gas flow, this orientation is susceptible to plugging when the concentration of solid particles is high.



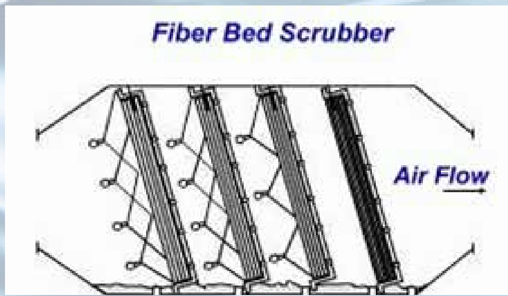
Cross-flow packed bed scrubber:

In the cross-flow scrubber, the gas stream flows horizontally through the packed bed, while the liquid flows down through the packing material. Because greater amounts of liquid can be used in this arrangement, the collector can handle higher concentrations of solid particles without plugging. In some designs, the particles are charged before entering the packed bed, in order to increase collection efficiency. These devices are referred to as ionizing wet scrubbers.



Fiber Bed Scrubbers:

A medium energy device used for the collection of liquid particles is the fiber bed scrubber. In this collector, the contaminated gas stream flows horizontally through on or more vertical mesh pads composed of randomly interlaced fibers or woven fibers. The density of the fibers controls the size of droplets that are removed. Scrubbing liquid is sprayed continuously or intermittently on the inlet side of each pad.



The system can be easily transported to the job site and lifted into place. Once the system is in place, the power, gas, compressed air and inlet connections can be made and the system is then ready for operation. In most cases, an installation requires 3-5 days on site.

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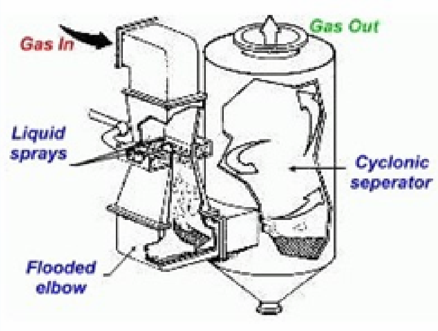
Venturi Scrubbers:

The most common high energy wet scrubber is the venturi, although it can also be operated as a medium energy scrubber. In the fixed-throat venturi, the gas stream enters a converging section where it is accelerated toward the throat section. In the throat section, the high velocity gas stream strikes liquid streams that are injected at right angles to the gas flow, shattering the liquid into small drops. The particles are collected when they impact the slower moving drops. The particles are collected when they impact the slower moving drops. Following the throat section, the gas stream passes through a diverging section that reduces the velocity. Some particle collection also occurs in this section.



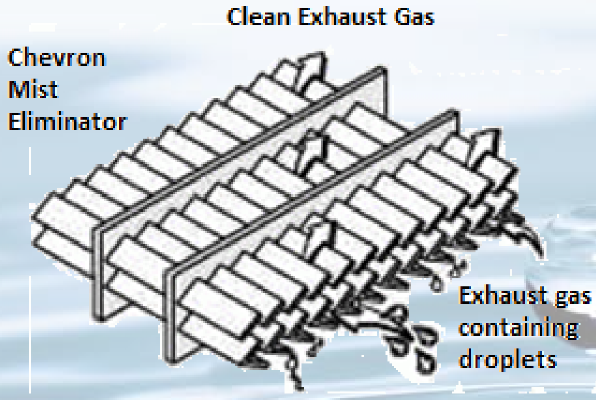
Venturi Scrubber

One variation of the standard venturi scrubber is the wetted-approach design. In this design, the scrubbing liquid is introduced at the beginning of the converging section using overflow weirs and a central spray nozzle. This is done to wet the converging section and protect it from particle erosion.

Another variation is the variable-throat venturi. Since the scrubbing energy is a function of the gas velocity in the throat, venturi's that can change their throat dimensions are used when the gas flow rate from the process varies. The position of the adjustable-throat mechanism is usually set to maintain a fixed pressure drop across the collector.

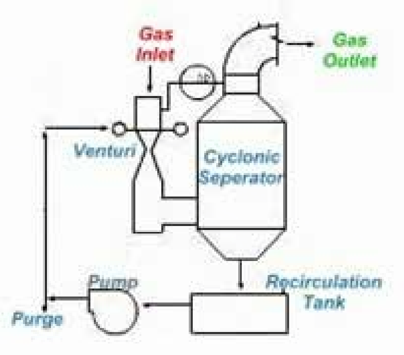
Mist Eliminators:

In all wet scrubbers, the process of contacting the gas and liquid streams results in entrained droplets. Since these droplets contain the contaminants, they must be removed before the gas stream exits the unit. This is referred to as mist elimination or entrainment separation.



The most common mist eliminators are chevrons, mesh pads and cyclones. Chevrons are simply zig-zag baffles that cause the gas stream to turn several times as it passes through the mist eliminator.

The liquid droplets are collected on the blades of the chevron and drain back into the scrubber. Mesh pads are made from interlaced fibers that serve as the collection targets. A cyclone is typically used for the small droplets generated in a venturi scrubber. The gas stream exiting the venturi enters the bottom of a vertical cylinder tangentially. The droplets are removed by centrifugal force as the gas stream spirals upward to the outlet.



Cyclonic mist eliminator in a wet scrubber system

The control efficiency a device has in capturing contaminants is affected by:

1. Particle Size, and

2. Pressure Drop.

Causes of decreased performance:

There are several operating problems that can occur in wet scrubbing system. The most common of these include the following:

- Inadequate liquid flow
- Improper liquid pH
- Liquid re-entrainment
- Poor gas-liquid contact
- Plugged nozzles, beds or mist eliminators
- Corrosion
- Is the system working efficiently?

The ability to evaluate potential problems during a field inspection will depend on how well the system is instrumented. Most large systems are well instrumented; however, smaller systems may have limited instrumentation. Performance evaluation of these systems will be difficult unless measurements of important parameters are made.

There should be two goals in any field inspection. First is to evaluate the source's compliance with any rule-specific monitoring requirements and with the provisions of the Title V permit. In addition, parameters that influence performance should be evaluated to see if there are shifts from their baseline values that could indicate reduced collection efficiency.

The most direct indicator of system performance is the opacity of the outlet gas stream. However, since the gas stream is usually close to saturation at the outlet of the scrubber, the presence of condensing moisture may make the observation difficult. For the same reason, opacity monitors are not typically used on wet scrubbers, since it is not possible to differentiate between light scattering due to particles and that due to water droplets. Therefore, less direct indicators of performance are typically used.

Performance Monitoring:

Perhaps the best indicator of adequate gas-liquid contact is the difference in temperature between the inlet and outlet of the scrubber. If that temperature difference has decreased, it is likely that the collection efficiency has also gone down. For example, a higher than normal temperature at the outlet of a scrubber, may indicate a decreased liquid flow rate.

The liquid flow rate into the scrubber is also important. If the flow rate is being monitored, the value during the inspection should be compared to the baseline or permit value. A decrease in the liquid flow rate, without a proportional decrease in the gas flow rate, will usually cause a decrease in the collection efficiency. If the flow rate is not being monitored, other indicators can be used. Indirect indications of decreased liquid flow rate include a decrease in the pump discharge pressure or an increase in the pressure in headers supplying spray nozzles. Increased pressure in a supply header is usually due to plugging of the nozzles, which reduces the liquid flow rate.

The pH of the inlet and outlet liquid should be evaluated. An inlet pH above 10 indicates a potential for scale accumulation that can plug nozzles, packed beds, and trays, reducing liquid flow rates and impairing gas-liquid contact. An outlet pH below 6 can cause severed corrosion of metal components.

Causes of changes in scrubber pressure:

Changes in scrubber pressure drop can occur for several reasons. Increased pressure drop across the packed bed or tray scrubber may indicate plugging of the bed or trays or packed beds. Increased pressure drop on a venturi scrubber may be caused by increased liquid flow rate or by adjusting a variable throat damper to a more closed position.

A decrease in the pressure drop across a tray scrubber may indicate warped or collapsed trays, while for a venturi scrubber it may be caused by decreased liquid flow rate or by adjusting a variable throat damper to a more open position.

Mist eliminator performance:

Similarly, the pressure drop across the mist eliminator provides an excellent indicator of its physical condition. For mist eliminators that are used to remove the relatively large droplets created in the scrubber, the increased pressure drop usually results from a buildup of material on the mist eliminator surfaces, narrowing the openings for the gas to flow through. The resulting higher gas velocities can drag the collected liquid through the mist eliminator and back into the outlet gas stream, reducing collection efficiency. A decrease in the pressure drop across the mist eliminator may indicate structural failure.

The performance of the mist eliminator can also be evaluated by observing the stack and areas adjacent to the stack. Rain out of droplets around the stack, mul-lips and discolored streaks at the stack discharge, or heavy drainage from open ports all indicate a poorly performing mist eliminator.

System parameter checklist:

To review: to determine if a wet scrubber system is working properly, field personnel should observe, if possible:

- Outlet Gas Stream Opacity, but take into consideration the presence of water droplets,
- Temperature Difference between the Gas Inlet and Outlet, and
- Liquid Flow Rate into the scrubber.

Other parameters include:

- pH Levels of the inlet and outlet liquids, and
- Pressure Drop changes in wet scrubbers and mist eliminators.,

As with any inspection of an air pollution control device, attention must be given to the systems:

- Records & Physical Condition
- Compliance with Applicable Rules

Wet scrubber systems used for air pollution control have many safety considerations including:

- Inhalation Hazards and Corrosive Liquids

INCINERATION

Incineration:

In industrial waste gas incineration, organic contaminants are removed from a gas stream by oxidizing them to other compounds. If the organic compounds are composed of carbon and hydrogen, then the products of that oxidation are carbon dioxide and water vapor. However, if the organic materials contain chlorine, fluorine or sulfur, then hydrochloric acid vapor, hydrofluoric acid vapor, sulfur dioxide, or other compounds may be formed. In general, incinerators are capable of destruction efficiencies greater than 95 percent. Some incinerator designs have destruction efficiencies greater than 99.99%.

The three common types of incinerators used in air pollution control are:

- Flares - both ground level and elevated
- Thermal Oxidizers
    - Direct Fired
    - Recuperative
    - Regenerative
    - Flameless
- Catalytic Oxidizers

An incinerator's efficiency in destroying a contaminant gas can be affected by the:

- concentration of the organic gas
- ignition/combustion temperature
- retention time
- mixing

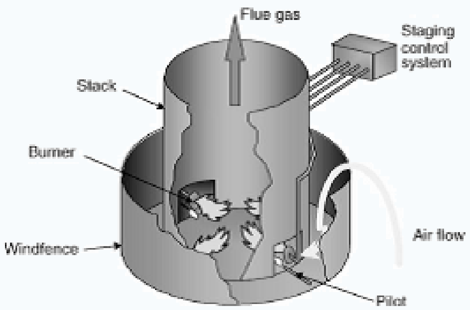
Endothermic Flare:

Flares are usually used for gas streams that have an organic vapor concentration greater than 2 to 3 times the lower explosive limit. If the waste gases do not have sufficient heat content, fuel will be added to the gas stream. This is referred to as a fired or endothermic flare.

A typical flare consists of a system that first collects the waste gases and then passes them through a knockout drum to remove any liquids before entering the flare stack. Flame arrestors are placed between the knockout drum and the flare stack to prevent flashback of flames into the collection system.

The flare stack is a hollow pipe that may extend to heights above 150 feet. The flare tip is at the top of the stack, where the waste gases are ignited by pilot flames. The flare tip is designed to provide good mixing characteristics over a range of waste gas flow rates, while maintaining smokeless combustion.

Steam jets are one of the most effective ways to mix air with the waste gases. The steam also reduces polymerization of organic compounds in the waste gas stream and reacts with the gases to produce oxygenated compounds that burn at lower temperatures.

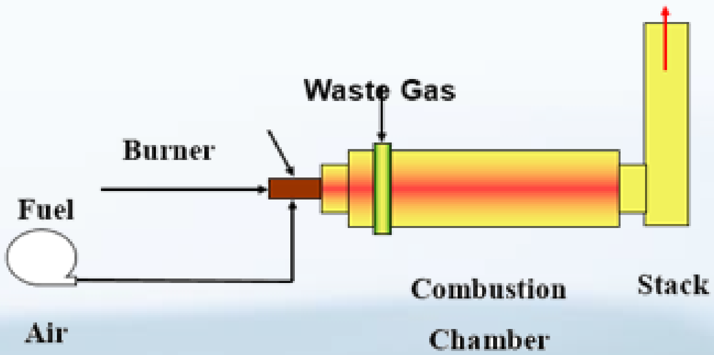


Ground Level Flares:

In order to reduce the noise, light and safety concerns inherent with an open flame, the flare may be located at ground level. Ground flares consist of multiple burners enclosed in a refractory-lined shell. The waste gases are introduced through a jet or venturi to provide turbulent mixing, and the combusted gases are discharged through a stack. Some plants incorporate both designs: a ground flare for normal operation and an elevated flare for emergency release.

Thermal Oxidizers:

Thermal oxidizers are used for contaminated gas streams that have an organic vapor concentration that is generally less than 50 percent of the lower explosive limit and usually less than 25 percent.



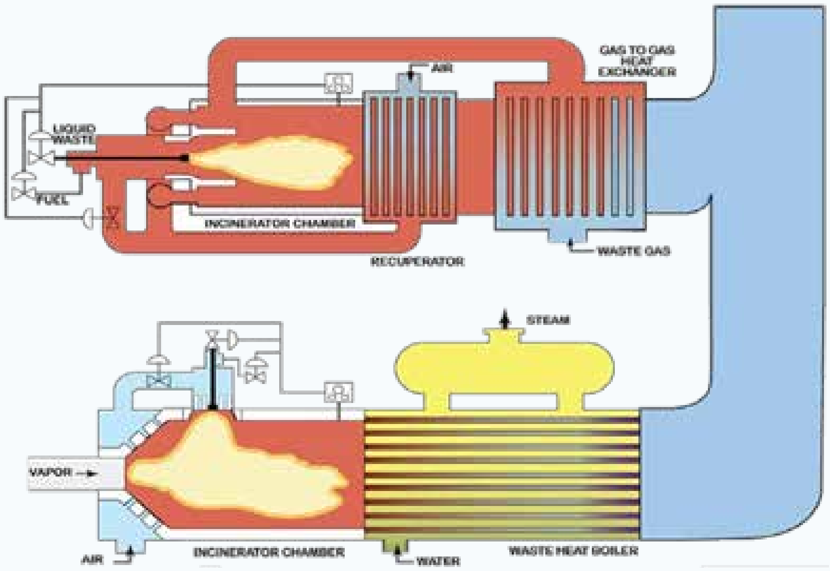
The thermal oxidizer consists of a refractory-brick lined chamber that has one or more gas- or oil-fired burners located at one end. The burners are used to heat the gas stream to the necessary temperature oxidize the organic contaminants, typically 1,300 to 1,800°F. The contaminated gas stream does not usually pass through the burner itself, unless a portion of the gas stream is used to provide the oxygen needed to support combustion of the fuel. The system can be configured either in a horizontal or vertical flow.

The combustion chamber is sized to provide sufficient residence time to complete the oxidation reactions. Typical residence times are 0.3 to 0.5 seconds, but may be longer than 1 second. The time needed for destruction depends on the temperature and mixing within the chamber as well as the compounds being treated.

Recuperative Thermal Oxidizers:

Recuperative Thermal Oxidizers incorporate the use of heat exchangers and/or waste heat boilers, which capture the available heat and use it to produce steam, heat process air streams, etc. Recuperative systems typically include major equipment such as:

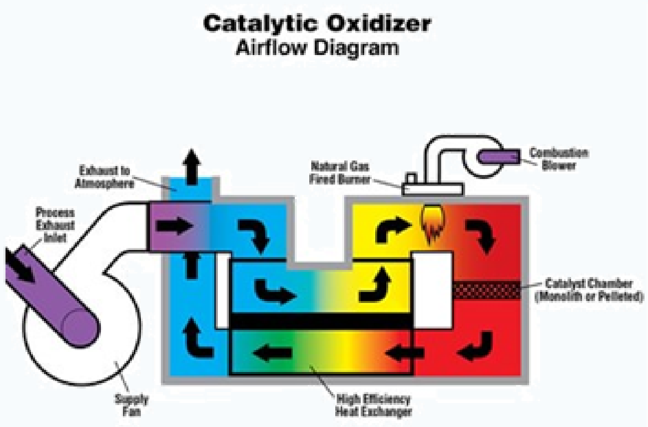
- ✓ Heat exchangers
- ✓ Waste Heat Boilers
- ✓ Air or Oil Heaters



Because of fuel costs, most incinerators use heat exchangers to recover some of the heat from the treated gas stream. That heat is usually used to pre-heat the contaminated gas stream before it enters the incinerator or to generate steam, hot air, or oil.

Catalytic Oxidizers:

Catalytic oxidizers are used for contaminated gas streams that have an organic vapor concentration that is less than 25 percent of the lower explosive limit. Concentrations greater than this cause high temperatures that can damage the catalyst material. A catalyst is a substance that accelerates a chemical reaction without undergoing a change itself.

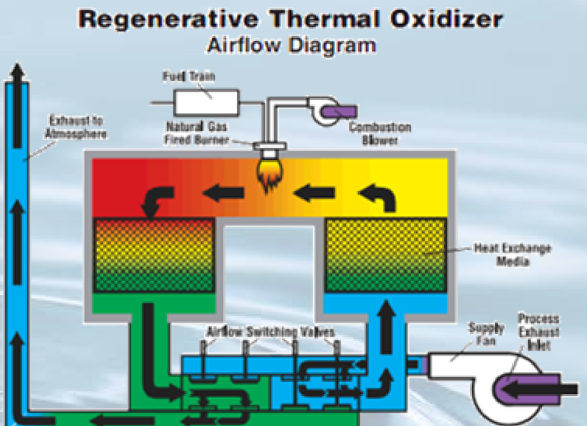


The typical catalysts used in incineration are noble metal oxides of platinum, palladium or rhodium that are deposited as a thin layer on a high surface area support material. Base metal oxides, such as vanadium pentoxide, titanium dioxide or manganese dioxide, may also be used. In catalytic oxidation, the contaminated gas stream is heated to the required temperature by a gas-fired burner and then passed through the catalyst material, referred to as the bed. The catalyst causes the oxidation reaction to occur at much lower temperatures than would be required for thermal oxidization. The typical catalytic oxidizer operates at 600 to 850°F. This is the principal advantage of catalytic oxidation. Because of the lower operating temperature, less fuel is required for heating, and refractory-lined combustion chambers are usually needed. In some cases, it is possible for the catalytic oxidizer to operate without supplemental fuel, except during start-up.

The primary disadvantages of catalytic oxidizers are the cost of the catalyst and performance problems related to physical and chemical deterioration of the catalyst material. Catalytic oxidizers usually cannot be used effectively on waste gas streams with high concentrations of liquid or solid particles.

Regenerative Thermal Oxidizer, RTO:

An RTO is a set of refractory beds that store heat. Heat recovery is achieved by passing the waste gas stream through a packed ceramic bed at the inlet to the incinerator that was previously heated with the gases exiting the incinerator. The first bed is used to pre-heat the waste gas stream. The second bed is used to store heat from the treated gas stream. The gas flow is reversed, based on a preset time.



A typical cycle consists of the following:

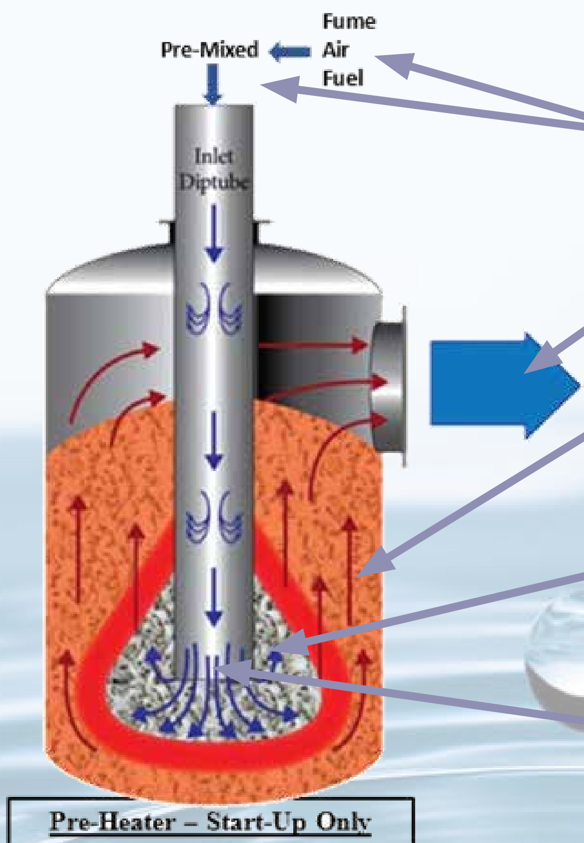
- Valves divert the flow (direction)
- The waste gas is preheated (heat recovery bed one) prior to entry into the combustion chamber
- VOC's are combusted in the combustion chamber
- Combusted gas heats the second heat recovery media bed
- Vent to Stack
- Valves switch again.

Flameless Thermal Oxidation:

Flameless oxidation is a thermal treatment that premixes waste gas, ambient air, and auxiliary fuel prior to passing the gaseous mixture through a preheated inert ceramic media bed. Through the transfer of heat from the media to the gaseous mixture the organic compounds in the gas are oxidized to innocuous by-products, i.e., carbon dioxide (CO_2) and water vapor (H_2O) which also releasing heat into the ceramic media bed.

The reason why a flame is not generated in the media bed is because the gas mixture is kept below the lower flammability limit based on the percentages of each organic species present.

PCC's Flameless Thermal Oxidizers are designed to operate safely and reliably below the composite LFL while also maintaining a constant system flow and enthalpy (temperature). Waste gas streams experience multiple seconds of residence time at high temperatures leading to measured destruction removal efficiencies that exceed 99.9999%. Premixing all of the gases prior to treatment eliminates localized high temperatures which leads to thermal NOx as low as 1 ppmv.



How Does Flameless Thermal Oxidation Work?:

Premix Waste Gas, Ambient Air, and Natural Gas

Gas mixture below flammable range (Below LEL)

Exhaust to atmosphere or to a waste heat recovery system, i.e. a waste heat boiler for steam generation

The Media Bed is preheated to initiate oxidation reactions (Bottom Mounted Preheat Burner)

Oxidation Zone - Control

Oxidizing - Not combusting, Maximum Temperature

1800-1900°F

Mixture of Air, Fume, & Fuel are mixed and sent down the dip-pipe. Control is performed by holding the reaction zone in a fixed location based on a thermocouple temperature measurement within the reaction wave.

Design Benefits:

- High DRE........99.9999%
- Low Thermal NOx < 1 ppmv
- Low Temperatures throughout
- Feed Forward Control to account for changing waste conditions

Review:

Causes for reduced performance:

There are several factors that contribute to loss of performance in thermal and catalytic oxidizers. These problems include:

- Low combustion temperature
- Inadequate residence time
- Inadequate mixing of the gases
- Burner combustion problems
- Short-circuiting through the heat exchanger
- Fouling or plugging of the heat exchanger
- Generation of additional pollutants in the incinerator
- Loss of catalyst activity

The ability to evaluate potential problems during a field inspection will depend on how well the system is instrumented. Most large incineration systems are well instrumented; however, smaller systems may have limited instrumentation. Performance evaluation of these systems will be limited unless measurements of important parameters are made.

There should be two goals in any field inspection. First is to evaluate the source's compliance with any rule-specific monitoring requirements and with the provisions of the Title V permit. In addition, parameters that influence performance should be evaluated to see if there are shifts from their baseline values that could indicate reduced destruction efficiency.

System parameter checklist:

To determine if an incinerator is operating correctly, field personnel should observe, if possible:

- Outlet Gas Stream VOC Concentration either with Permanent or Portable Analyzers
- Outlet Gas Stream Temperature
- Retention time in the combustion chamber system sizing based on waste gas flow rate.
- Proper mixing of waste gas, oxygen and supplemental fuel (if required)
- Decreases and Increases in the Gas Flow Rate
- System pressure drop
- Stack Opacity

As with any inspection of an air pollution control device, attention must be given to the System's:

- Records & Physical Condition, and
- Compliance with Applicable Rules.

Incinerators used for air polution destructio have many safety considerations including:

- Hot Surfaces, and
- Hot Work

Bio-Oxidation (aka Bio-Filters)

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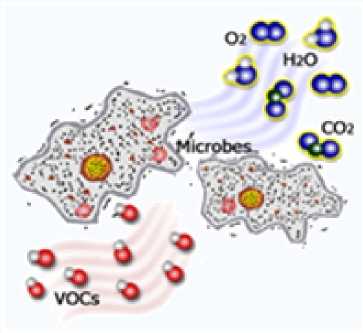
Introduction:



Biological oxidation is a natural process that has taken place for as long as microbes, fungi and bacteria have been in existence. Natural, biodegradation of dead plant and animal material is the most common and original biological oxidation process. Successful utilization of this naturally occurring process relies on how effectively we can control and maintain the critical elements that impact the maintenance, reproduction, and growth of the microbial populations. Engineered biooxidation systems simply take advantage of the natural ability of the micro-organisms to biodegrade organic (and some inorganic) compounds. The more advanced systems utilize comprehensive engineering, design flexibility, and automated control. This attention to detail yields more efficient operation, reduced maintenance, and optimal system performance.

Description: What is Bio-oxidation (aka Bio-filtration)?

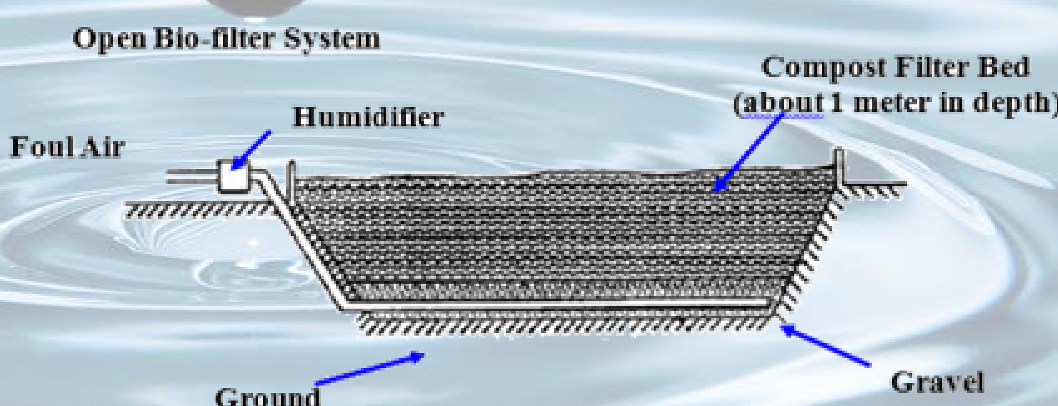
In air emissions control, bio-oxidation is simply the use of microbes to collect and bio-degrade pollutants from a contaminated air stream. Any organic compound, with the help of microbes, will decompose (decay) given the proper environment and sufficient time. Additionally, certain microbes also can biodegrade inorganic compounds such as hydrogen sulfide and nitrogen oxides.

How do Bio-Oxidizers Work?

Microbes, fungi and bacteria, have relatively simple life cycles; they are present, eat, grow, reproduce and die. Some species of bacterial may have 100 generations in a 24-hour time period. Their diet is based primarily on carbon-based compounds, water, oxygen (for aerobic reactions) and macronutrients (nitrogen, phosphorus). Bio-oxidizers use microbes to remove pollutants from airstream emissions through their metabolism of the compounds.

The basic concept is quite simple, however the execution cab be quite complicated. A traditional bio filter is usually a rectangular pit that contains an enclosed plenum on the bottom, a layer of gravel above the plenum, and several feet of media (bed) on top of the gravel.

These “traditional” open top system designs typically had a very large footprint. The compost media breaks down quickly causing compaction, airstream channeling, and bed collapse. Additionally, the operating parameters are inherently difficult to control..



A number of materials are used for bed media such as peat, composted yard waste, bark, coarse soil, gravel or plastic shapes. The gravel allows the air from the plenum to move into the bed media to contact the microbes that live in the bed. The gravel also permits excess, condensed moisture to drain out of the bed to the plenum. A fan is used to collect contaminated air from a building or process, usually forcing the air through the media bed. The microbes reduce pollutant concentrations by collecting and metabolizing pollutants. During the biodegradation process, enzymes in the microbes convert compounds into energy, CO_2 and water, much in the same way our food is processed by our bodies.

Why is Bio-Oxidation Important?

Operational Cost Savings! Operating costs are considerably less than the costs of more traditional air control technologies. Thermal and catalytic oxidizer (TO) control units consume large volumes of natural gas. Bio-oxidizers only use small amounts of electrical power to drive pump and fan motors. Normally, biooxidation systems do not require full-time labor and the only operating supplies needed are small quantities of macro- and micronutrients.

Bio-oxidation is a "green" process, whereas the traditional approaches for air pollution and odor control are not. Combusting any fuel generates oxides of nitrogen (NOx), particulate matter, sulfur dioxide (SO_2), and carbon monoxide (C)). Bio-oxidizers do not generate these pollutants or any other "criteria" pollutants, and no hazardous waste materials. The typical by-products associated with a bio-oxidizer are water and carbon dioxide (CO_2).

Bio-oxidizers have proven themselves to be effective control devices for industrial air streams. Proper design and engineering are critical to the overall successful operation, maintenance and the long-term performance of the system. Compound loadings, air temperature, humidity and operating pH are key factors that contribute to the performance of any bio-oxidation system. Bed back pressure, pollutant loading and air velocities are also critical elements that must be considered when designing and configuring a system.

Operational Factors Affecting Performance:

Factors that have influence include particulate material, available nutrients, available oxygen and the type of contaminant to be degraded. The following information will provide an overview of the key criteria required to maintain a fully operational bio-oxidation system.

There are a number of variables that affect the operation and efficiency of a bio-oxidizer that include: temperature, pH, moisture, type of contaminant compound, compound loading, macronutrient feeding, retention time, and bed media. These are crucial variables for which optimum conditions must be determined, controlled and maintained.

Advancements in the technology:

Over the last decade, a new generation of advanced bio filter systems (bio-oxidation systems) has come to market. These systems are based on the same basic biological principals as earlier systems but with advancements that make them much more compatible for industrial applications. For instance, the media used provides increased surface area per unit volume (i.e. more air-to-biofilm contact area) with a support structure that virtually eliminates compaction. Advanced systems are designed to provide the optimum atmosphere for the microbes to do their best work.

These systems are available in a variety of designs: bio trickling scrubbers, bio trickling plus bio filter chambers and/or bio filters alone. The combination of a bio trickling stage with a bio filter stage allows for the degradation of a wide variety of compounds in one cost-effective system. The specifics of the application will determine the appropriate design choices. The proper sizing allows for the optimum residence time for efficient treatment of the emissions. The bio trickling or absorber section consists of an inorganic substrate (X-flow media) with a constant water recirculation that allows redistribution of nutrients and constant re-inoculation of bacteria and fungi for enhanced biological growth, as well as for humidification. The Media chamber is filled with a variety of proprietary and non-proprietary medias which promote treatment and minimize compaction and channeling within the bed.

The basic system consists of a bio-trickling or absorber chamber that will humidify the airstream, initiate the removal of the water soluble compounds, provide nutrients to the entire bio-system and minimize particulate transfer to the organic or inorganic media chamber.

Water is continuously recirculated within the chamber via the common sump located at the base of this chamber.

The organic or inorganic media section completes the THC/VOC removal process by way of maximized, direct media contact with the air stream, with periodic sump water spray for nutrient redistribution and re-inoculation of bacteria and fungi. The media provides the best substrate for bio-film development and final removal of the hydrophobic THC/VOC compounds, prior to discharge to the exhaust stack.

Conclusion

Advanced bio-oxidation systems have been much refined since the initial bio-filter systems were put into service 50 plus years ago. The advanced systems apply to many more industrial applications than ever before and can save industry hundreds of thousands of dollars in annual operating and maintenance costs over a thermal oxidizer. Industry also receives significant reductions in VOCs emitted and a significant reduction in GHG creation by utilizing this technology.

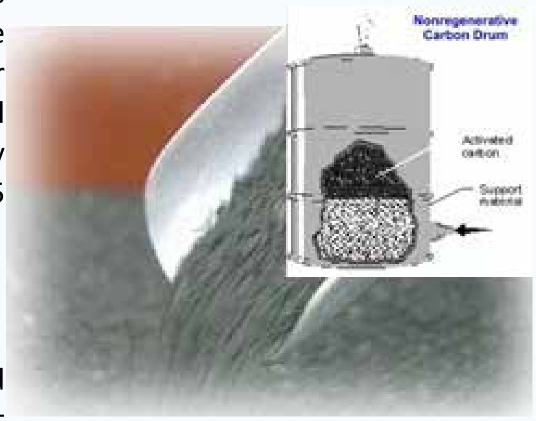
Regulatory agencies are more open to accepting advanced bio filter systems for industrial pollutant control and this technology has been accepted by the US EPA as Best Available Control Technology (BACT). Industry has been more accepting of the technology due to the benefit of reduced energy use, reduced maintenance and the reduction in carbon footprint.

Carbon Adsorption Devices

A Process Combustion Corporation Company

Carbon Adsorption - What is Adsorption?

In adsorption processes, gaseous contaminants are removed from a gas stream by transferring them to the surface of a solid adsorbent. These adsorbent materials include silica gel, activated alumina, molecular sieves, polymers and activated carbon. The most common material for the adsorption of organic pollutants is activated carbon. A properly designed activated carbon system is generally capable of removing 95 to over 98 percent of an organic contaminant.



Types of Adsorption Processes:

There are two types of activated carbon systems: those that regenerate on site and those that do not. The two most common industrial adsorbers are a fixed-bed design that regenerates on site and a fixed-bed design that does not regenerate on site, often referred to as a carbon drum.

System Characteristics:

The amount of material adsorbed by activated carbon is termed its retention or capacity and is expressed in weight percent or in pounds of organic contaminant adsorbed per 100 pounds of carbon. There are several types of capacities and they all depend on the operating conditions and on the particular organic contaminant being collected. Saturation capacity is the maximum amount or organic material the carbon can hold. Breakthrough capacity is the amount of organic material the carbon can hold before significant organic concentration begins to exit or break through the carbon bed. Heel capacity is the amount of organic material remaining in the carbon bed after it has been regenerated. Working capacity is the difference between breakthrough capacity and heel capacity and represents the amount of organic material that can be adsorbed in each operating cycle. A typical working capacity is 10-20 pounds of contaminant per 100 pounds of carbon.

Parameters Affecting Adsorption:

The ability of activated carbon to retain organic contaminants is influenced by a number of parameters, including temperature, pressure, contaminant concentration, contaminant molecular weight and the presence of moisture and particles in the gas stream.

Retention and Adsorption:

At lower temperatures, the retention of the organic contaminant is highest. Because of this, carbon adsorbers are usually operated at temperatures less than about 125°F. The low retention at higher temperatures provides one method for regeneration. At lower system pressures, retention is lower, providing another method for regeneration. Retention also increases as the organic concentration increases. However, more total carbon is usually needed at higher concentrations because of the greater quantity of organic contaminant that must be collected.

Retention is affected by the molecular weight of the contaminant molecules. As the molecular weight of the molecules increases, retention increases. Moisture in the gas stream can also affect retention. Water will adsorb onto activated carbon, competing with the organic contaminant for adsorption sites. Since adsorption is also affected by the presence of liquid and solid particles in the gas stream, particulate matter must be removed before entering the adsorbers.

Inlet gas concentration and temperature:

The inlet concentration to the carbon adsorbers should also be checked. Adsorbers designed to operate at 10-25 percent of the Lower Explosive Limit will usually have an LEL monitor in the inlet duct to shut the system down if the concentration increases above this safety limit. Otherwise, the measurement will have to be made with a portable analyzer. Increased inlet concentration could lead to breakthrough, unless the regeneration frequency has been increased.

The inlet gas temperature is one of the most important variables affecting performance. Increased gas temperature will substantially reduce the capacity of the carbon bed, leading to breakthrough. The current inlet gas temperature and, if it is being recorded, the temperature over the last several months should be evaluated for significant increases above baseline values.

Pressure drop across the beds:

The pressure drop across the carbon bed should be evaluated. As the carbon bed ages, it settles and compacts, causing the pressure drop to increase from baseline values. Since old carbon may have less capacity than new carbon, an increase in static pressure drop may indicate reduced performance. An increase in the pressure drop can also be caused by accumulation of particulate matter on the inlet side of the bed. The blinding of some of the carbon granules, together with poor gas flow distribution, will cause increased emissions. Decreased pressure drop is usually due to partial or complete collapse of the fixed bed because of corrosion of the support grid. This will also cause increased emissions.

Review:

To review, the common types of activated carbon adsorbers that capture air pollution regenerate:

- **On Site**
- **Off-Site**

Carbon adsorption systems have retention capacity that includes the:

- **Heel and Breakthrough capacity**
- **Between these two points is the Working capacity**
- **The Saturation capacity is the maximum amount of organic compounds the carbon bed can hold.**

Retention can be affected by:

- **Temperature**
- **Pressure**
- **Organic Concentration**
- **Contaminant Molecular Weight**
- **Moisture**
- **Particulate Matter in the system**

System parameter checklist

To determine that a carbon adsorbers system is working efficiently field personnel should observe, if possible:

- **Organic Vapor Concentration in the inlet/ outlet gas streams**
- **Inlet Gas Temperature**
- **Pressure Drop across the carbon bed**
- **Gas Flow Rates**
- **Regeneration Frequency and Cycle Times**

Safety Tips:

Carbon adsorption systems used for air pollution control have many safety considerations including:

- **Inhalation Hazards**
- **High Temperature Steam**

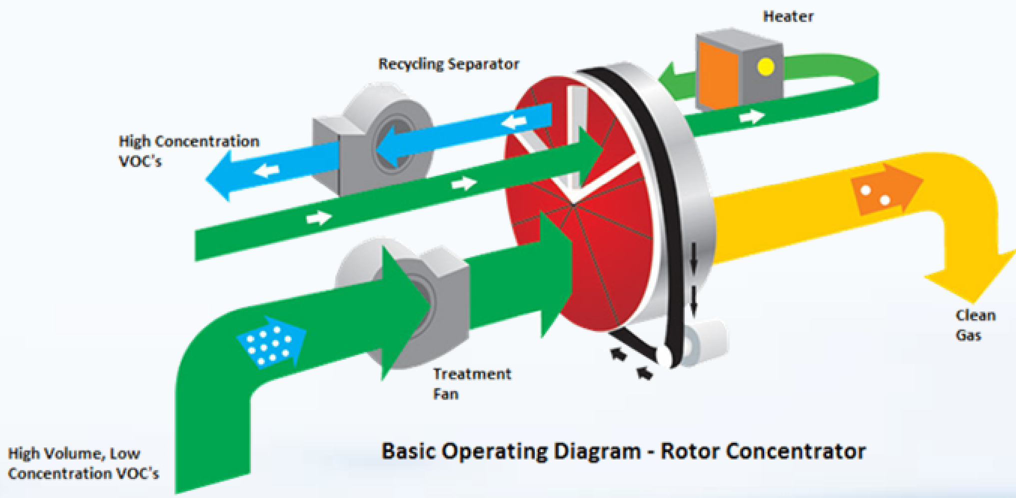
Rotor Concentrator/ Fluidized Bed Concentrators

Rotor and Fluidized Bed Concentrators

For high volume airstreams with relatively low organic concentration, the energy required to bring the process stream up to the thermal oxidation temperature can be significant. A technology has developed that uses a Rotor Concentrator or Fluidized Bed Concentrator (FBC) in a 2-step process, and has proven to be effective in high-volume, low-concentration air streams.

Process Description:

In the Rotor Concentrator the first part of that system consists of slowly a rotating concentrator wheel, utilizing zeolites or carbon deposited on a substrate, which adsorbs the organics as they are exhausted from he original process and passed through the wheel. A sector of the concentrator wheel is partitioned off from the main section of the rotor and clean heated air is passed through this section to desorb the organics. The air volume of clean heated air varies for applications, but is roughly 10% of the original airstream volume.



Basic Operating Diagram - Rotor Concentrator

As the clean heated air passes through the rotor section, the organics are desorbed, resulting in a process stream that is 10% in volume of the original process stream and 10 times the original concentration. For example, if the process airstream was 50,000 cfm with 1% concentration then the desorption stream will be 5,000 cfm and 10% LEL. The desorption airstream will drive off all the organics in that particular sector of the wheel and as the shell continues to turn the entire wheel is desorbed. As the concentrated organic, low volume airstream exits and in the second part of the system it is processed through a thermal recuperative or regenerative oxidizer.

Consequently, what has occurred is that a large air stream with low concentration, which requires considerable energy to heat-up, has been reduced to a low airstream with a high concentration, which is significantly less costly to process.

The concentrator wheel with a thermal oxidizer, the original process stream is drawn through the rotor on the cooling pass. A secondary fan draws this air and forces this volume through the secondary heat exchanger, where the reduced air volume temperature is raised to the required desorption temperature. The preheated air is then used to desorb the air in the pie shaped sector of the wheel. As the air exits the desorption section the organic concentration is approximately 10 times the concentration of the original process stream. This low volume, higher concentration stream then enters the induced draft section of a catalytic or thermal recuperative or regenerative thermal oxidizer, where the organics are destroyed.

Destruction Efficiency:

It should be noted that the total hydrocarbon reduction efficiency for the Concentrator is the adsorption efficiency of the Concentrator times the destruction efficiency of the oxidizer.

Hence, if the Concentrator can adsorb 98% of the organics in the airstream, and the oxidizer can destroy 99% of the organics that pass through it, then the overall system organic reduction is: DESTRUCTION EFFICIENCY = .98 x .99 = .97 = 97%