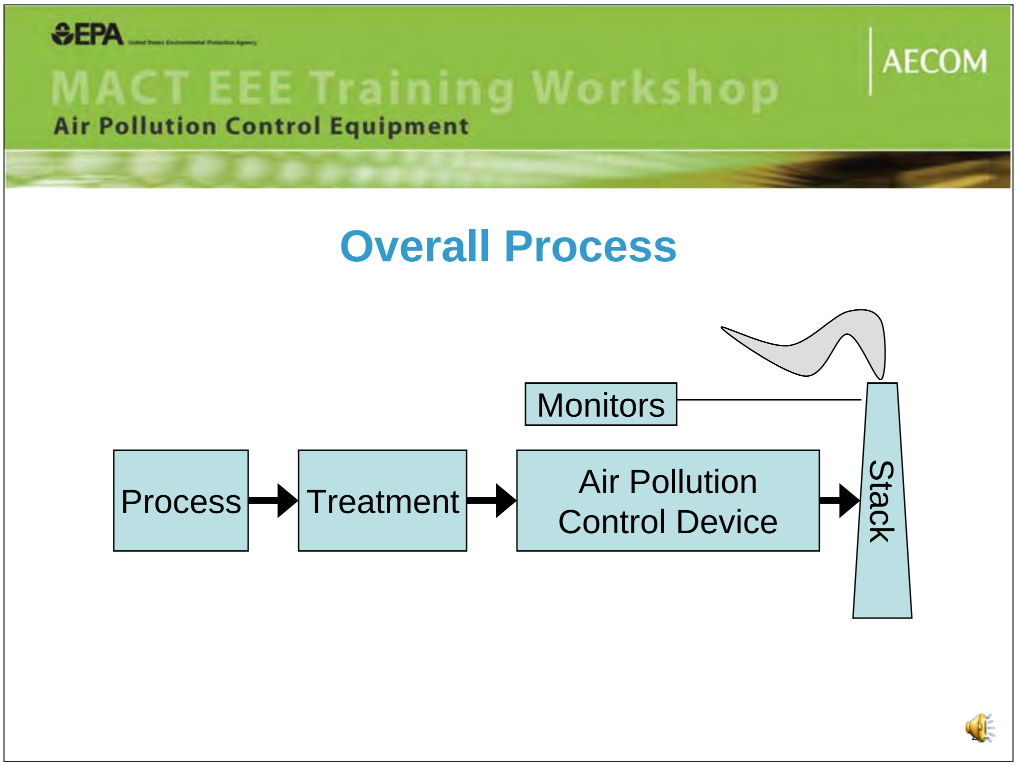
MACT EEE Training Workshop

AECOM

Dallas, Texas November 3-7, 2008

Air Pollution Control Equipment



This module will focus on air pollution control equipment. The flow diagram presented in this slide shows schematically a process that might be the subject of MACT EEE, the hazardous waste combustor MACT. The process would be such as a chemical process. The treatment would be the part of the air pollution control that combusted the hazardous waste, such as an incinerator, solid or liquid fuel boiler, or cement or light aggregate kiln. The air pollution control device would be one that follows the combustion device to remove hazardous constituents from the gas stream before being released to the atmosphere. This module will discuss various air pollution control devices.

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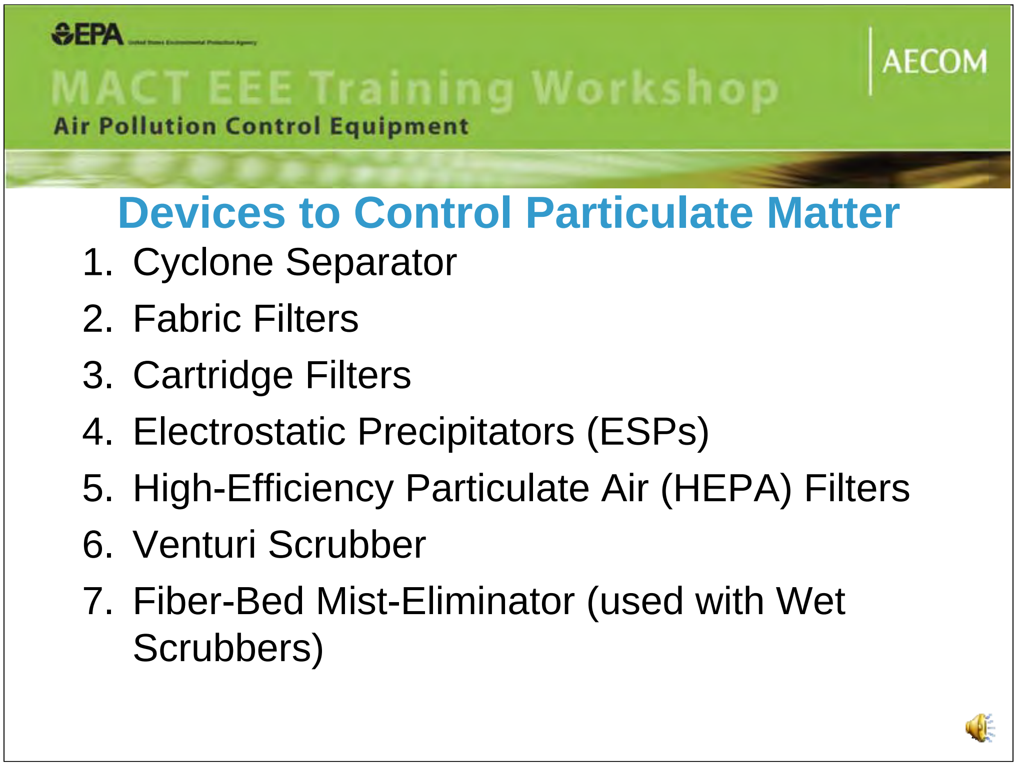
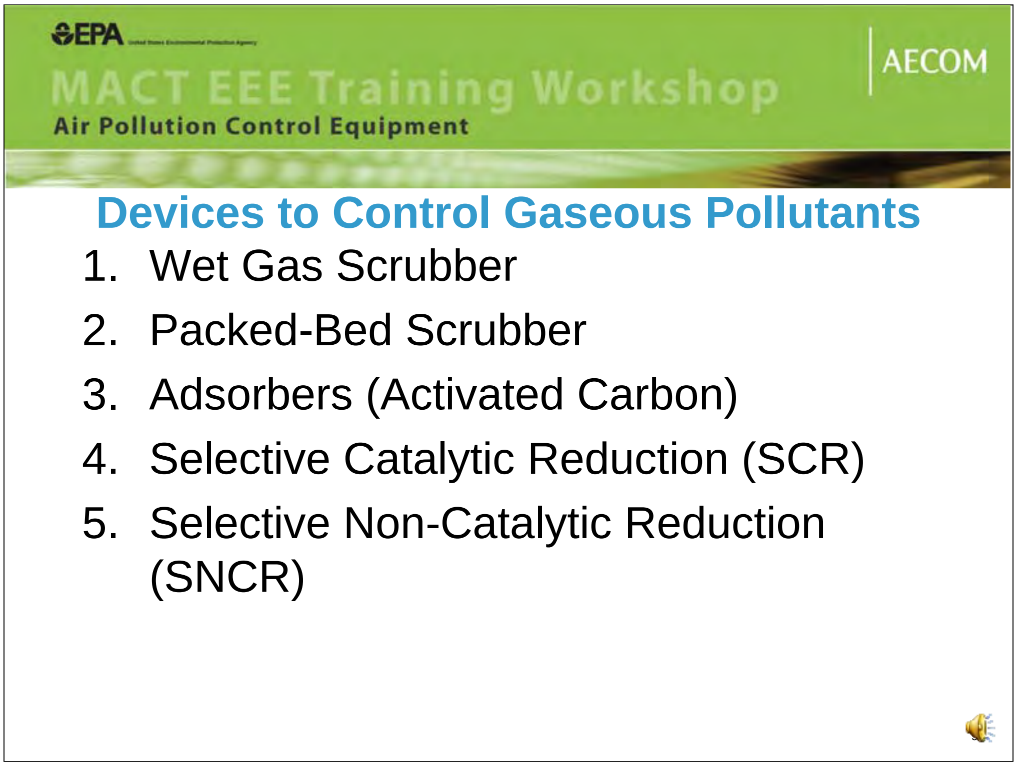
MACT EEE Air Pollution Control (APC) Devices

- Function – HAP Control
- HAP – Organic, Acid, Particulate
- APC Devices:
  - Dry and Wet Particulate Control Device
  - Baghouse (Fabric Filter)
  - Wet and Dry Gas Scrubber
  - Electrostatic Precipitator (ESP)
  - Activated Carbon Adsorption, Bed and Injection

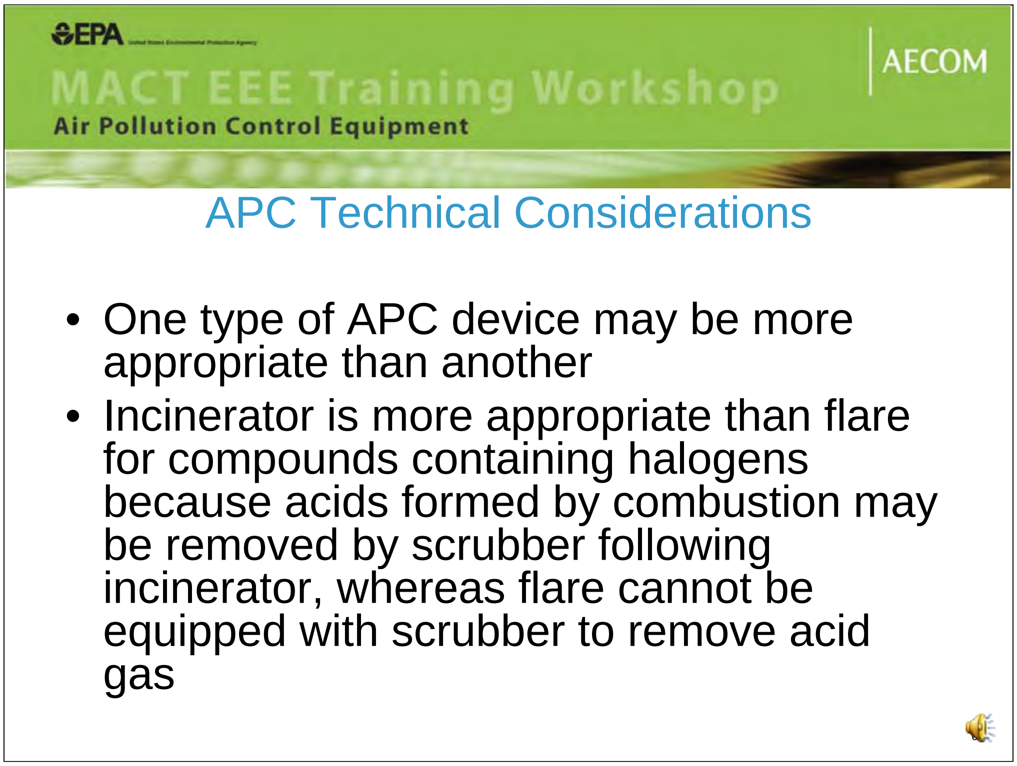
The function of air pollution control devices generally and for the MACT EEE rule specifically is to control or remove hazardous air pollutants (HAP) from the off gas stream before being released to the atmosphere. The HAP to be controlled can be organic, acidic, or a particulate. Some types of air pollution control devices that will be discussed are Dry and Wet Particulate Control Devices, Baghouses (also called Fabric Filters), Wet and Dry Gas Scrubbers, Electrostatic Precipitators (ESP), and Activated Carbon Adsorption, Bed and Injection.



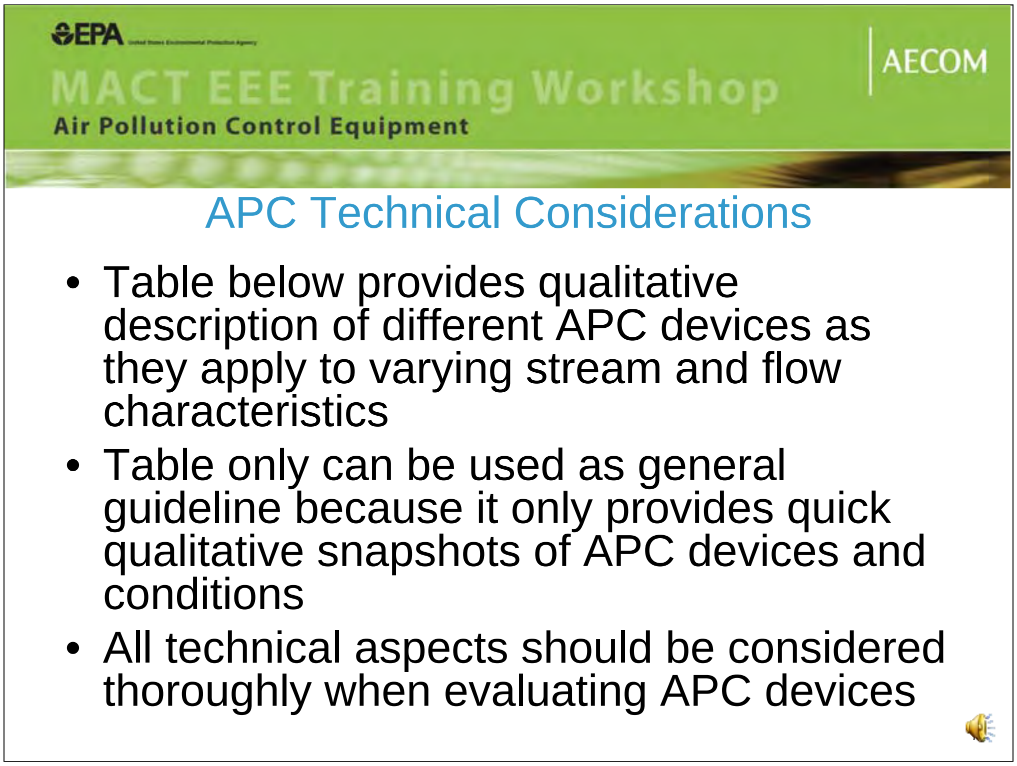
Air pollution control devices used to control particulate matter are: Cyclone Separators, Fabric Filters, Cartridge Filters, Electrostatic Precipitators (ESPs), High-Efficiency Particulate Air (HEPA) Filters, Venturi Scrubbers, and Fiber-Bed Mist-Eliminators (used with Wet Scrubbers).



Air pollution control devices used to control gaseous pollutants are: Wet Gas Scrubbers, Packed-Bed Scrubbers, Adsorbers (Activated Carbon), Selective Catalytic Reduction (SCR), and Selective Non-Catalytic Reduction (SNCR).



There are technical considerations for air pollutant control devices since one type of APC device may be more appropriate than another. An Incinerator, for example, is more appropriate than flare for compounds containing halogens because acids formed by combustion may be removed by scrubber following incinerator, whereas flare cannot be equipped with scrubber to remove acid gas.



The Tables shown in slide that follow provide a qualitative description of different APC devices as they apply to varying stream and flow characteristics. These Tables only can be used as general guideline because they only provide quick qualitative snapshots of APC devices and conditions. All technical aspects should be considered thoroughly when evaluating APC devices.

Technical Considerations – Stream Characteristics

Device	Low Concentration	High Concentration	High Temperature	High Volume	High Moisture
Cyclone	B-C	B-C	A-C	A	A-B
Baghouse	A-B	D-F	A-B	A	B-F
ESP	A-D	D-F	A	A-D	B-D
Scrubber	B-C	C-D	B-F	B-C	A
Carbon	A-C	D-F	C-F	B-C	D-F
Condenser	D-F	A-B	D-F	D-F	D-F
Flare	A	D-F	A	A	C-D
Incinerator	A	A	A	A	B

Device ranking is from Excellent (A) to Poor (F)

The table compares the stream characteristics for a Cyclone, Baghouse, ESP, Scrubber, Carbon Adsorber, Condenser, Flare and Incinerator. For low concentration streams, a baghouse, ESP, carbon adsorber, flare or incinerator are shown a possible good candidates. For a high concentration stream, a condenser and an incinerator are good candidates, for high temperature or high volume streams, all but scrubber, carbon adsorber and condenser are good candidates. For high moisture streams, a cyclone or a scrubber are the best choices.

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Technical Considerations – Contaminants

Device	Halogenated	Inorganic Acids	Condensible Particulate	Size > 10 Microns	Size < 10 Microns	High Vapor Pressure
Cyclone			B-D	C-D	D-F	
Baghouse			B-F	A	A-B	
ESP				A-D	B-D	
Scrubber	A-F	A-B	B-C	A	A-B	A-C
Carbon	A-C	D-F	D-F	F	F	B-D
Condenser	D-F	D-F	D-F	D-F	D-F	D-F
Flare	F	D-F	A			A
Incinerator	B*	B-D	A	A	B	A

Device ranking is from Excellent (A) to Poor (F)

* If followed by scrubber

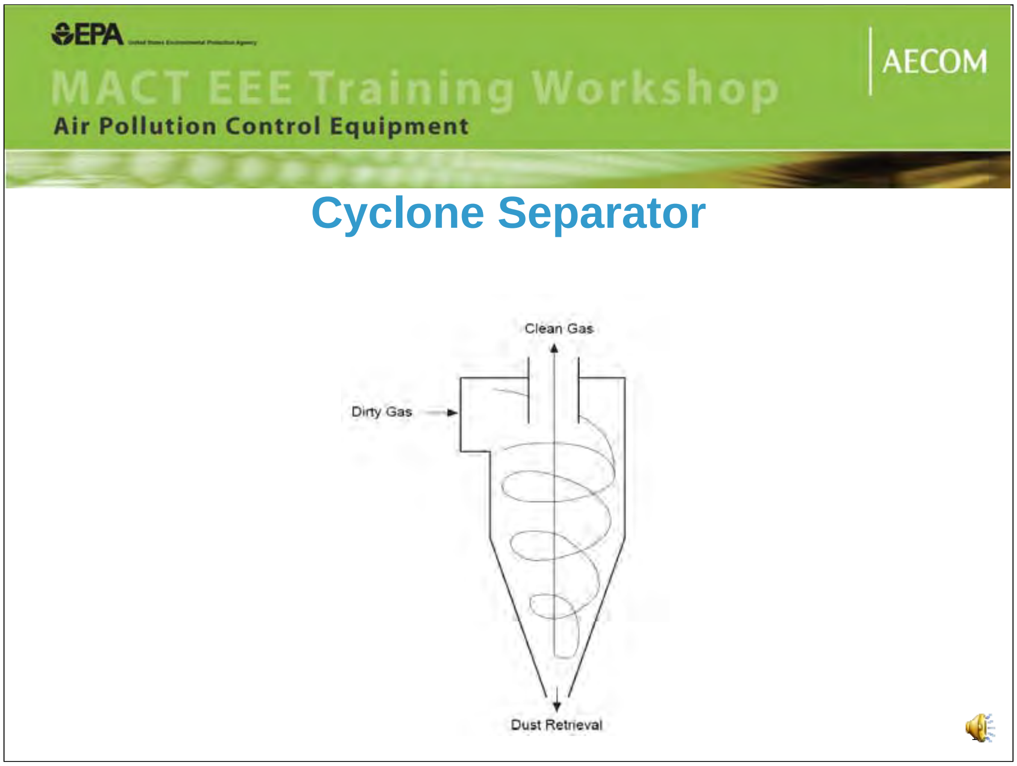
The table compares the contaminant characteristics for a Cyclone, Baghouse, ESP, Scrubber, Carbon Adsorber, Condenser, Flare and Incinerator. For streams that are halogenated, a scrubber or carbon adsorber are good candidates. Note that an incinerator is a good choice if followed by a scrubber. For inorganic acids in the stream, a scrubber is the best choice. For condensible particulate, a flare or incinerator are good choices. For particulate that is small, that is less than 10 microns, a baghouse, ESP, scrubber, or incinerator are good choices, whereas for later particulate, a baghouse or scrubber are the best choices. For high vapor pressure contaminants in the stream, a scrubber, flare or incinerator are the best choices.

Technical Considerations – Source of Contaminant

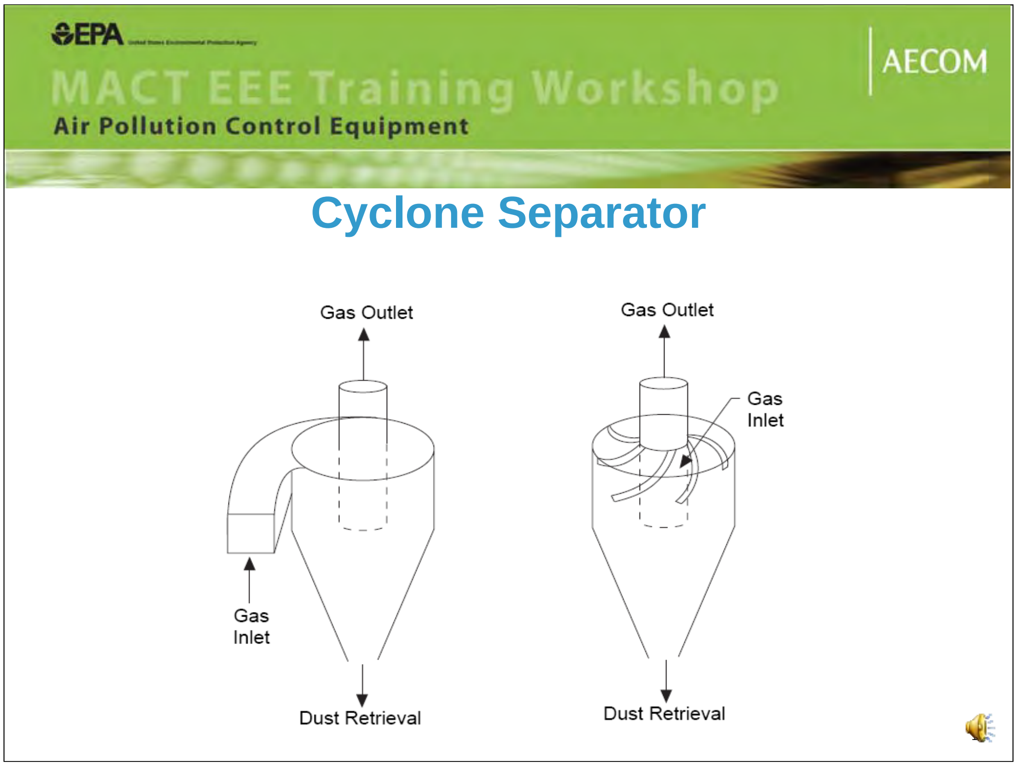
Device	Non-Continuous (Batch)	Continuous	Variable Flow Rate
Cyclone	A	A	A
Baghouse	A	A	A
ESP	B-D	A-C	B-D
Scrubber	B-C	A-C	B-C
Carbon	C	A-C	C
Condenser	D-F	D-F	D-F
Flare	A	A	A
Incinerator	C	A	B

Device ranking is from Excellent (A) to Poor (F)

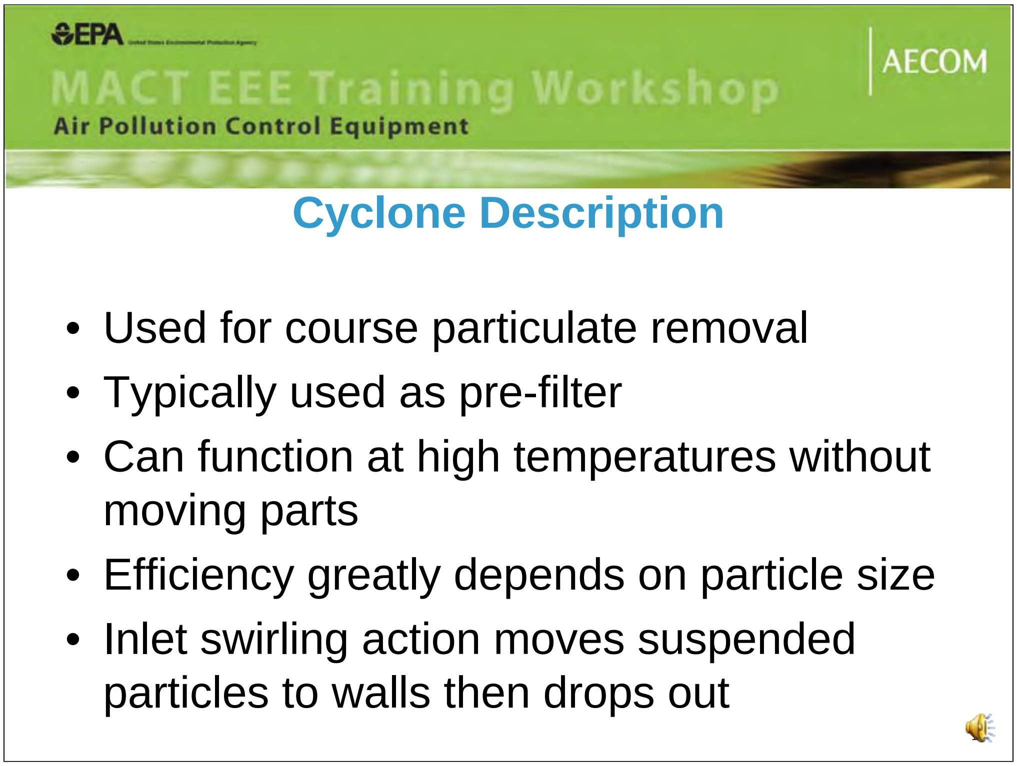
The table compares the characteristics of sources of contaminant for a Cyclone, Baghouse, ESP, Scrubber, Carbon Adsorber, Condenser, Flare and Incinerator. For non-continuous or batch processes, a cyclone, baghouse, and flare are good candidates. For continuous processes, all but a condenser could be considered for application. For a variable flow rate process and therefore variable contaminant concentration, a cyclone, a baghouse and a flare are good candidates.



This slide shows how a cyclone separator works. As the schematic shows, dirty gas enters on the side at the top, normally at an angle, then swirls around the interior of the cyclone spinning particulate to the sides of the cyclone. The removed dust slides to the bottom of the cyclone and exits at that point. The gas with reduced particulate exits the top of the cyclone.



This slide shows other schematics of cyclones with devices to aid the swirling action of the cyclone.



Cyclone separators are primarily used for course particulate removal. Mostly they are used as a pre-filter to another filter to remove the smaller, finer particulate. Cyclones have no moving parts and typically can handle high temperatures without difficulty. The efficiency of cyclones greatly depends on the size of the particulate, the larger particle being removed at higher efficiency than smaller particles. The inlet swirling action, as discussed earlier, moves the particles that are suspended in the gas to the walls of the cyclone where the velocity is lower and the particles will drop out of the gas stream.

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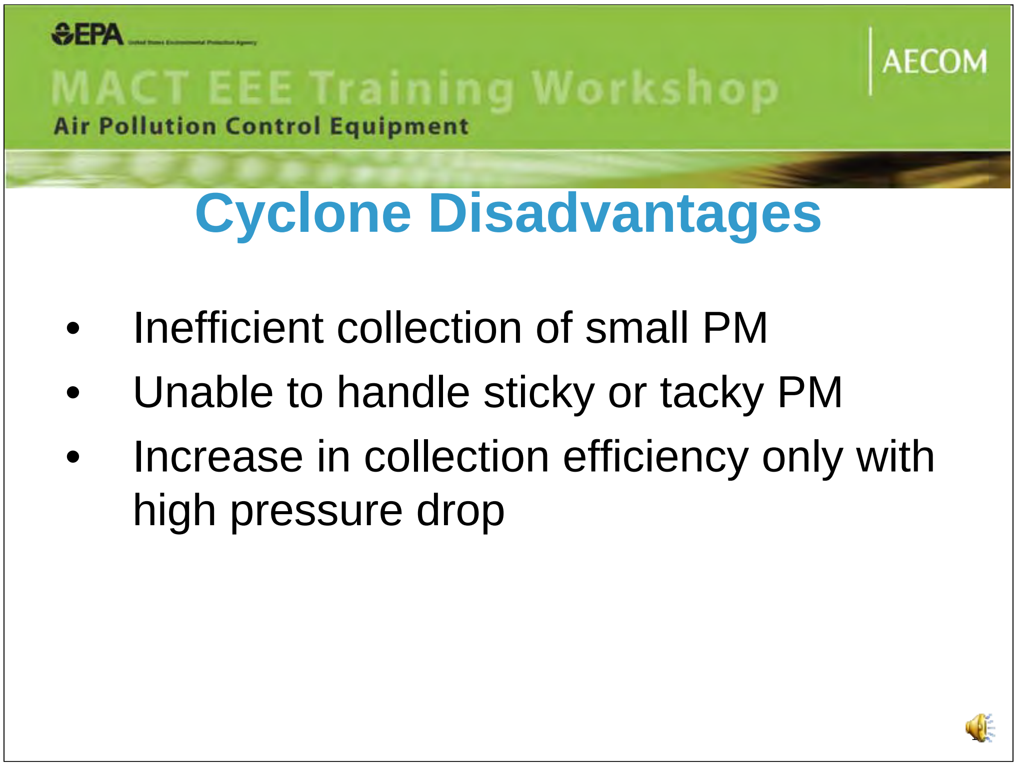
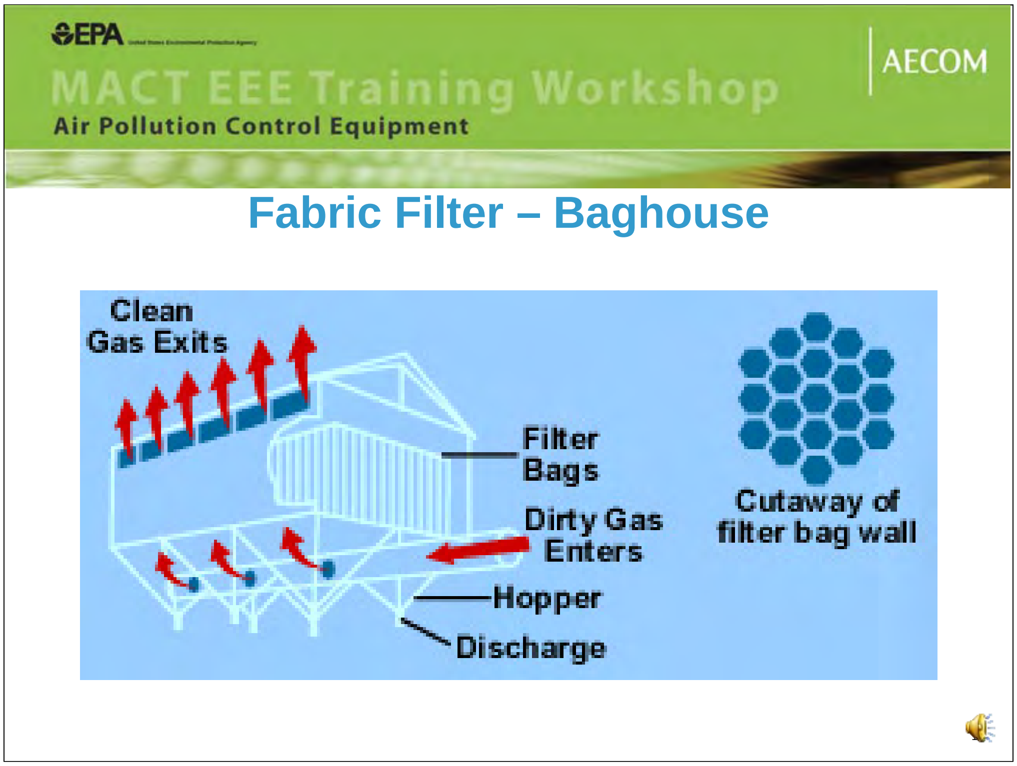
Cyclone Advantages

- Low cost
- Simple; no moving parts
- Low pressure drop compared to PM removed
- Wide temperature & pressure capabilities
- Dry collection of PM
- Relatively small space requirement

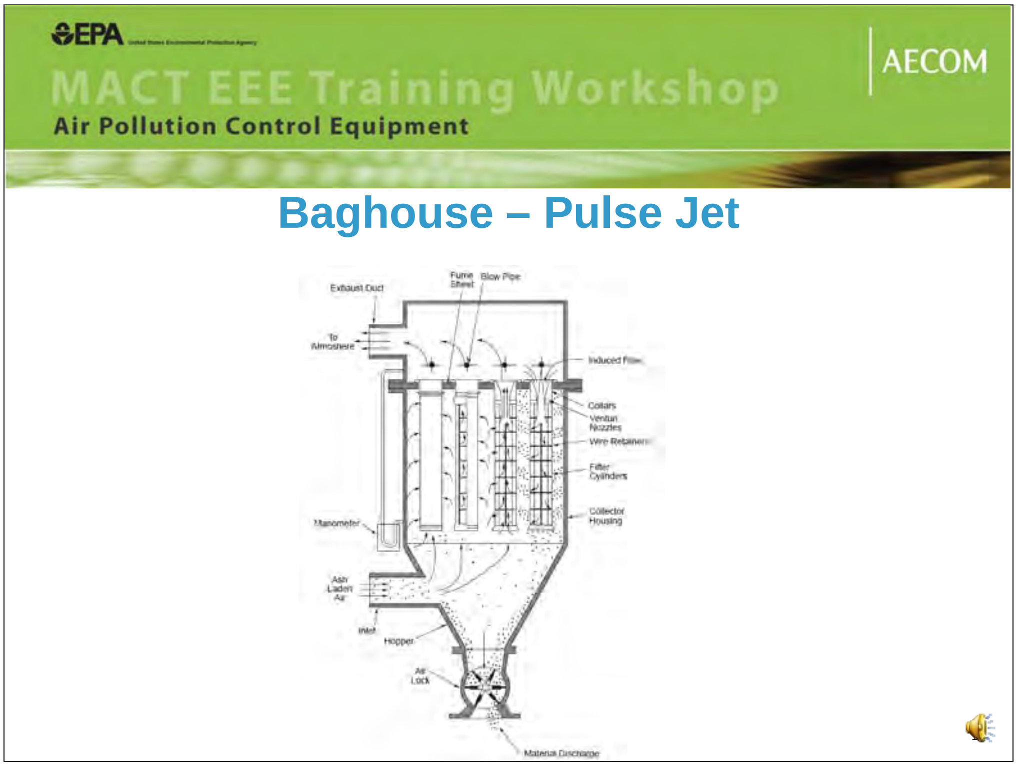
The advantages of cyclones is that they are low cost, simple in operation because they have no moving parts, the pressure drop is low compared to the particles removed. Cyclones also can operate under wide ranges of temperature and pressure, they work well in dry gas streams for removal of particulate and a relatively small space is required for them.



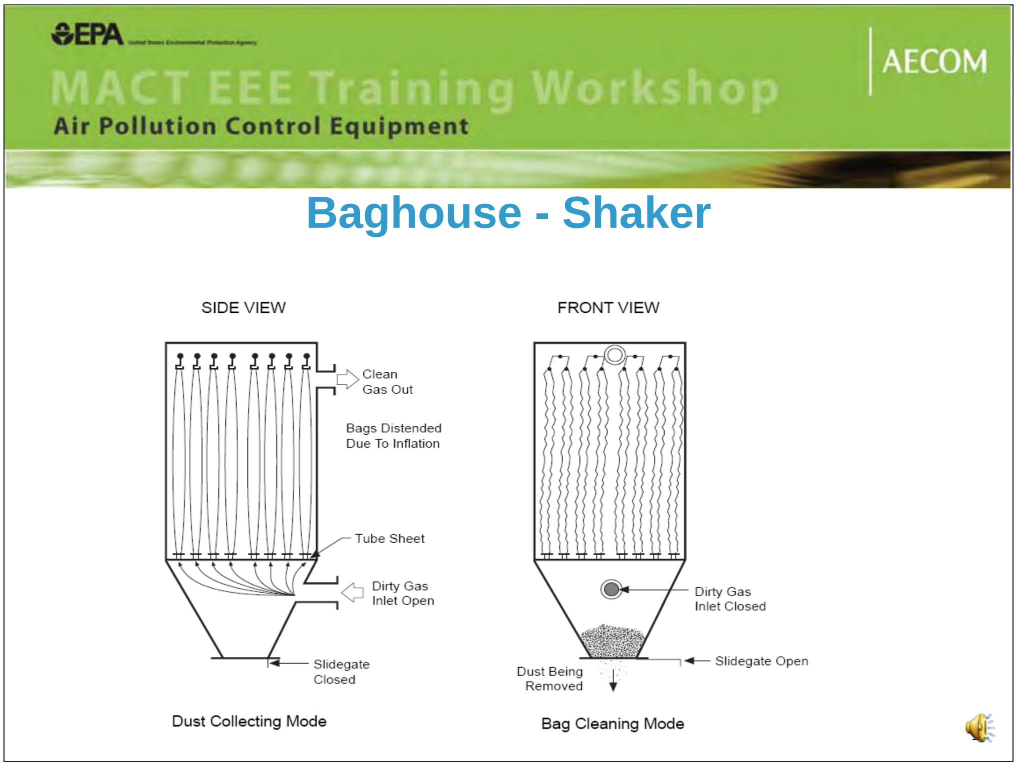
The disadvantages of cyclones are that they are not highly efficient for collection of small particulate, they do not operate well with sticky or tacky particles and to increase their collection efficiency results in higher pressure drop across the cyclone.



This slide depicts a fabric filter, commonly referred to as a baghouse because of the filter bags it uses to collect particulate. In this schematic, the dirty gas enters from a plenum below the bags, flows through the bags from the outside to inside of the bags, then the cleaned gas exits from the top of the bags and the baghouse. Particulate that accumulates on the bags is removed by various means that will be discussed later and falls to the bottom of the baghouse into a hopper for removal.



This slide shows another schematic of a baghouse with a pulse jet to remove the particulate from the bags. A blow pipe directs gas into the bag, reversing the direction of gas through the bag, which blows the particulate off the bag and allows it to drop to the hopper below. This process rotates between bags so that only a few bags are pulsed at a time.



This slide shows a shaker mechanism for particulate removal from bags. Here the bags are vibrated or moved back and forth to dislodge the particulate from the bag and allows the dust to settle in the bottom hopper.

This slide shows another schematic view of a bag house.

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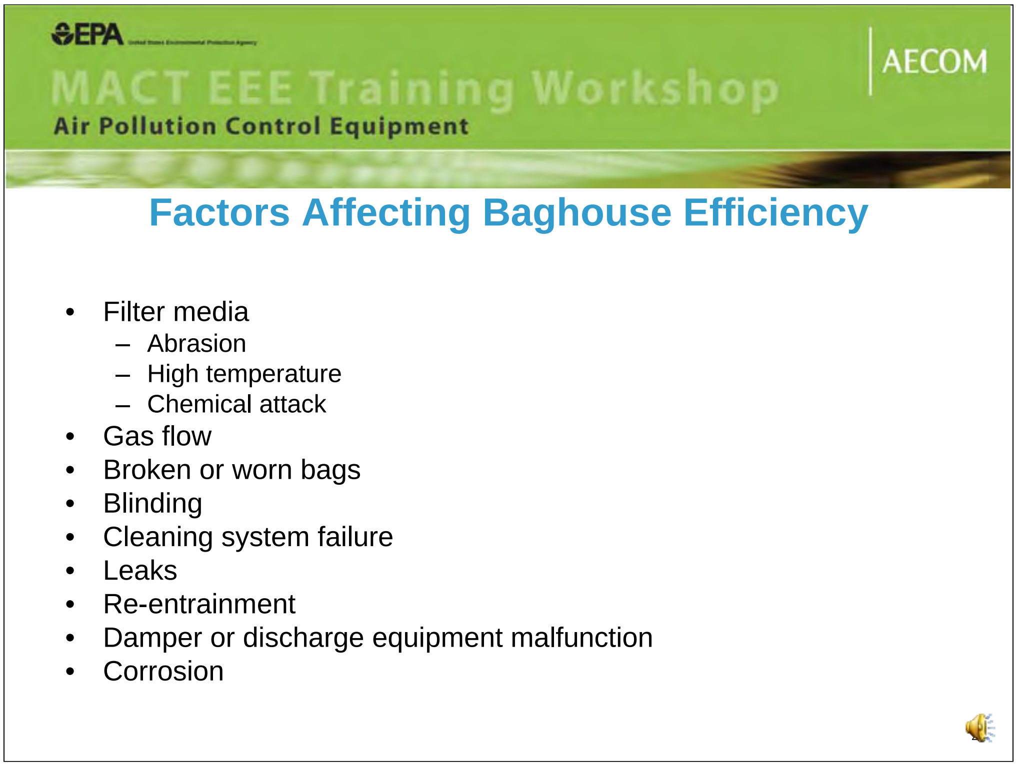
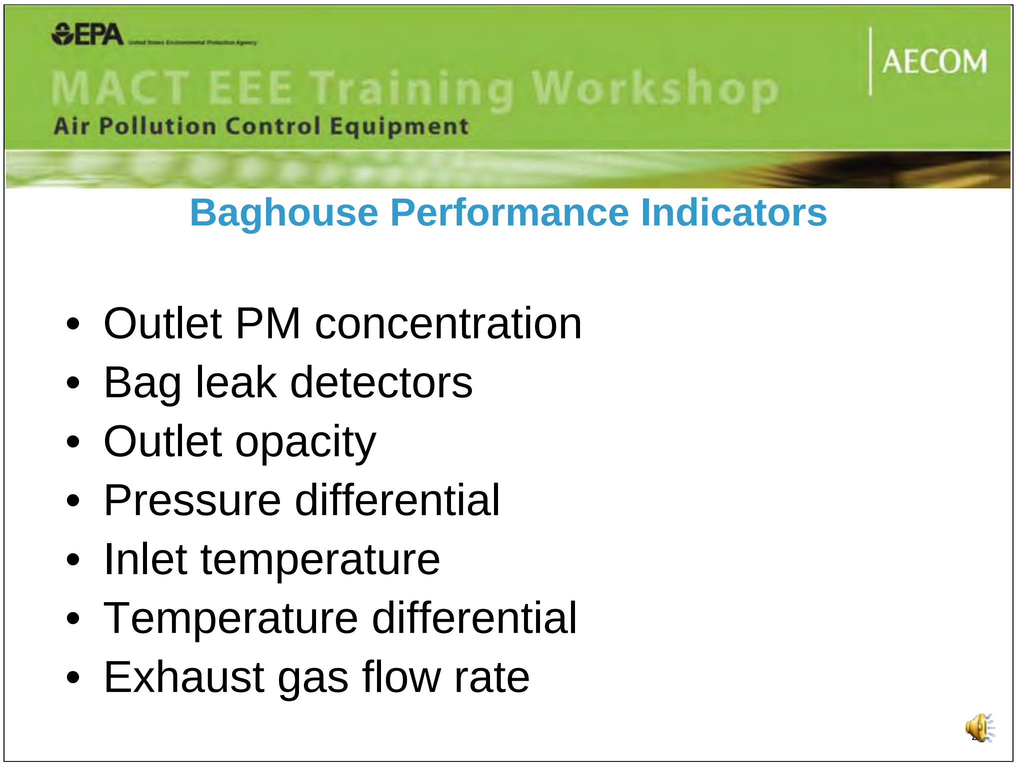
Baghouse Description

- Particles trapped on filter media, then removed
- Either interior or exterior filtration systems
- Up to 99.9% efficiency
- Efficiency increases with use; decreases after cleaning
- 4 types of cleaning systems
  - Shaker (off-line)
  - Reverse air (low pressure, long time, off line)
  - Pulse jet (60 to 120 psi air, on line)
  - Sonic horn (150 to 550 Hz @ 120 to 140 dB, on line)

The fabric filter or baghouse as seen in the schematics previously presented traps particles on the filter media and then removes the particles by one of several means. Although normally the collection side of the bag is the exterior, the interior side can also be used. Some baghouses can remove particulate up to 99.9 percent efficiency. To clean the bags, four types of systems are used: shaker, normally done while the baghouse is off-line; reverse air flow, which is low pressure, takes a rather long time and must be done off-line; pulse jet with 60 to 120 psi air pressure done while the baghouse is on-line; and use of a sonic horn to vibrate the bags.



Factors that affect a baghouse's efficiency are filter media that can be affected by abrasion, high temperature or chemical attach; gas flow rate; broken or worn bags that allow particulate to pass through; blinding; cleaning system failure; leaks around bag seals or other locations; re-entrainment of particulate after cleaning system operation; malfunction of a damper or discharge equipment; and corrosion of metal parts within the baghouse.



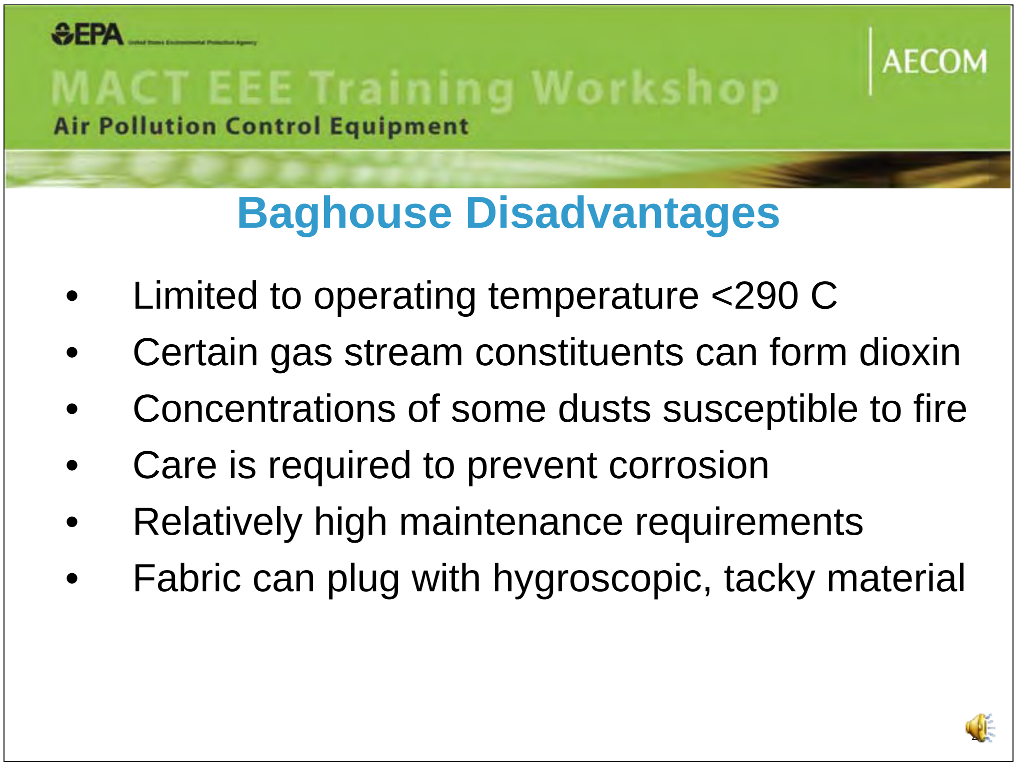
Some performance indicators for baghouse operation are the outlet concentration of particulate; detectors of bag leaks; opacity of the outlet gas stream; pressure differential across the filter; inlet temperature; temperature differential; or exhaust gas flow rate.

Other baghouse performance indicators are the operation of the cleaning mechanism; current draw of the fan motor; and inspections and maintenance of the equipment.

Baghouse Advantages

- Extremely high collection of coarse and fine PM
- Insensitive to gas stream fluctuations
- Available in large number of configurations
- Collected material is recovered dry
- Collection efficiency not effected by PM resistivity
- Special catalyst-impregnated bags available

Advantages are a baghouse is has an extremely high collection of coarse and fine particulate; the baghouse’s insensitivity to gas stream fluctuations within its operating range; a large number of configurations are possible; the collected material is dry; the resistivity of the particulate does not effect the collection efficiency; and the bags can be made of special catalyst-impregnated material.



A baghouse's disadvantages are: it is limited to an operating temperature of less than 290 degrees Celcius; certain gas stream constituents can form dioxin, concentrations of some dusts susceptible to fire, care is required to prevent corrosion, there are relatively high maintenance requirements, and the fabric can plug with hygroscopic, tacky material.

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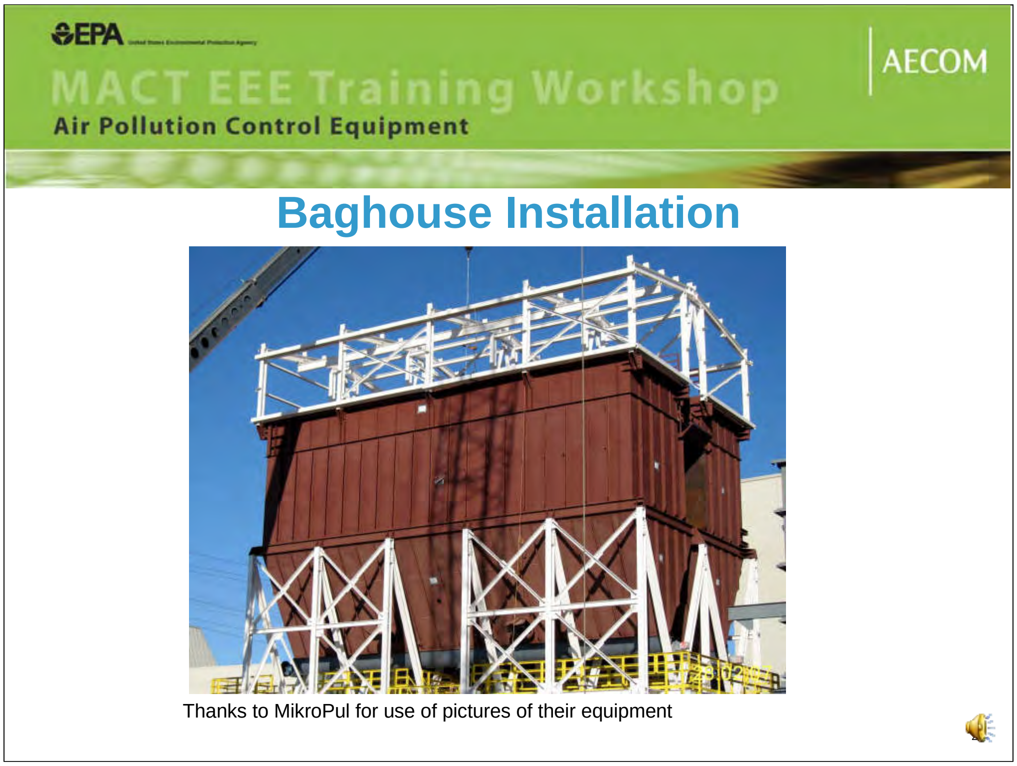
Baghouse Installation

Thanks to MikroPul for use of pictures of their equipment

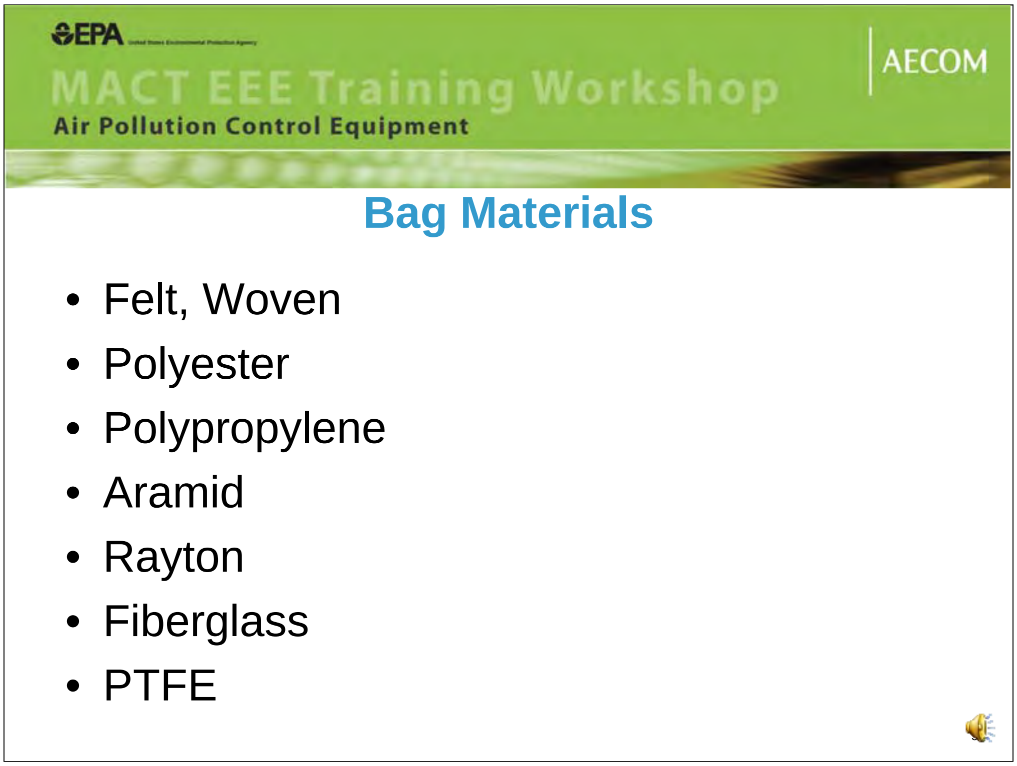
This slide shows an installation of several large baghouse cells.



Another baghouse installation is shown in this slide.

This slide shows an extremely large baghouse installation.

This slide shows several bag configurations and illustrates an installation without the surrounding sides.



Bags can be produced from a variety of materials such as woven felt, polyester, polypropylene, aramid, rayton, fiberglass and PTFE (teflon).

This slide shows the retainers that hold the bags in place and the venturi nozzles at the top of the bag retainers.

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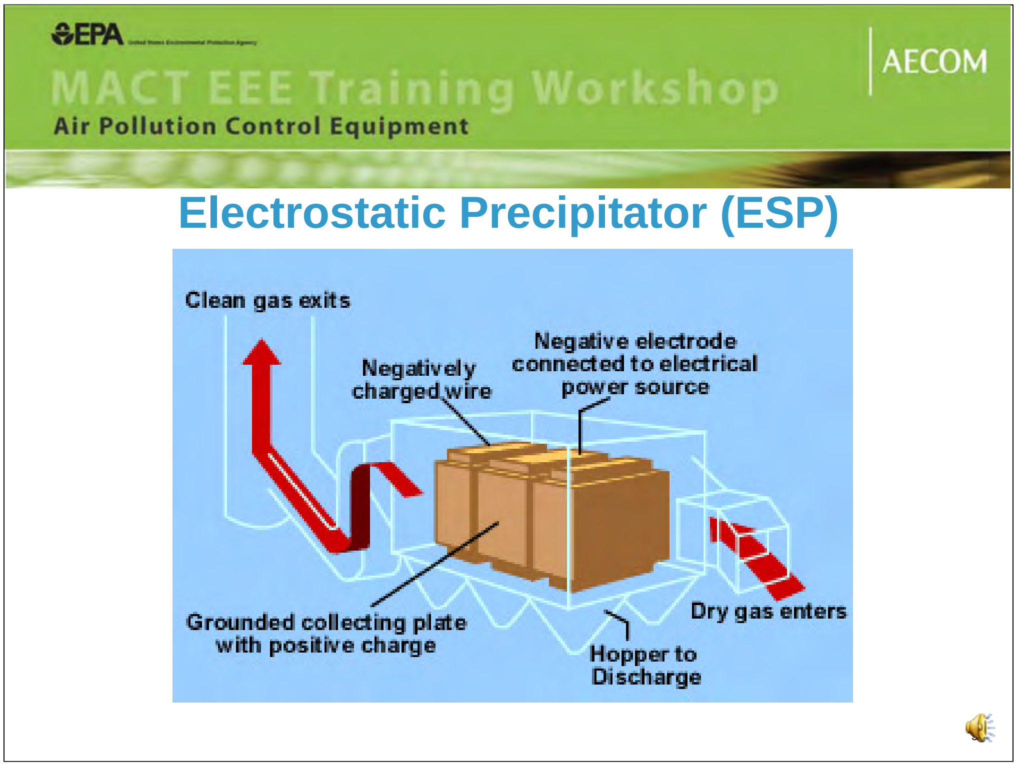
Cartridge Filters

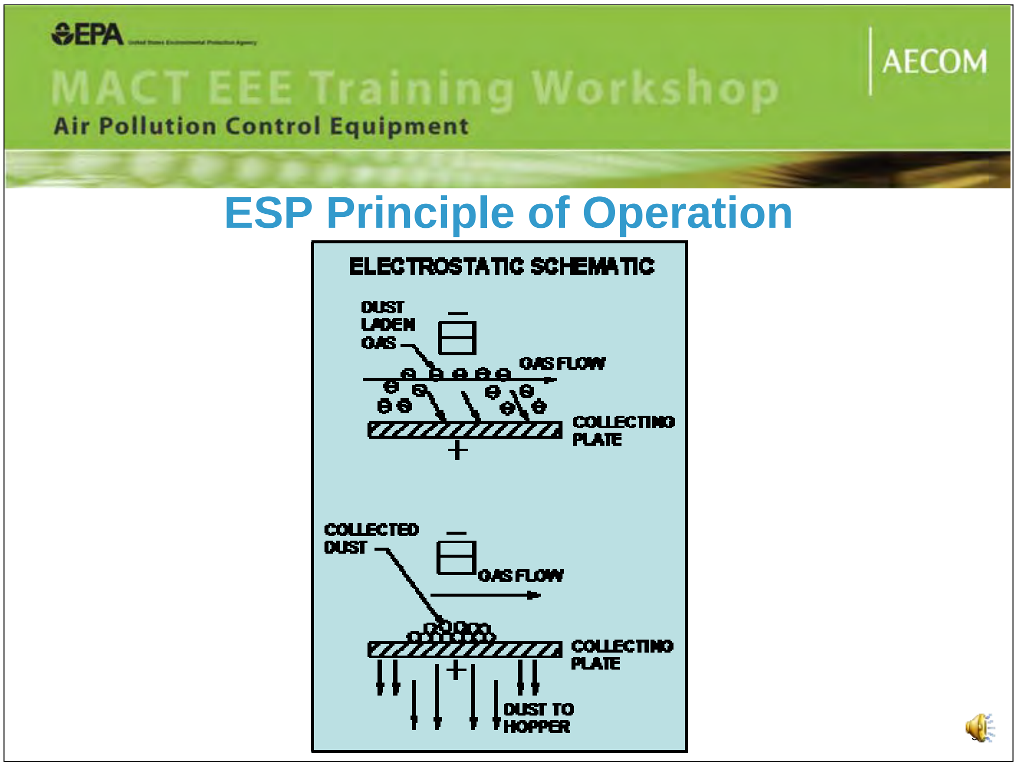
- Basically the same as a Baghouse with Cartridges rather than bags
- Somewhat more sensitive to moisture depending on the cartridge
- Can get higher collection efficiency than Baghouse

A variation of the baghouse is a cartridge filter system, sometimes referred to as dust collectors. The cartridge filter system is basically the same as a baghouse and uses cartridges rather than bags. The cartridges are more sensitive to moisture, depending on the material of the cartridge. The cartridge system can provide higher dust collection efficiencies than a baghouse.

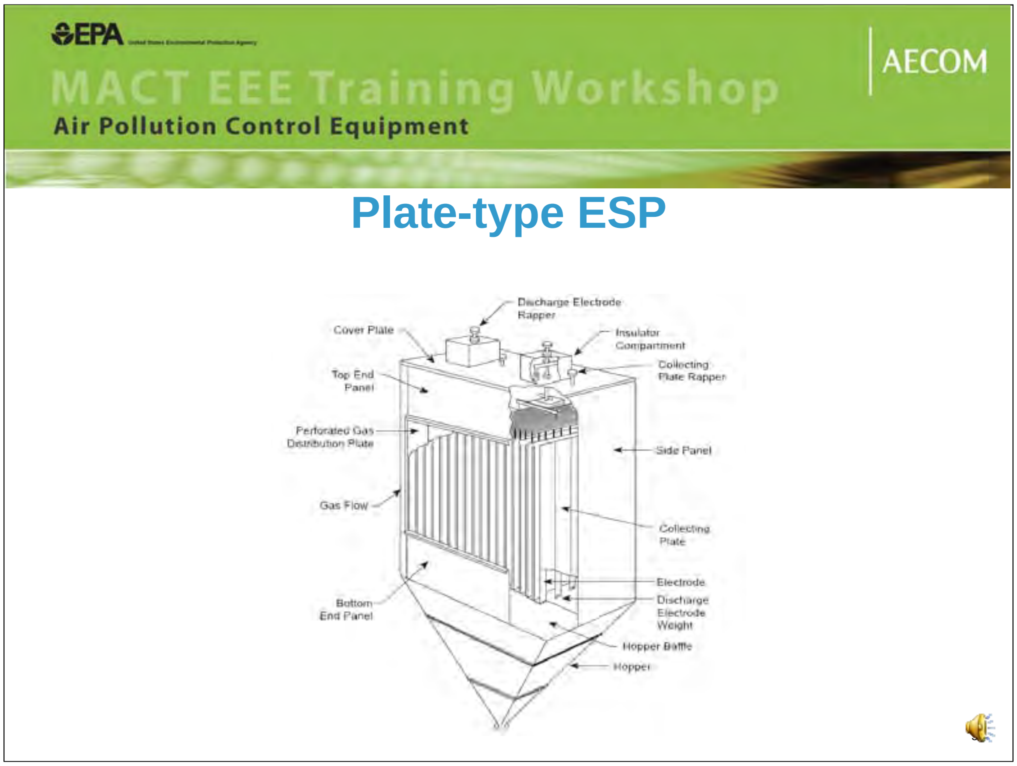
This slide shows both a cartridge and the cartridge housing.



Another widely used particulate control device is the electrostatic precipitator, frequently referred to as an ESP. Dry gas enters the ESP and flows around the electrodes and plates. The electrode is negatively charged and the collection plate is positively charged, making the particulate with high resistivity to be attracted to the plate. The gas exiting the ESP has been cleaned of particulate and released to the atmosphere. Particles that have been collected are released from the plates by several means and fall to the bottom of the housing into hoppers that allow for removal of the collected particulate.



This slide further illustrates the principle of operation of the ESP. The particles in the dust laden gas are attracted to the plate then later removed with the cleaned gas exiting the control device.



This slide provides a different view of a plate-type ESP. The illustration shows the rapper for the collection plates and discharge electrodes.

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ESP Description

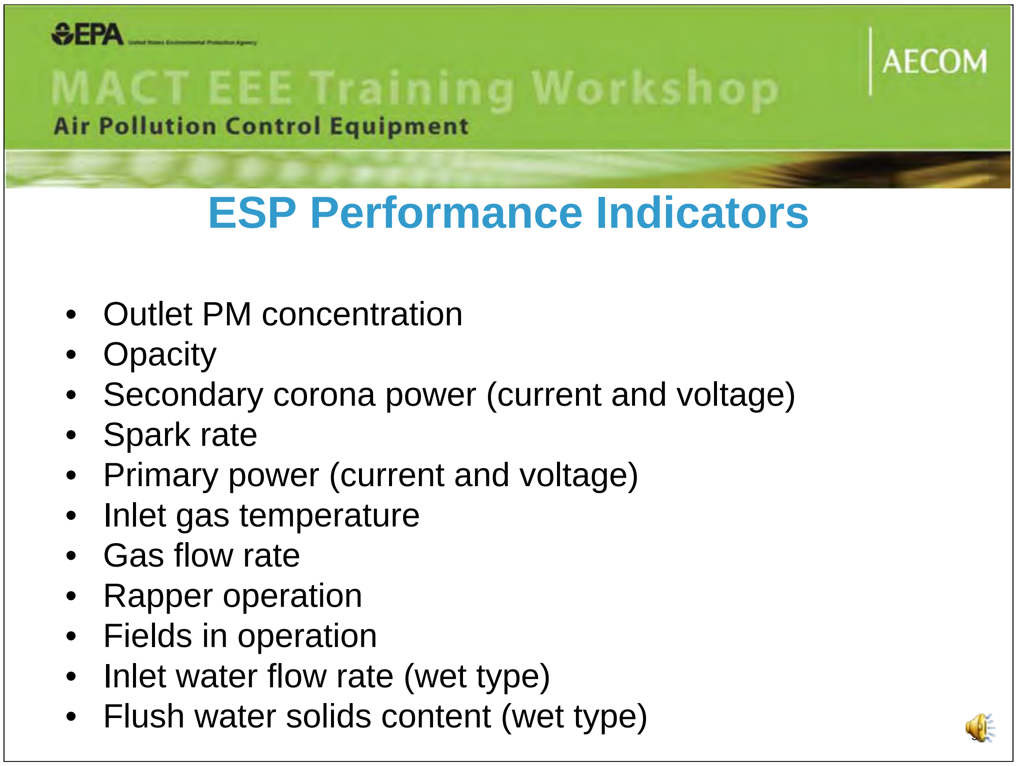
- Charged particles are attracted to plates and removed from exhaust gas
- Two types
  - Dry type use mechanical action to clean plates
  - Wet type use water to pre-quench and to rinse plates
- High voltages are required
- Multiple sections (fields) may be used
- Efficiencies up to 99% can be obtained

The charged particles are attracted to plates and removed from the dust laden gas stream before exiting. The ESP has two types: either a dry type of system that uses a mechanical action like rapping to clean plates or a wet type that uses water to pre-quench and to rinse the particulate off the plates. An ESP operates with high voltage to provide the charging and attraction of the particle to be removed. Most ESPs are designed with multiple sections or fields. The ESP system can obtain particulate removal efficiency to 99 percent.

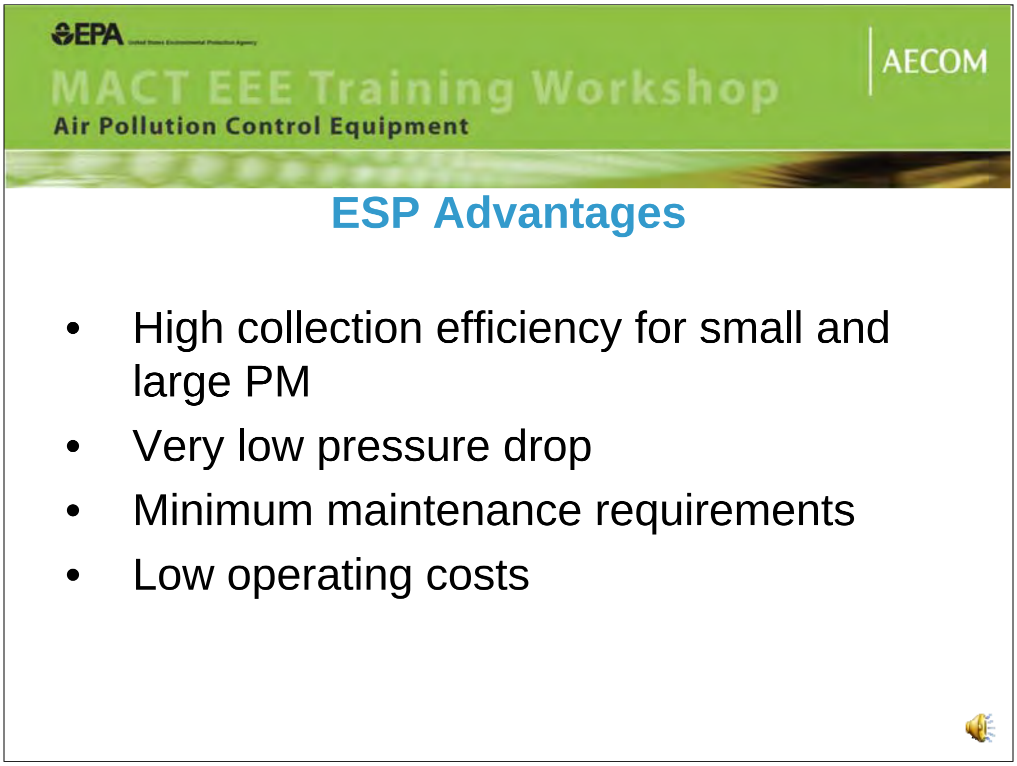
Factors Affecting ESP Efficiency

- Gas temperature, humidity, flow rate
- Particle resistivity
- Fly ash composition
- Plate length
- Surface area

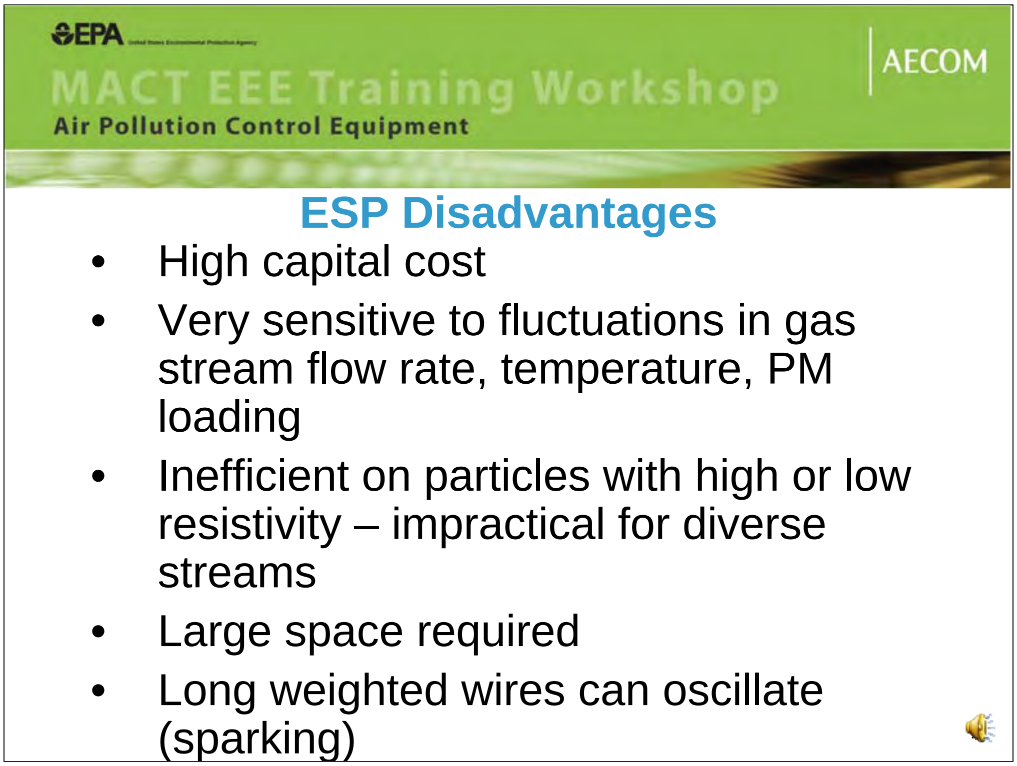
The factors that affect an ESP's efficiency are: the temperature, humidity and flow rate of the gas to be cleaned; the resistivity of the particle to be removed; the composition of the fly ash, that is the collected particles; the length of the collection plate; and the total surface area of the collecting plates.



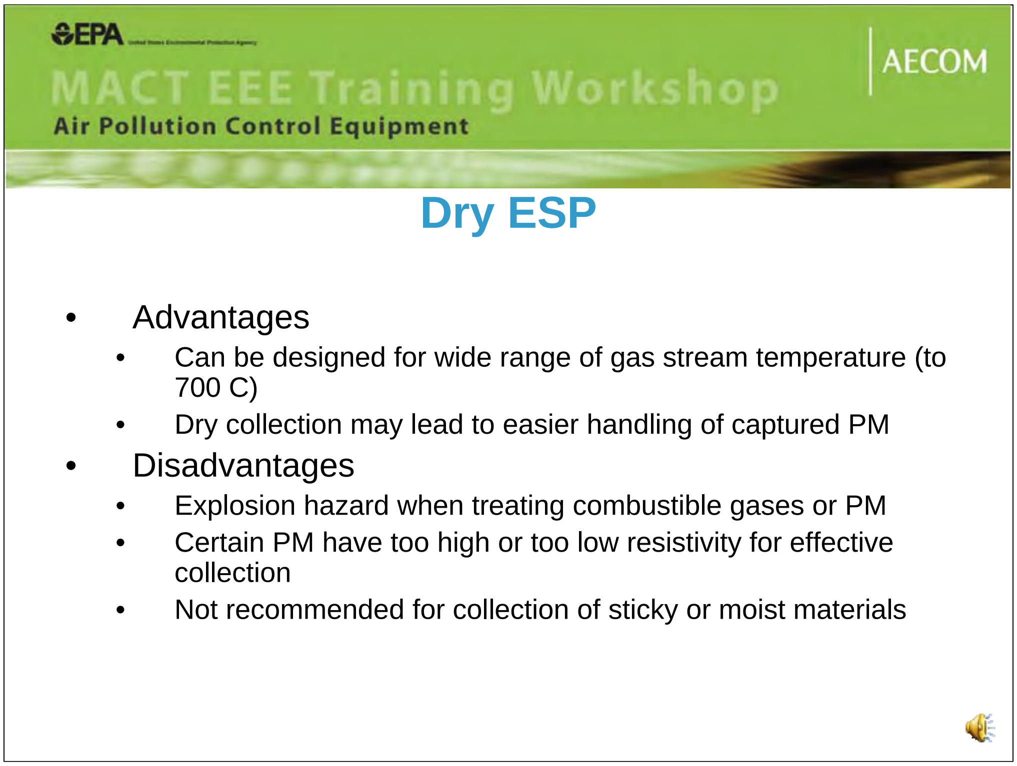
Performance indicators for an ESP are: the outlet concentration of the particulate; the opacity of the exhaust gas; the current and voltage of the primary and secondary corona; the spark rate caused by arcing in the ESP; the inlet gas temperature; the flow rate of gas through the ESP; the rapper operation; the fields in operation; the inlet water flow rate if a wet ESP; and the solids in the flush water if a wet ESP.



Advantages of an ESP system are: the systems have a high collection efficiency for small and large particulate particles, the system normally has a very low pressure drop, and maintenance requirements and operating costs are low.



Some disadvantages of an ESP are: the capital cost of the installation is high; the ESP is sensitive to fluctuations in the gas flow rate, temperature and particulate loading; they are inefficient on particles with high or low resistivity making them not practical for a stream with a diverse composition; a large space is required for installation; and on large systems the long weighted wires can oscillate and cause sparking within the ESP.



Advantages of a dry ESP are: that they can be designed for a wide range of gas stream temperature up to 700 degrees Celsius and collection of dry particles tend to be easier to handle of the captured particles. Some disadvantages of a dry ESP system are: they can present an explosion hazard when the gases contain combustible materials; some particles have too high or too low resistivity for good collection; and a dry system is not recommended for collection of sticky or moist materials.

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Wet ESP

- Advantages
  - Washing of collectors eliminates re-entrainment of PM due to rapping
  - Humid atmosphere allows collection of PM with high resistivity, sticky particles and mists, and absorption of soluble gases
- Disadvantages
  - Inlet gas stream temperature <190 F
  - Construction of non-corrodible materials
  - Collected PM in form of slurry

Advantages of a wet ESP system are: that the washing of collectors eliminates the re-entrainment of particles into the gas stream during rapping and the humid atmosphere inside the ESP allows for collection of particulate with high resistivity , sticky particles, mists, and absorption of soluble gases. The wet ESP has the disadvantages that the inlet gas stream must be below 190 degrees Fahrenheit, the materials of construction must be non-corrodible, and the collected particulate forms a slurry in the effluent water.

This slide shows a High-Energy Particulate Air filter, called a HEPA filter, which is a particulate collection device similar to a cartridge filter system.

HEPA Filter Advantages

- Specifically designed for collection of submicron PM
- Insensitive to major fluctuations in process stream
- Very simple operation
- Provisions included for sensitive in-place testing
- Filters are usually changed outside of housing

The advantages of the HEPA filter are that they are specifically designed for collection of submicron particulate; they are insensitive to major fluctuations in process stream, their operation is very simple, provisions can be included for sensitive in-place testing, and the filters are usually changed outside of housing.

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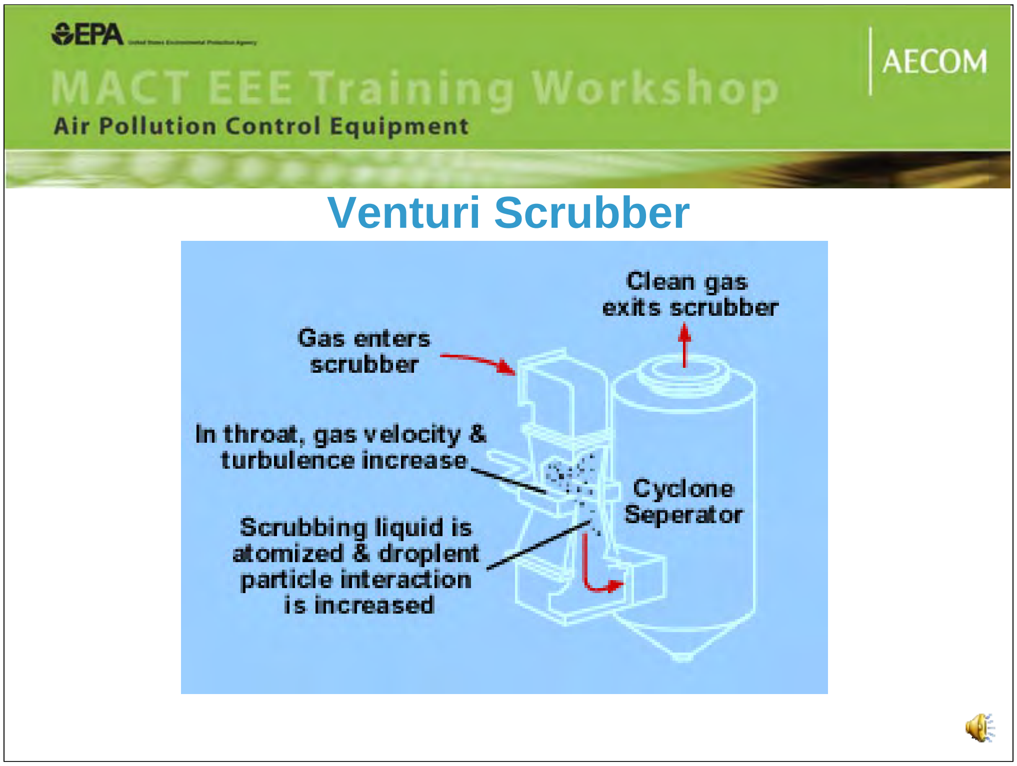
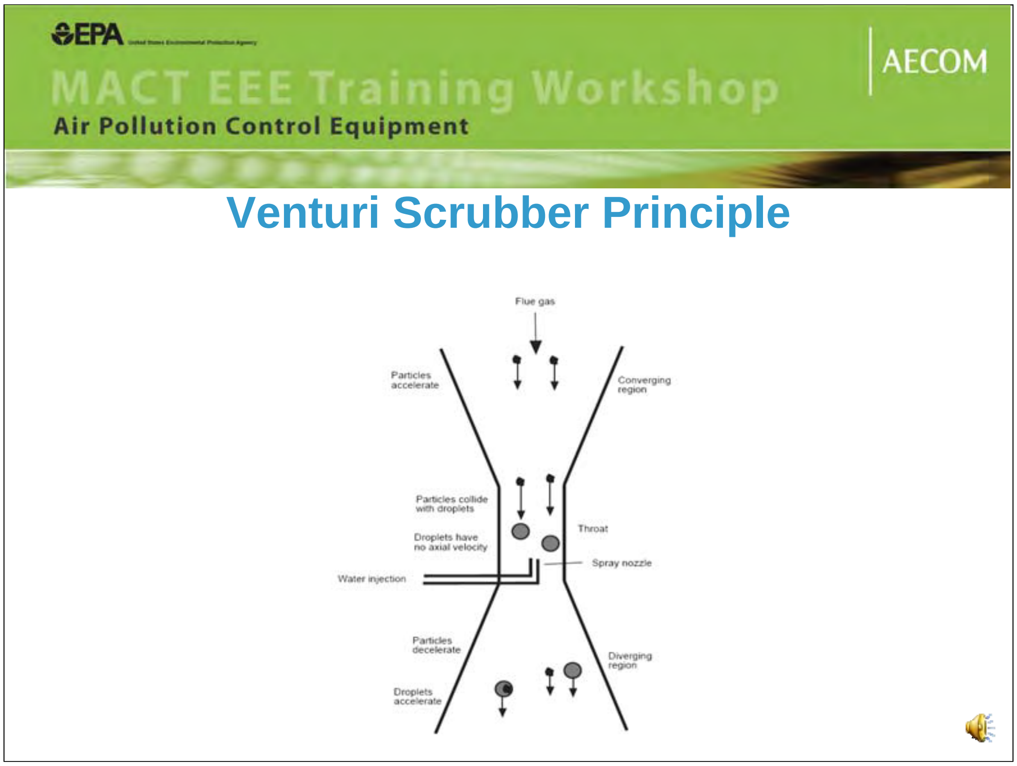
HEPA Filter Disadvantages

- Media irreversibly damaged by mechanical stresses, high temperature, or high humidity
- Frequent filter changes are usual (filters cannot be cleaned)
- Spent filters may generate a large volume of secondary waste with high disposal restrictions

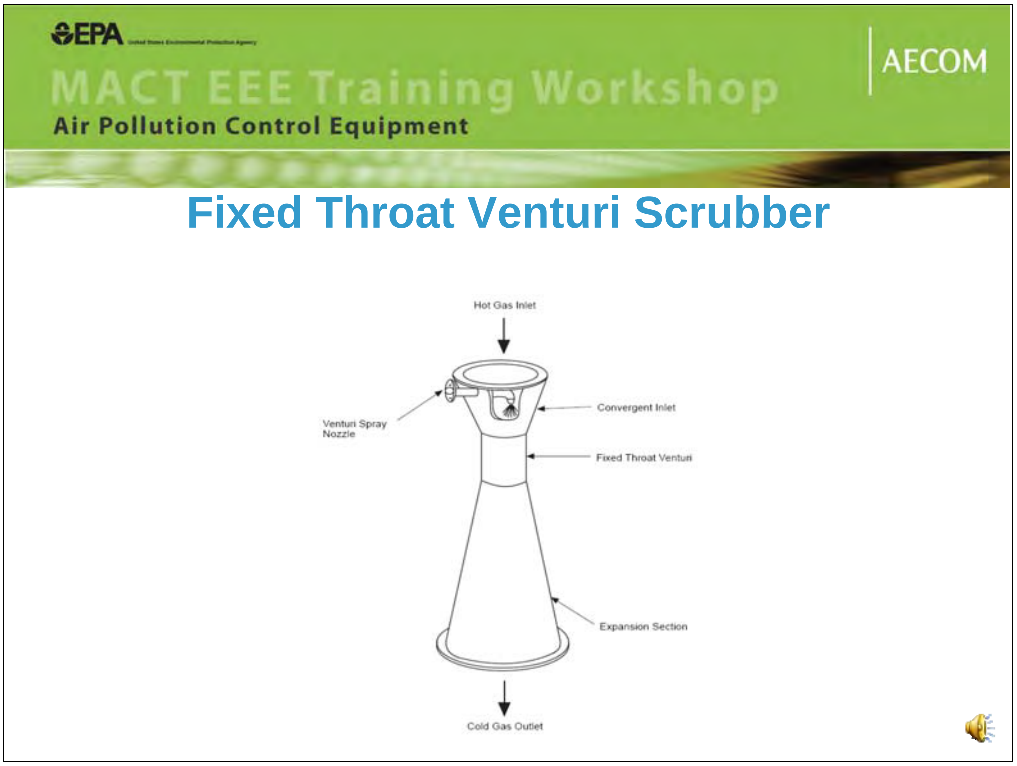
Disadvantages of the HEPA filter are that the media can be irreversibly damaged by mechanical stresses, high temperature or high humidity; frequent filter changes are usual and filters cannot be cleaned; and spent filters may generate a large volume of waste with high disposal restrictions depending on the characteristics of the particulate removed.



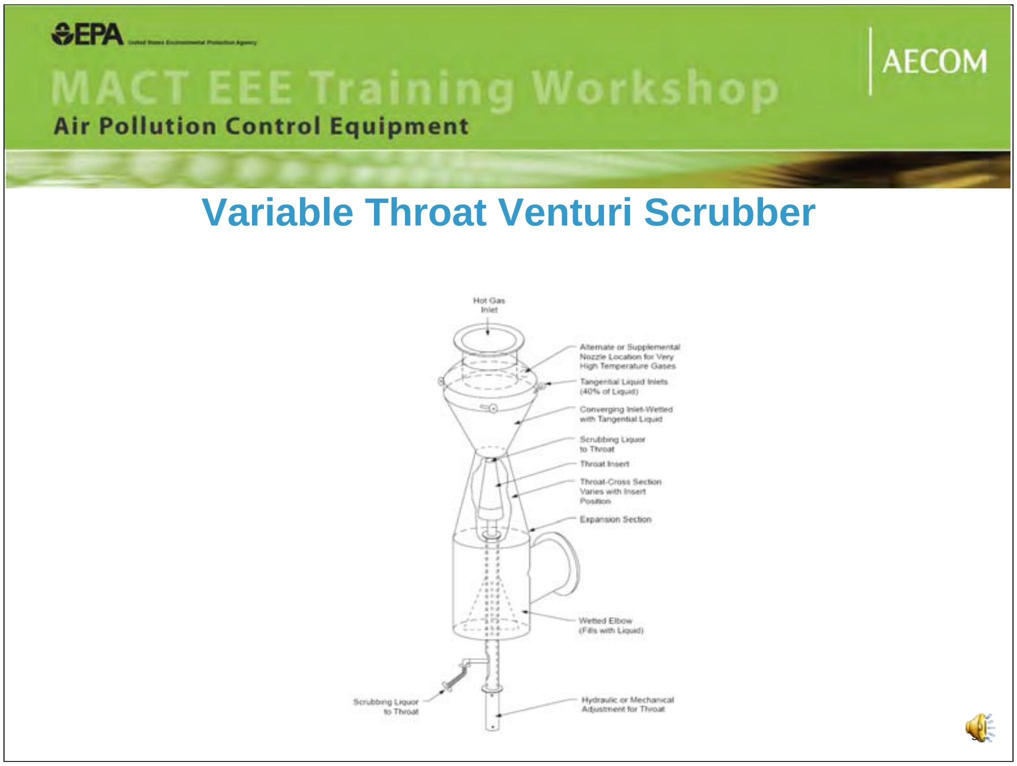
This slide shows a schematic diagram of a venture scrubber. The dirty gas enters the scrubber and the venturi, which is a reduction in area of the duct, increases the velocity and turbulence. At the throat of the venturi the scrubbing liquid is injected as an atomized droplets that cause the particles to interact and agglomerate. From the throat the area of the duct increases, slowing the gas velocity as it enters a cyclone separator that allows the velocity to be reduced further and the agglomerated particles to fall out.



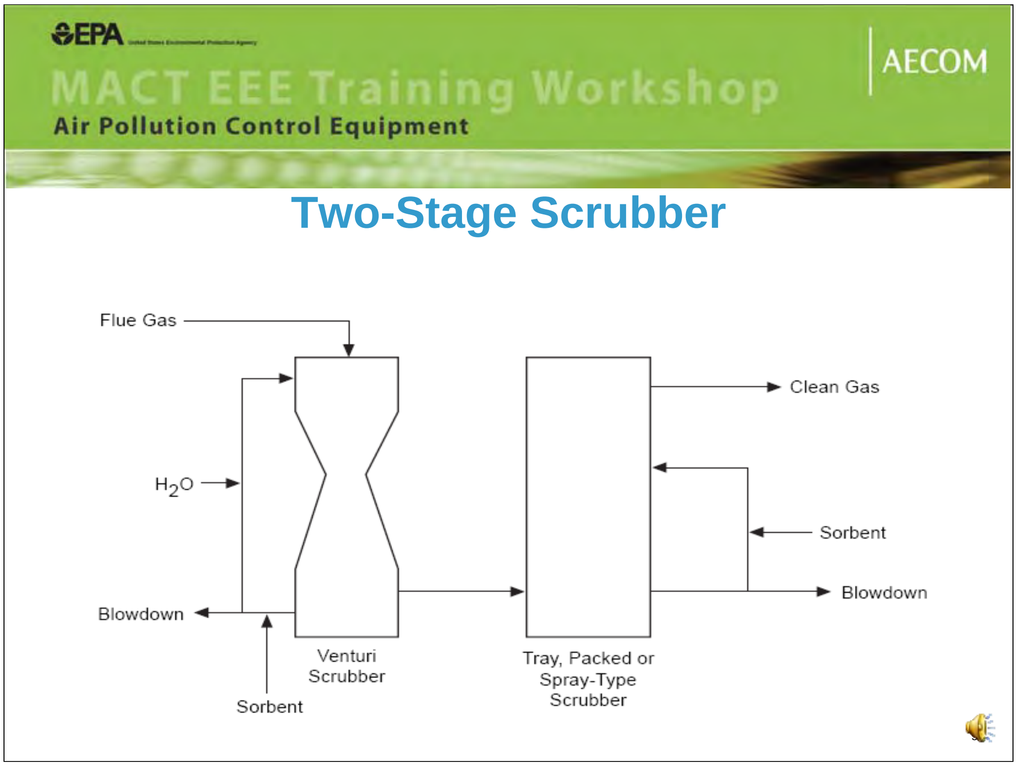
This slide shows another schematic of the venturi scrubber principle.



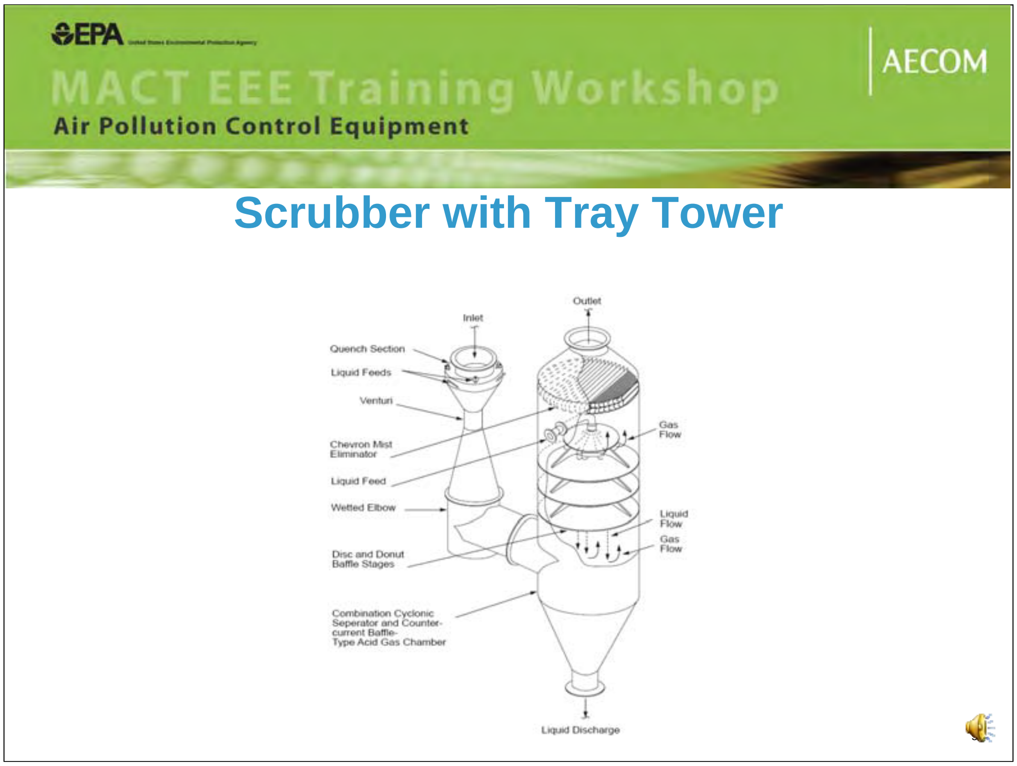
This slide shows a variation on the vernturi scrubber type. The throat of the venturi has a fixed area.



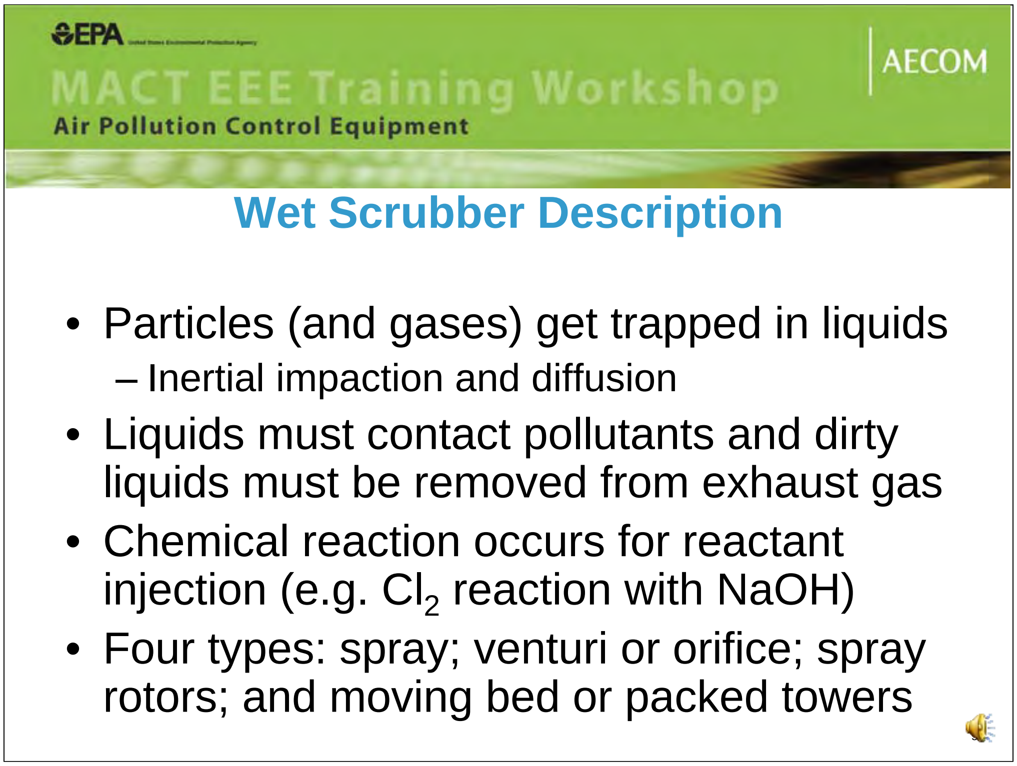
This slide shows a variable throat venturi.



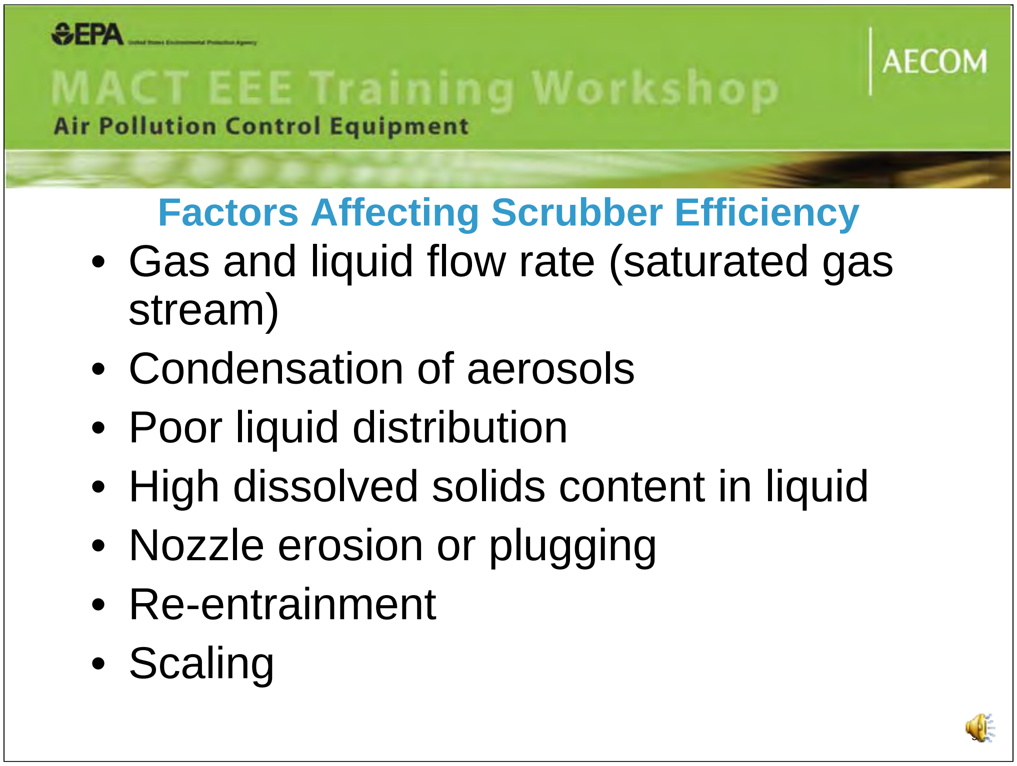
Some installations, such as the one presented in this slide, have the removal part of the scrubber separate from the venturi. The second stage can be a tray, packed or spray-type scrubber to allow for sorbent interaction with the gas stream.



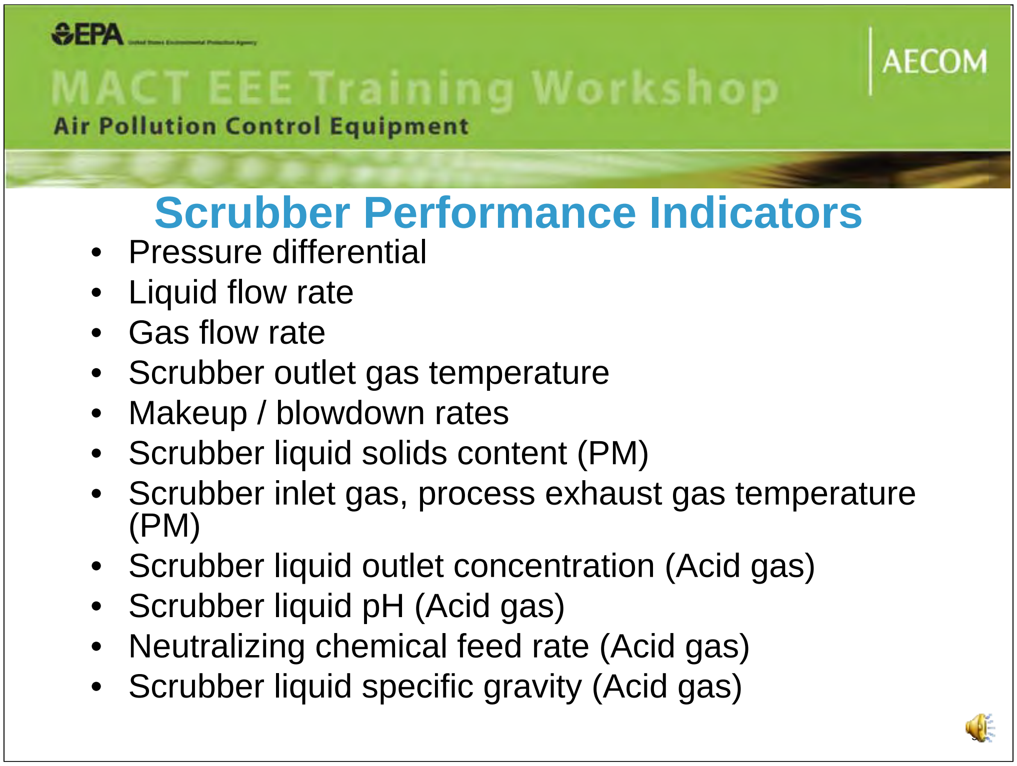
This slide shows a venturi scrubber followed by a tray tower.



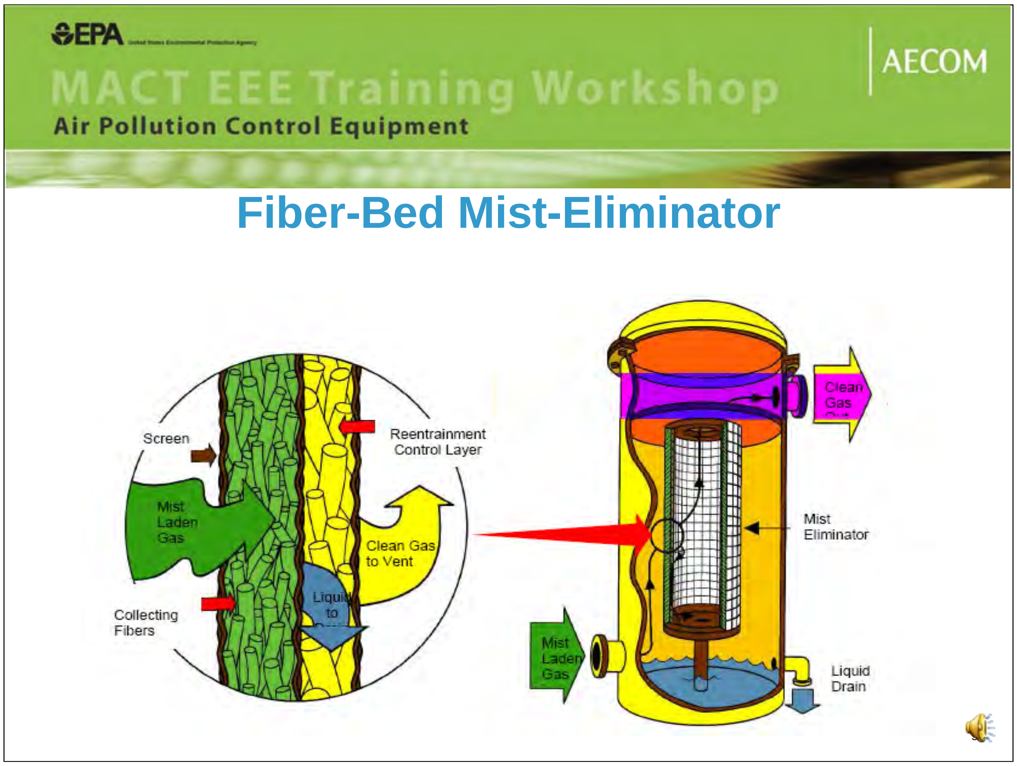
The wet scrubber operates by particles, and gases to a degree, becoming trapped in the scrubber liquid due to the inertial impaction and diffusion created. The liquid must contact the pollutants and the resulting dirty liquids in the gas stream must be removed prior to release to the atmosphere. If the scrubber liquid has a chemical reagent, such as sodium hydroxide or caustic, a chemical reaction will occur when the liquid is injected. Generally, there are four types of wet scrubbers: spray, venturi or orifice, spray rotors, and moving bed or packed towers.



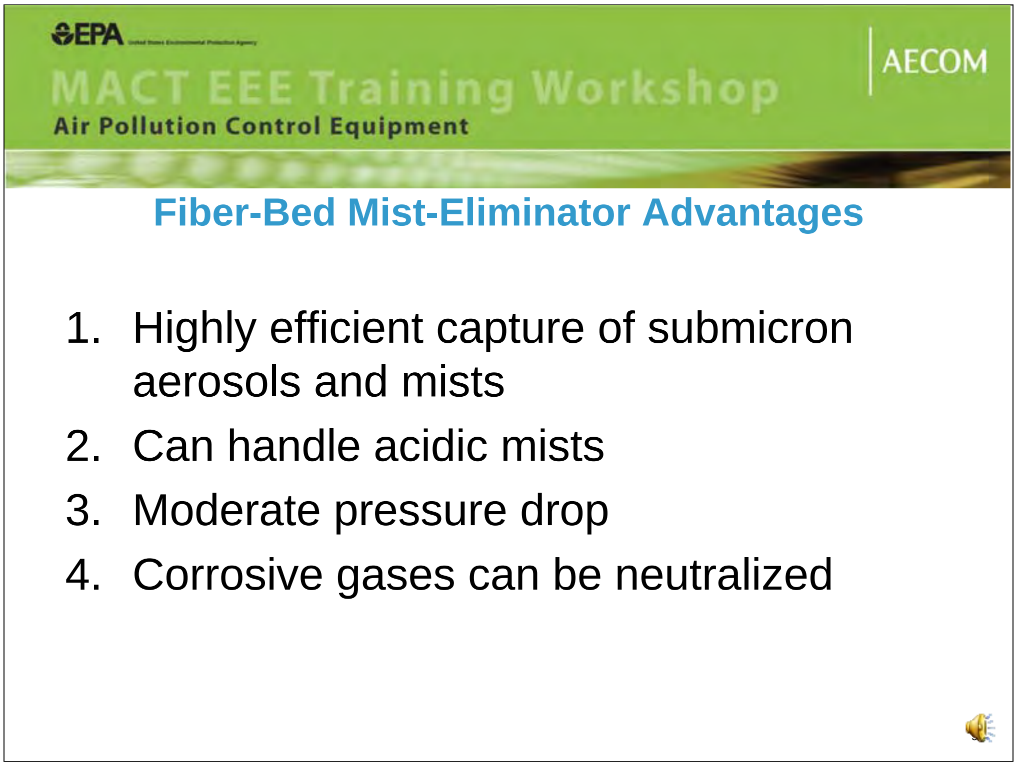
Several factors affect the scrubber's efficiency: the gas and liquid flow rate, the condensation of aerosols, liquid distribution throughout the gas stream, high dissolved solids in the recirculated liquid, nozzle erosion or plugging, re-entrainment of the pollutants, and scaling.



Indicators of the scrubbers performance are: pressure differential across the scrubber, the liquid and gas flow rate, the scrubber outlet gas temperature, the makeup and blowdown rates, the solids content in the scrubber liquid, the temperature of the gas entering the scrubber, the liquid outlet concentration of pollutants, especially acid gases, the pH of the liquid, the neutralizing chemical feed rate, and the liquid density.



This slide shows a fiber-bed mist eliminator. This device's main function is to remove liquid droplets from the gas stream.



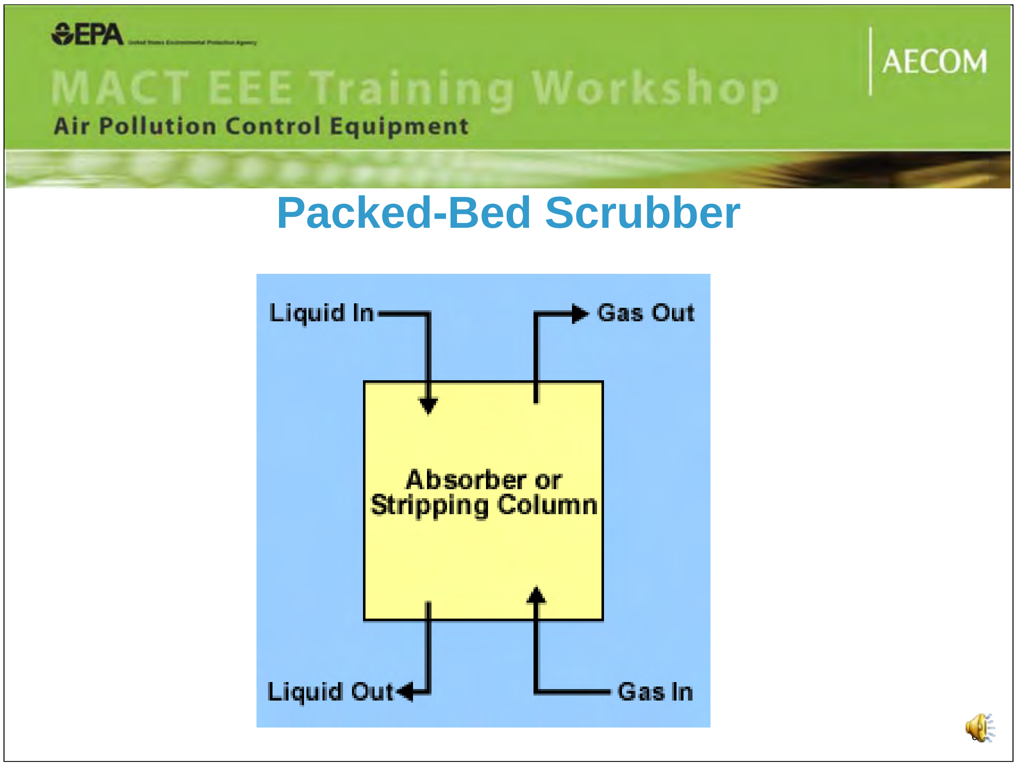
Advantages of the fiber-bed mist eliminator are: it has a high efficiency for capturing submicron aerosols and mists, it can handle acid mists, it creates a moderate pressure drop, and corrosive gases can be neutralized within the mist eliminator.

Fiber-Bed Mist-Eliminator Disadvantages

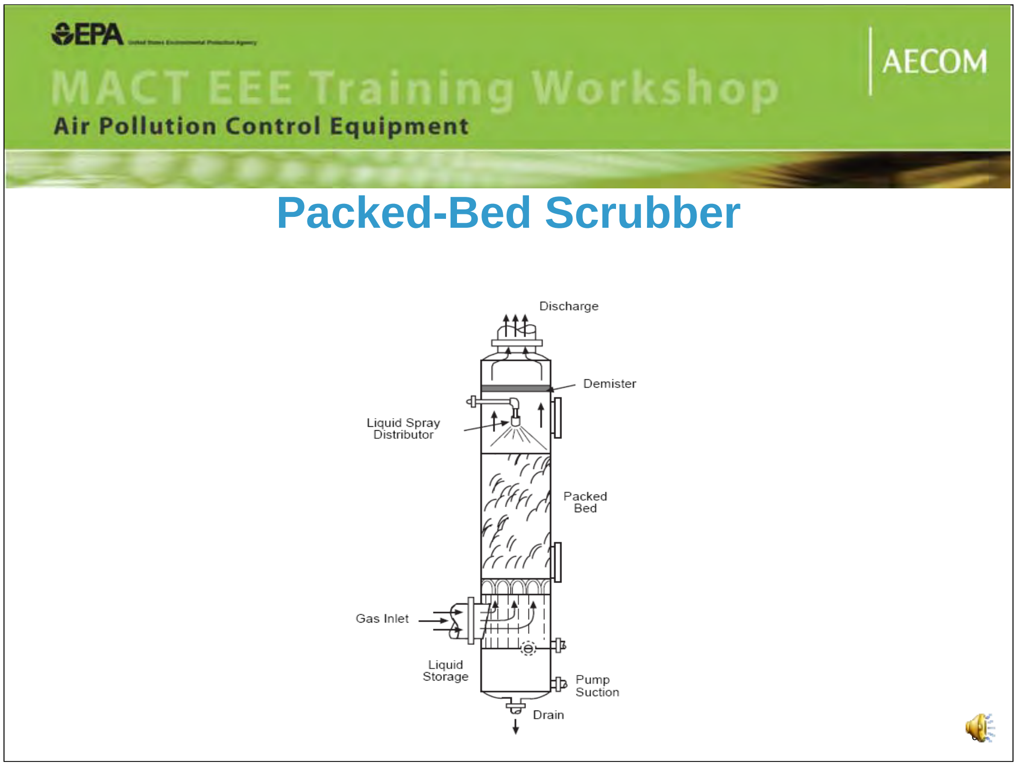
- Intolerant of PM in gas stream
- Must have corrosion resistant construction
- Effluent liquid must be handled
- Limited to gas stream inlet temperature <120 F

The mist eliminator’s principal disadvantages are: that it is not tolerant of particulate in the gas stream that would cause it to plug, the construction must be corrosion resistant, the effluent liquid must be addressed, and the inlet temperature of the gas stream is limited to about 120 degrees Fahrenheit.

This slide shows a schematic of a mist eliminator.



A packed bed scrubber operates such as illustrated in this slide. The gas entering the column generally vents upward through the column while the scrubbing liquid drops downward through the column, providing a countercurrent flow of the liquid and gas. This countercurrent flow allows for interaction of the liquid with the gas to react with pollutants such as acids.



This slide is a schematic of a packed bed scrubber. Also in this application, the liquid flows counter to the flow of gas through the scrubber. The scrubber is packed with a media that allows for exposure of a large surface area that promotes the interaction of the liquid and gas. The exit of the packed bed scrubber will have a demister to remove any liquid carryover.

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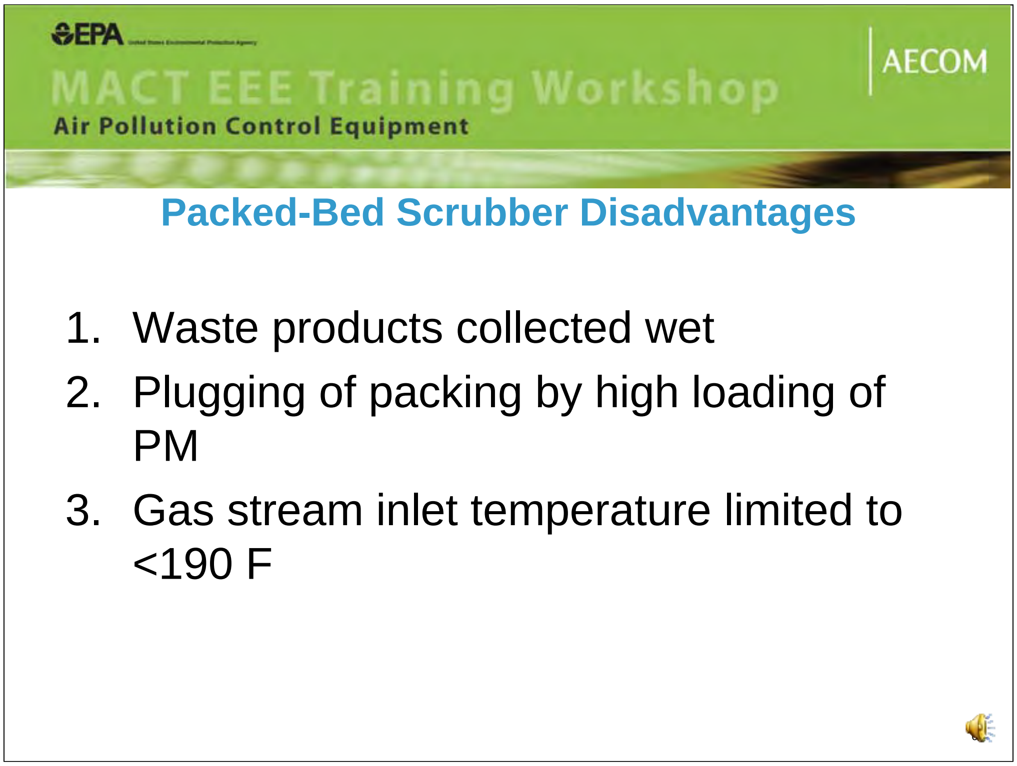
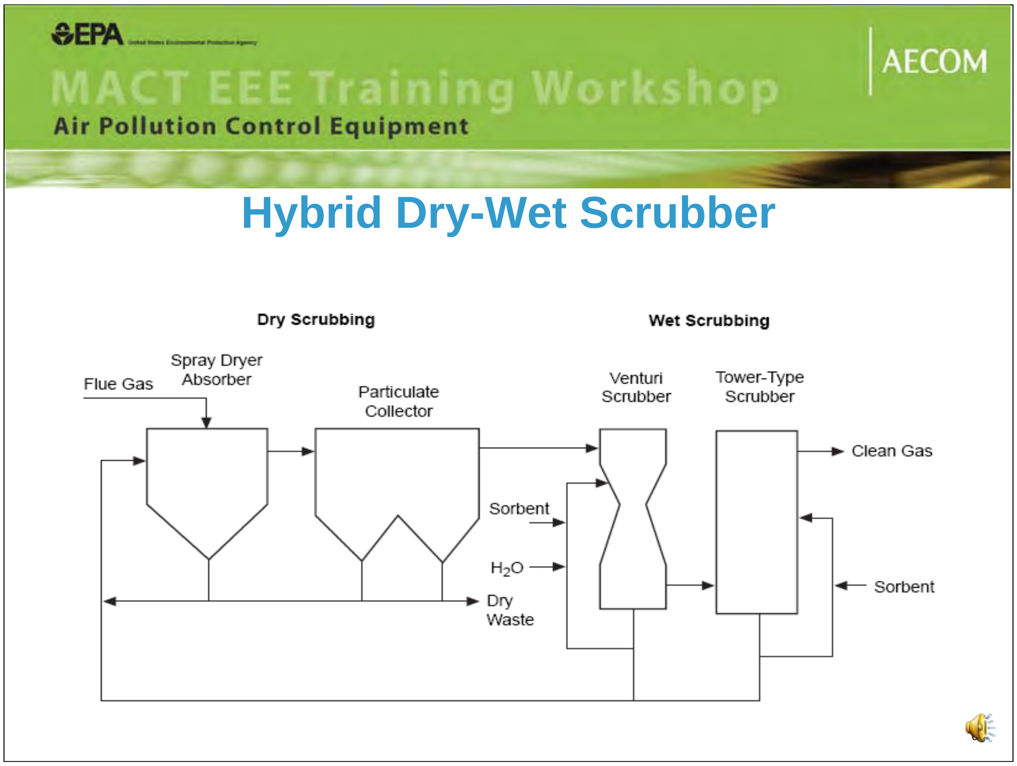
Packed-Bed Scrubber Advantages

1. Highly efficient collection of acid gases
2. Relatively low capital cost
3. Small space requirements

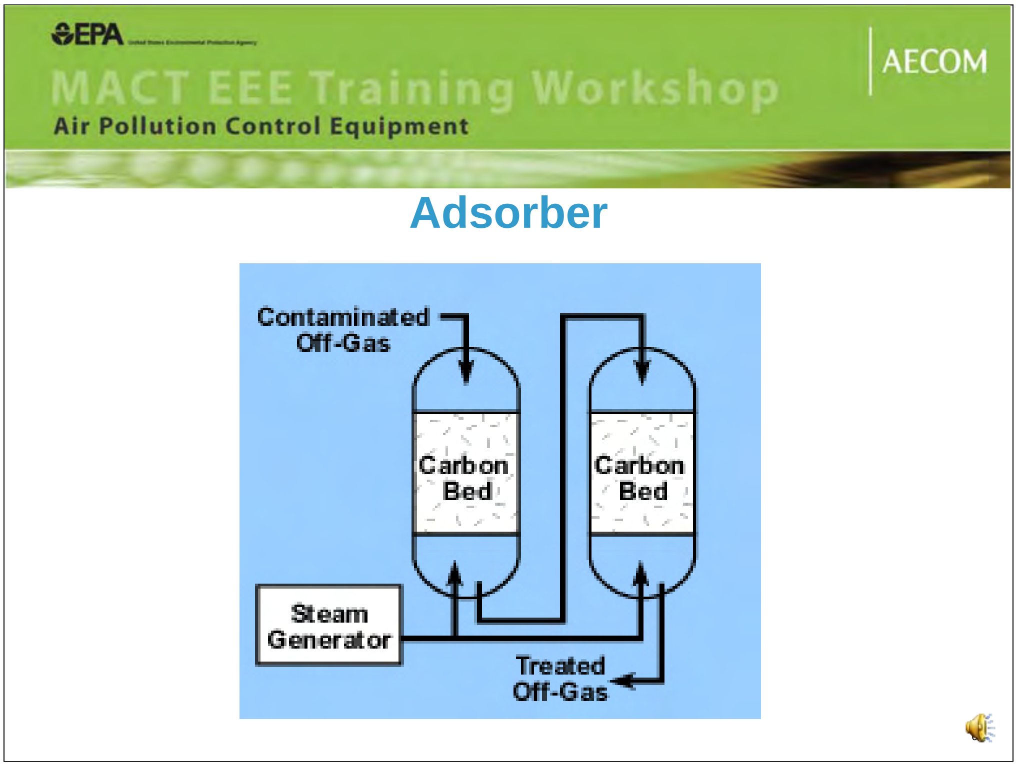
The advantages of the packed bed scrubber are: it has a highly efficient collection of acid gases, for a relatively low capital cost, and the space requirements are comparatively minimal.



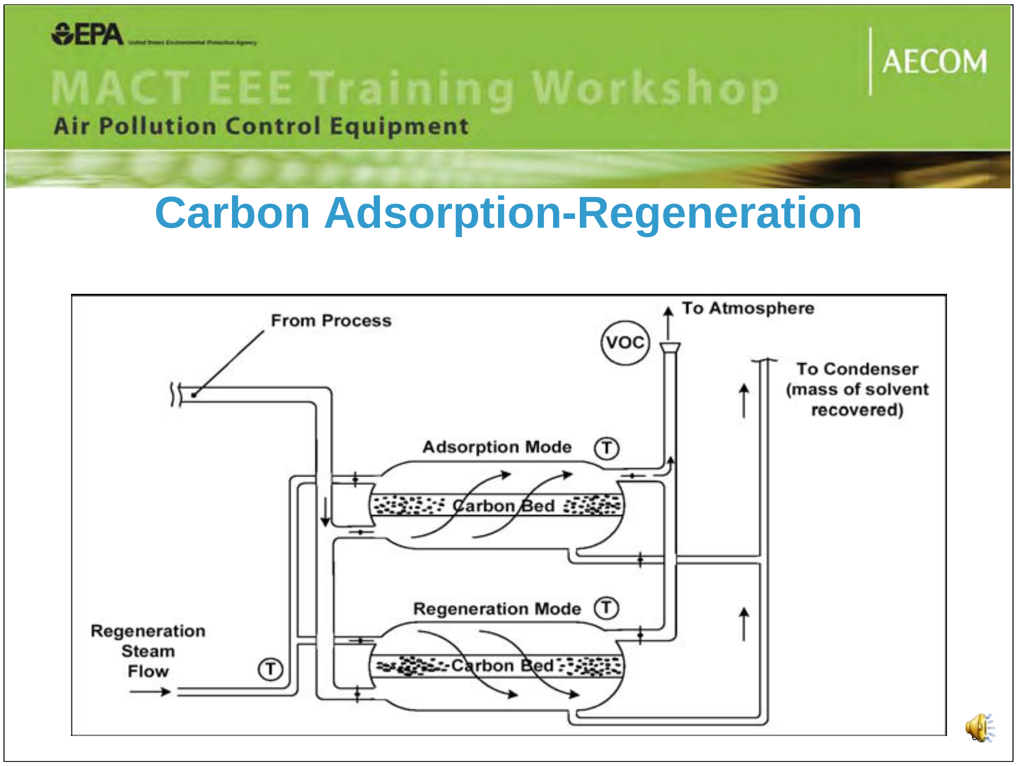
The disadvantages of a packed bed scrubber are the waste products collected wet, plugging of packing by high loading of particulate, and the gas stream inlet temperature is limited to less than 190 degrees Fahrenheit.



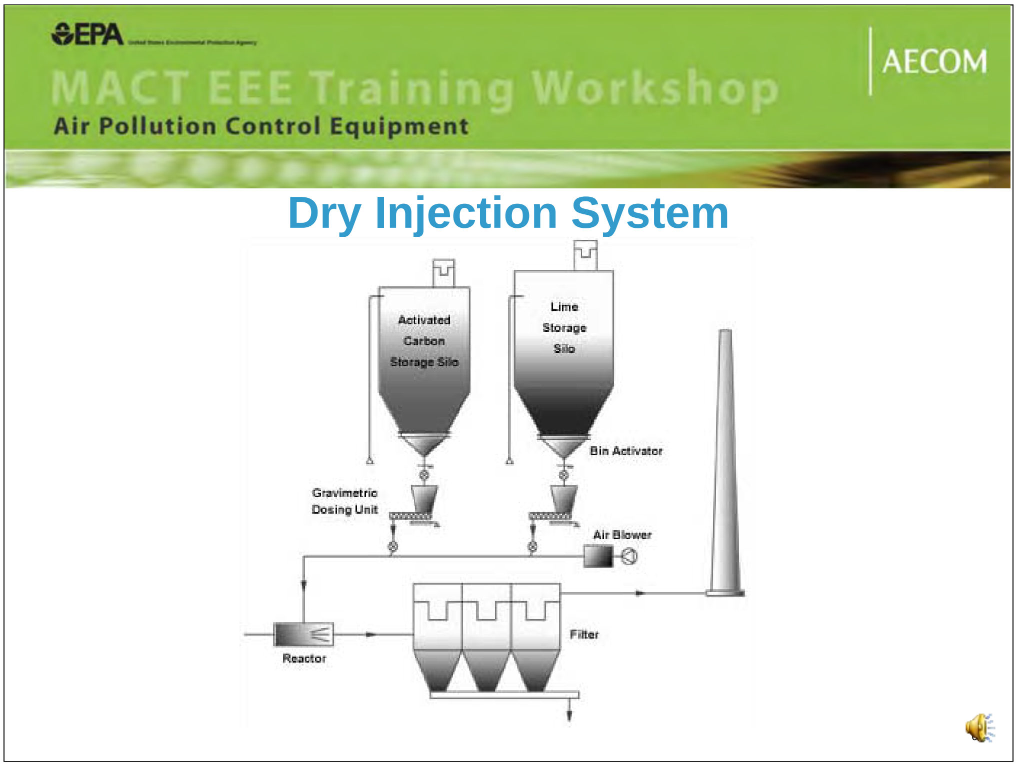
This slide shows a hybrid dray and wet scrubber system. The dirty gas first flows through a spray dryer absorber in which an absorber is sprayed into the chamber. The gas with absorber is followed by a particulate collector to remove the sprayed absorber material. The gas then enters the venturi scrubber as discussed previously then through a packed tower type scrubber before being exhausted to the atmosphere.



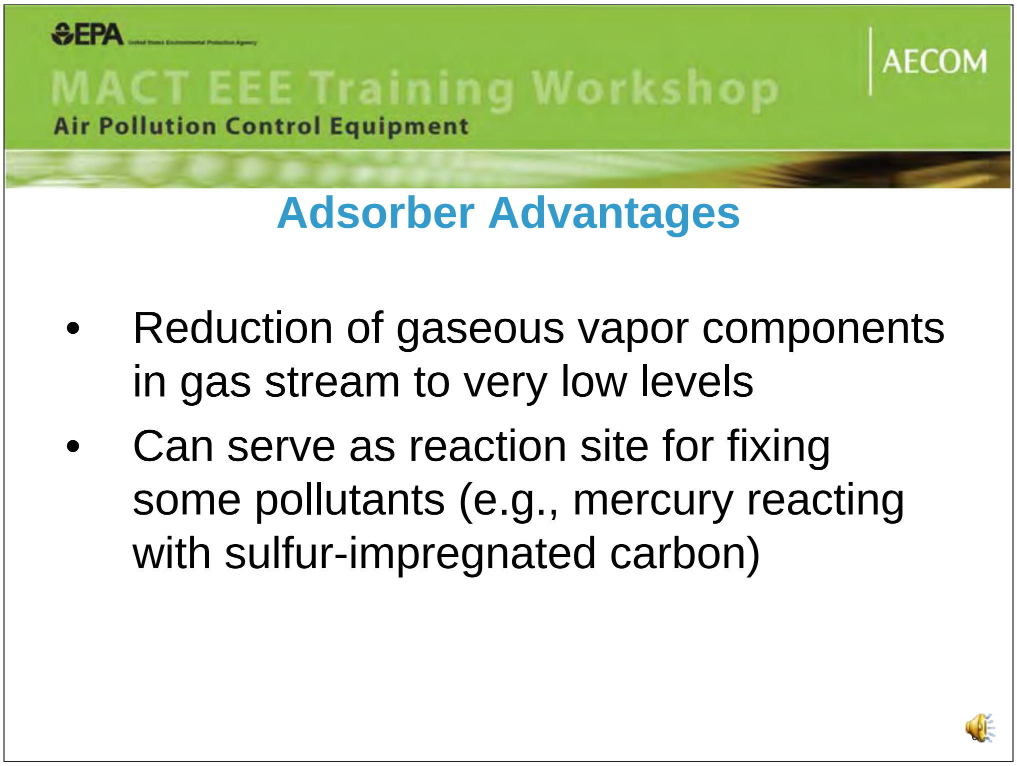
This slide illustrates a carbon bed adsorber. Gas from a process containing a contaminant enters one of two carbon beds that remove the contaminant by adsorption by the carbon. The carbon may be re-activated by injection of steam countercurrent to the flow of the gas. The gas stream cannot entering the carbon at the time of regeneration. With this arrangement, when the first carbon bed becomes saturated, the second carbon bed replaces the first carbon bed and a new carbon bed as the second bed.



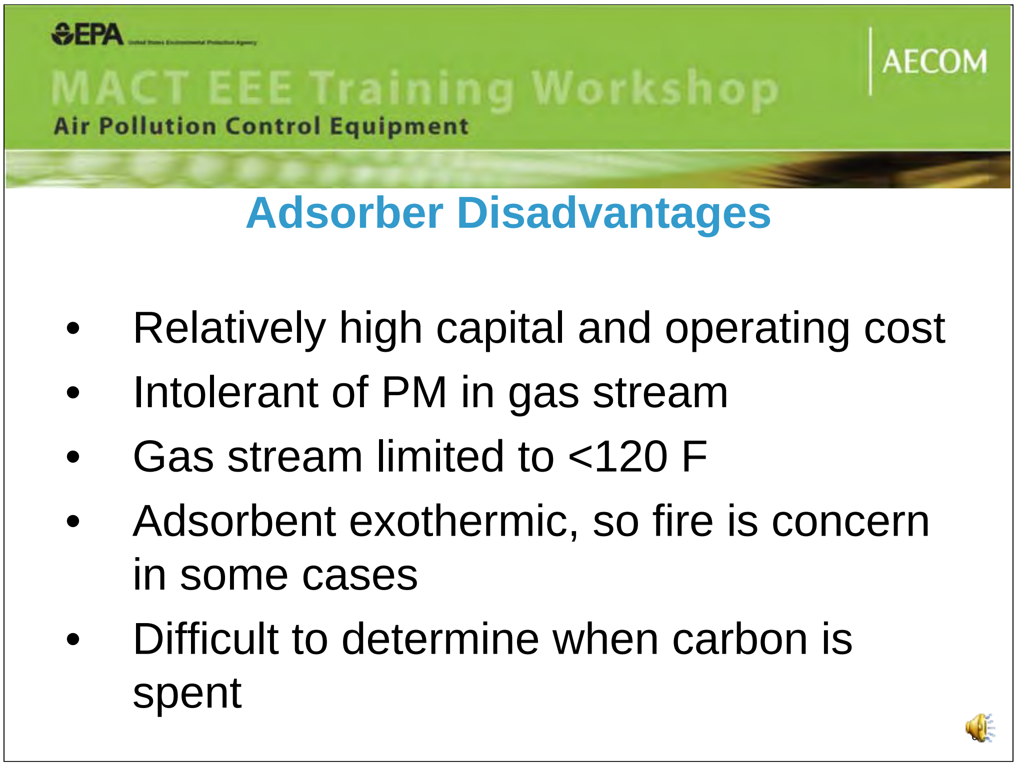
This slide shows a different arrangement of the carbon beds such that the contaminated gas stream is flowing through one carbon bed while steam is regenerating the other carbon bed. The steam that has stripped the contaminant from the carbon vents to a condenser to remove the contaminant.



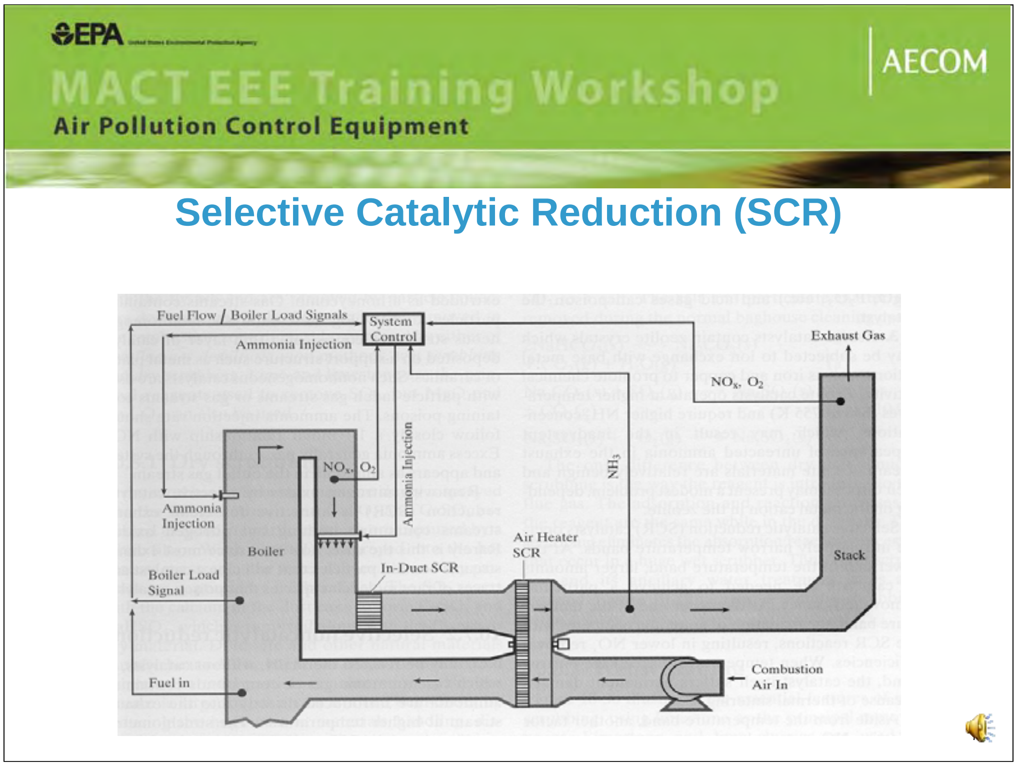
This slide illustrates a dry injection system. In this system, activated carbon and lime are injected into the gas stream prior to a dry collection system such as a fabric filter. The carbon removes a contaminant that can be adsorbed by the carbon and the lime reacts with acidic contaminants.



The advantages of a carbon adsorption system are: the reduction of gaseous vapor components in gas stream to very low levels and it can serve as reaction site for fixing some pollutants such as mercury reacting with sulfur-impregnated carbon.



Disadvantages of an adsorber are: its relatively high capital and operating cost, it is intolerant of PM in gas stream because of blinding that occurs, the gas stream limited to less than 120 degrees Fahrenheit, adsorbent can be exothermic, so fire is concern in some cases, and it is difficult to determine when carbon is spent.



Although not a control device mentioned in MACT EEE, a selective catalytic reduction, or SCR, system is mentioned here because such a system might be encountered at a site due to compliance with other rules. The schematic shown here illustrates how the SCR operates. The primary objective of the SCR is to reduce the NOx in the gas stream.

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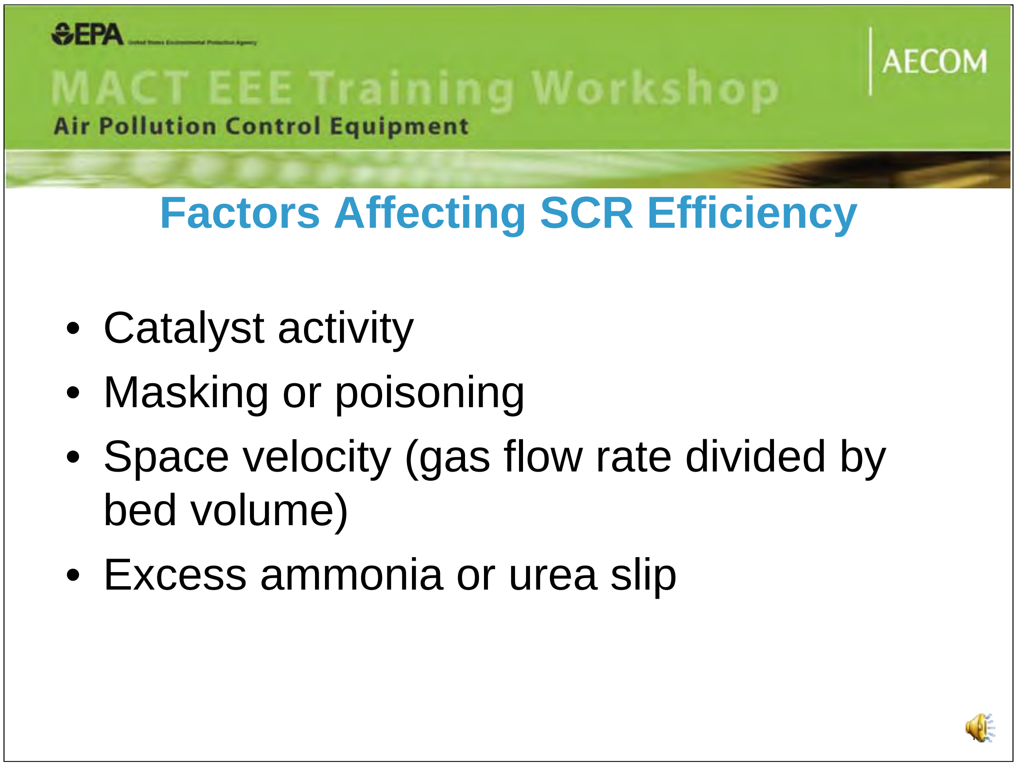
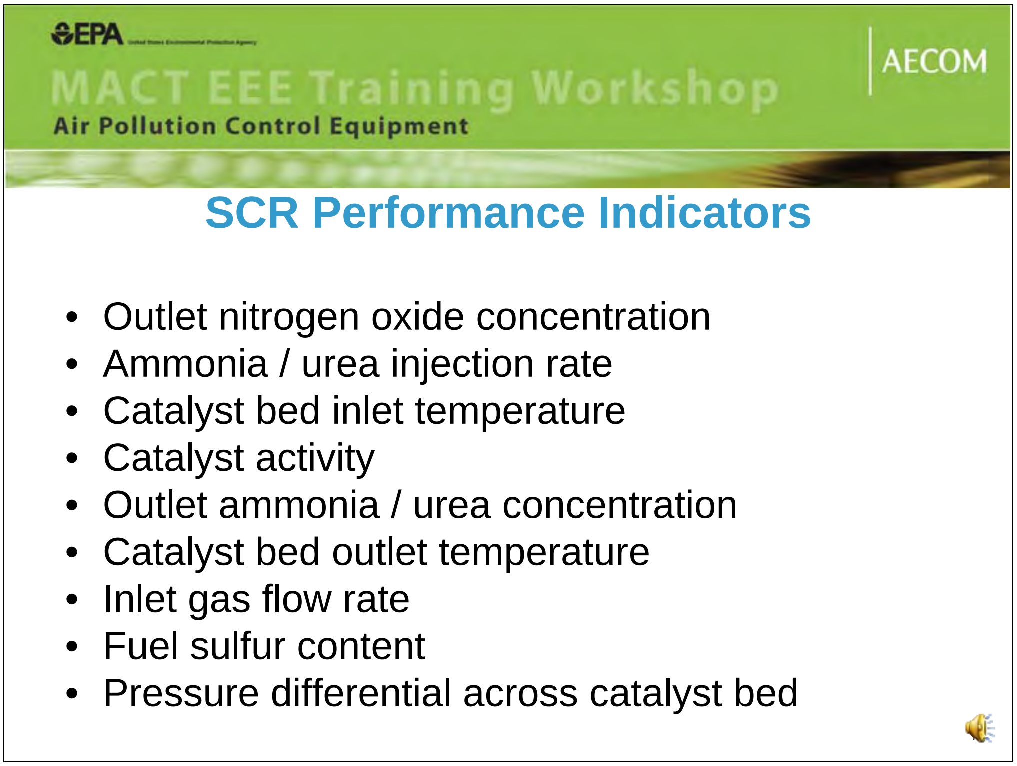
SCR Description

- Ammonia or urea is injected into exhaust streams with plenty of oxygen to reduce nitrogen oxide to nitrogen and oxygen
- Efficiency ranges from 70 to 90 percent
- Catalysts made from base and precious metals and zeolites
- Operating temperatures range from 600 to 1100°F

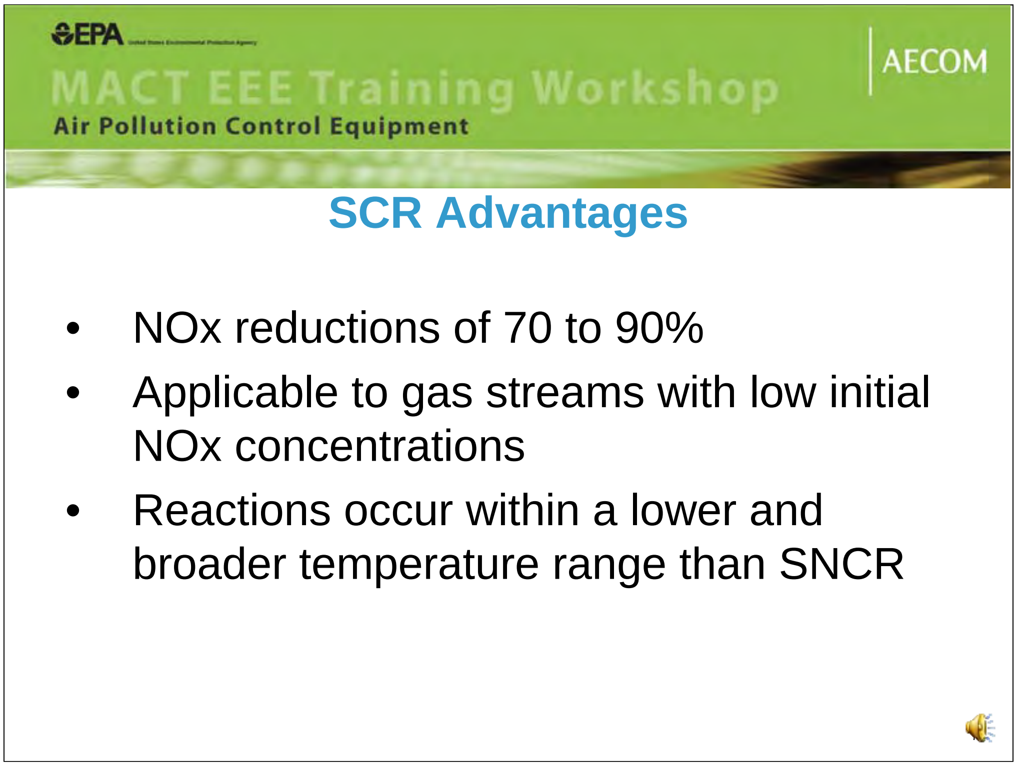
The SCR system injects ammonia or urea into the gas stream, the gas stream needing an abundance of oxygen, to reduce nitrogen oxide to nitrogen and oxygen. The system efficiency ranges between 70 to 90 percent removal of nitrogen oxides. The gas flows through a catalyst bed made from base and precious metals and zeolites. The system operates within a temperature range of 600 to 100 degrees Fahrenheit.



The factors that affect an SCR's efficiency are: the activity level of the catalyst, masking or poisoning of the catalyst, the space velocity factor, which is the gas flow rate divided by the bed volume, and slip caused by the excess ammonia or urea injected into the gas.



An SCR performance is indicated by the outlet nitrogen oxide concentration, the ammonia or urea injection rate, the catalyst bed inlet temperature and activity, the outlet ammonia or urea concentration, the catalyst bed outlet temperature, the inlet gas flow rate, the fuel sulfur content, and the pressure differential across catalyst bed.

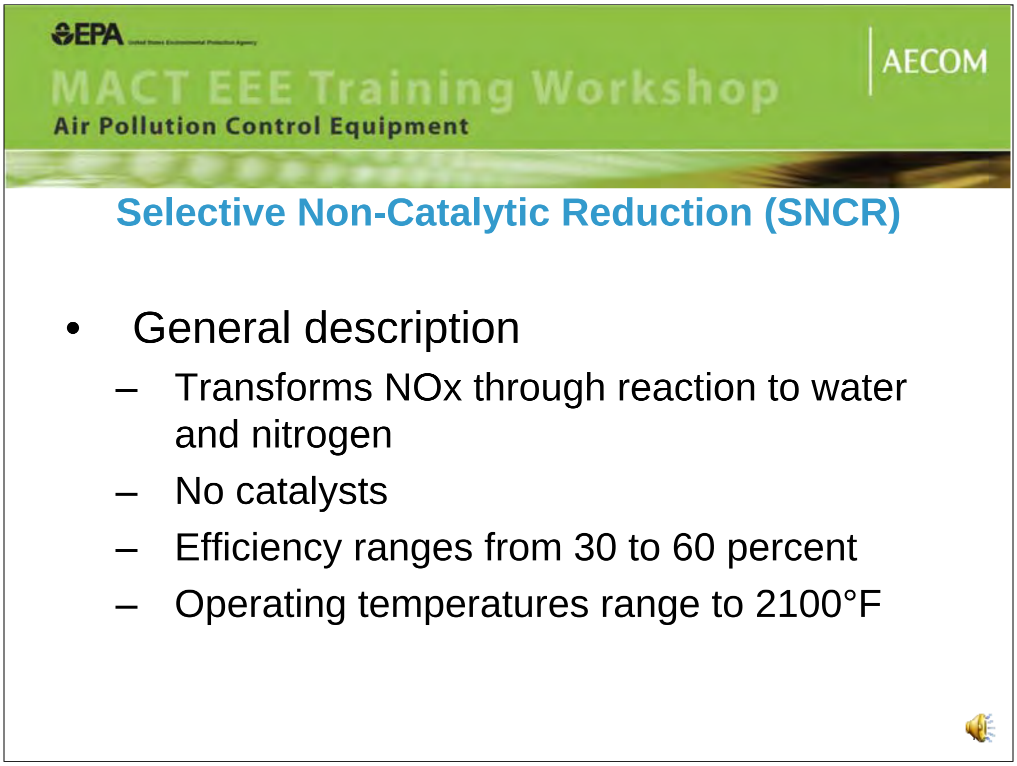


An SCR system has the advantages of reducing NOx by 70 to 90 percent, it can be used with gas streams with low initial NOx concentrations, and the reactions occur within a lower and broader temperature range than SNCR.

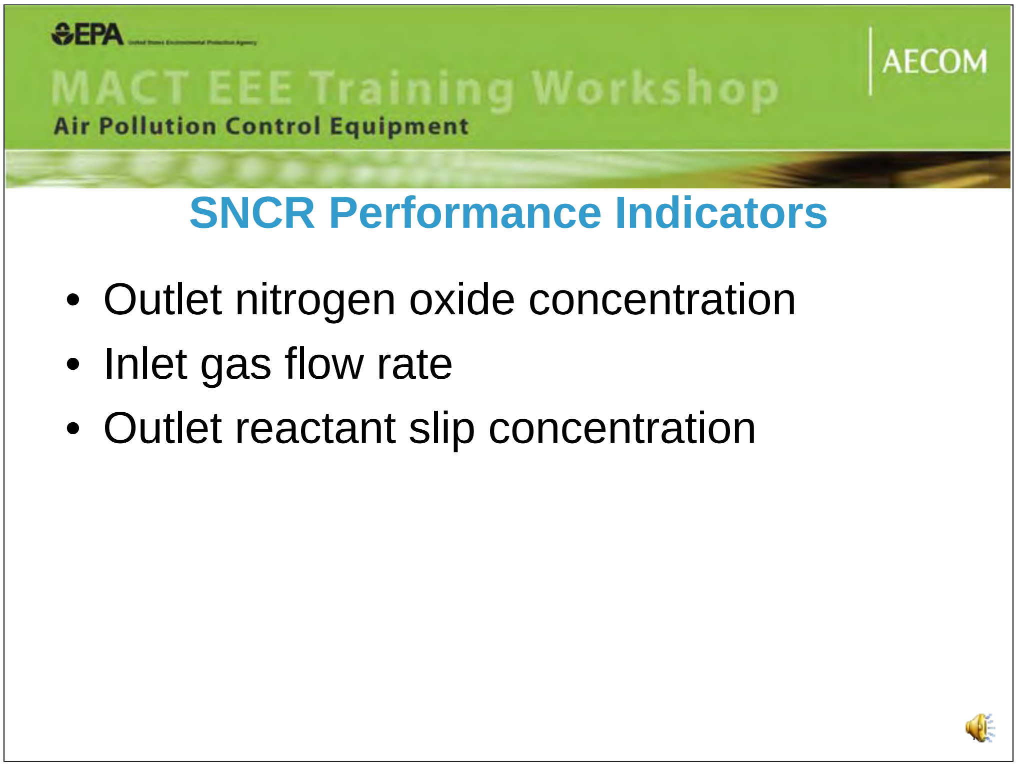
SCR Disadvantages

- Large volume of catalyst and reagent is required
- May produce unacceptable ammonia slip
- Usually requires heating of gas stream to SCR operating temperature
- Intolerant of PM in gas stream

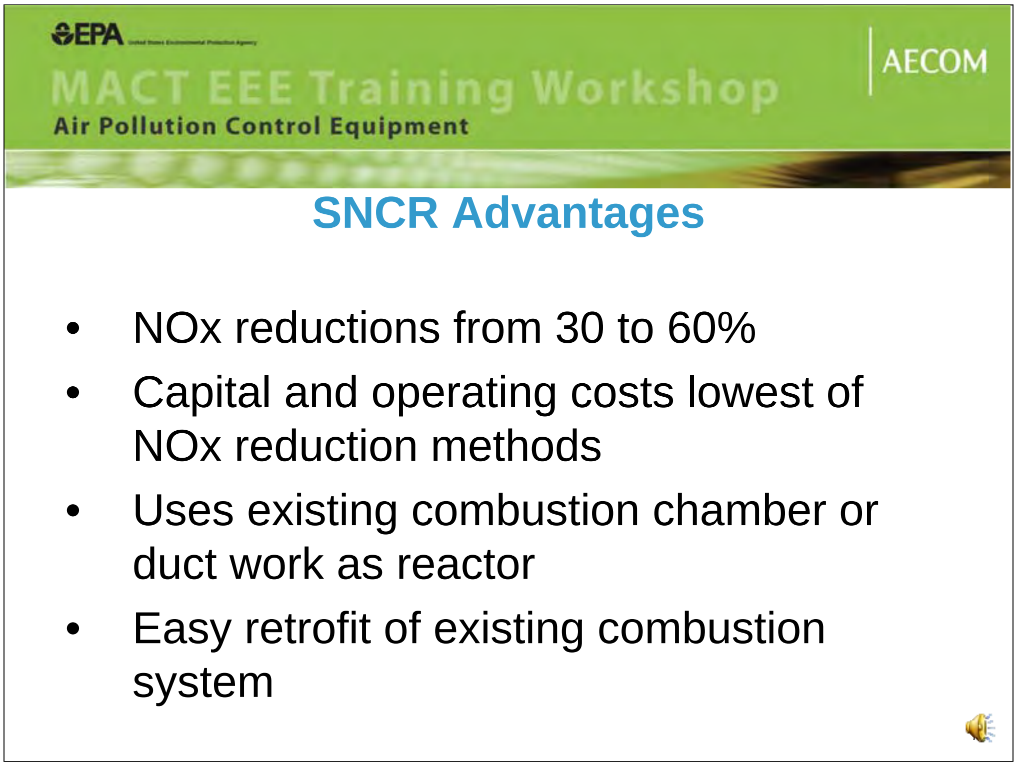
The disadvantages of SCR are that a large volume of catalyst and reagent is required, it may produce unacceptable ammonia slip, it usually requires heating of gas stream to SCR operating temperature, and it is intolerant of particulate in gas stream.



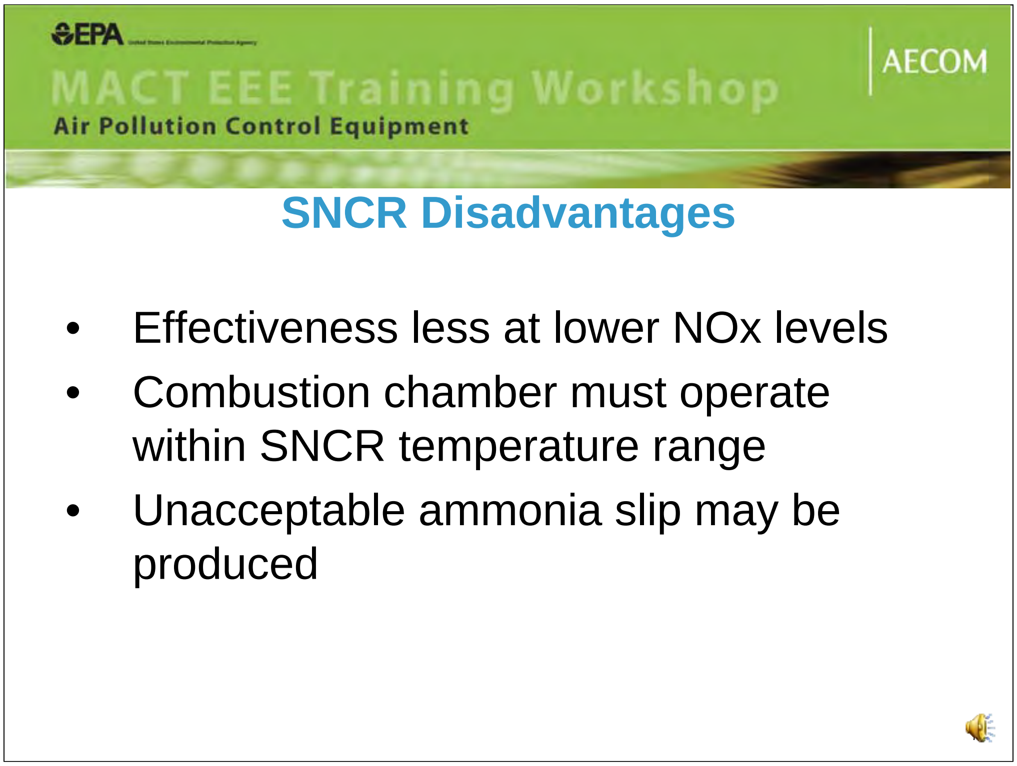
A similar process for NOx reduction is a Selective Non-catalytic reduction, or SNCR, system. This system transforms NOx through reaction to water and nitrogen. Efficiencies range from 30 to 60 percent and operating temperatures range up to 2100 degrees Fahrenheit.



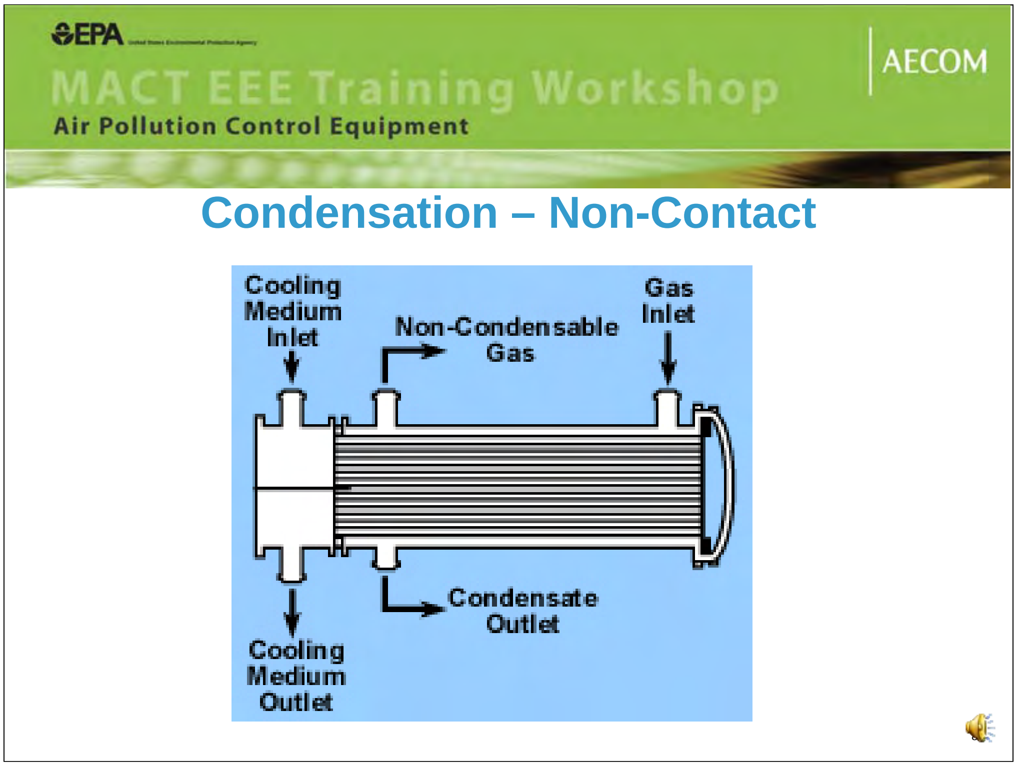
The primary SNCR performance indicators are the outlet nitrogen oxide concentration, the inlet gas flow rate, and the outlet reactant, such as ammonia, slip concentration.



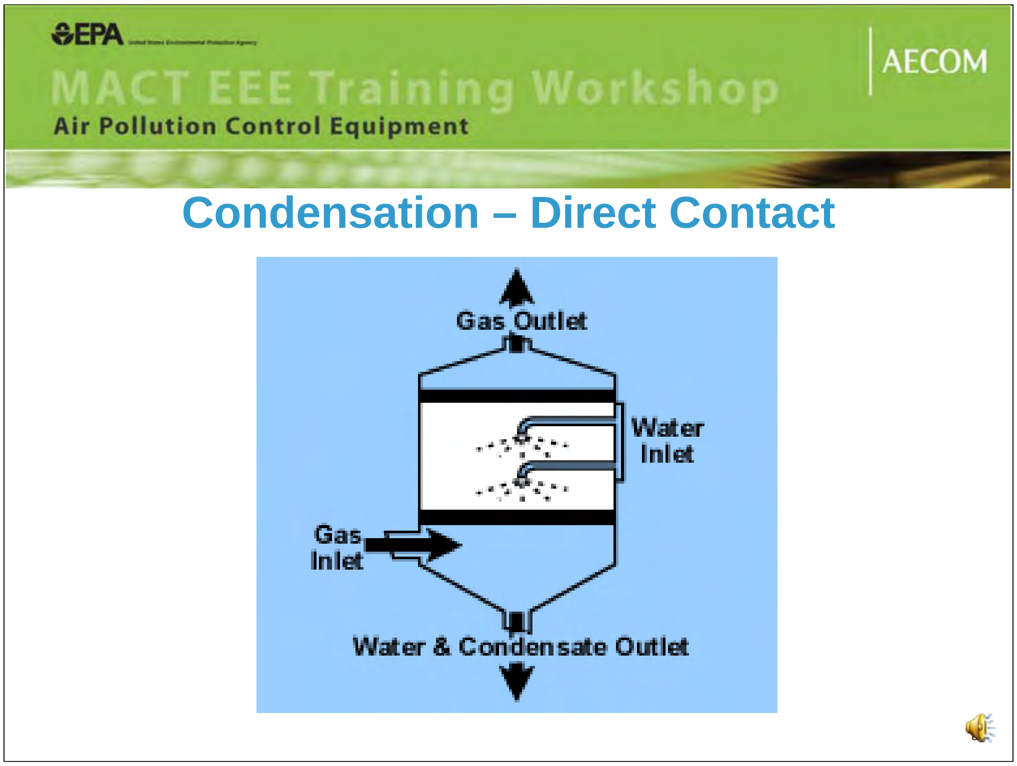
The advantages of a SNCR system are: NOx can be reduced by 30 to 60 percent, the capital and operating costs are lowest of NOx reduction methods, it uses existing combustion chamber or duct work as reactor and does not require an additional reactor chamber, and it is easy to retrofit to existing combustion system.



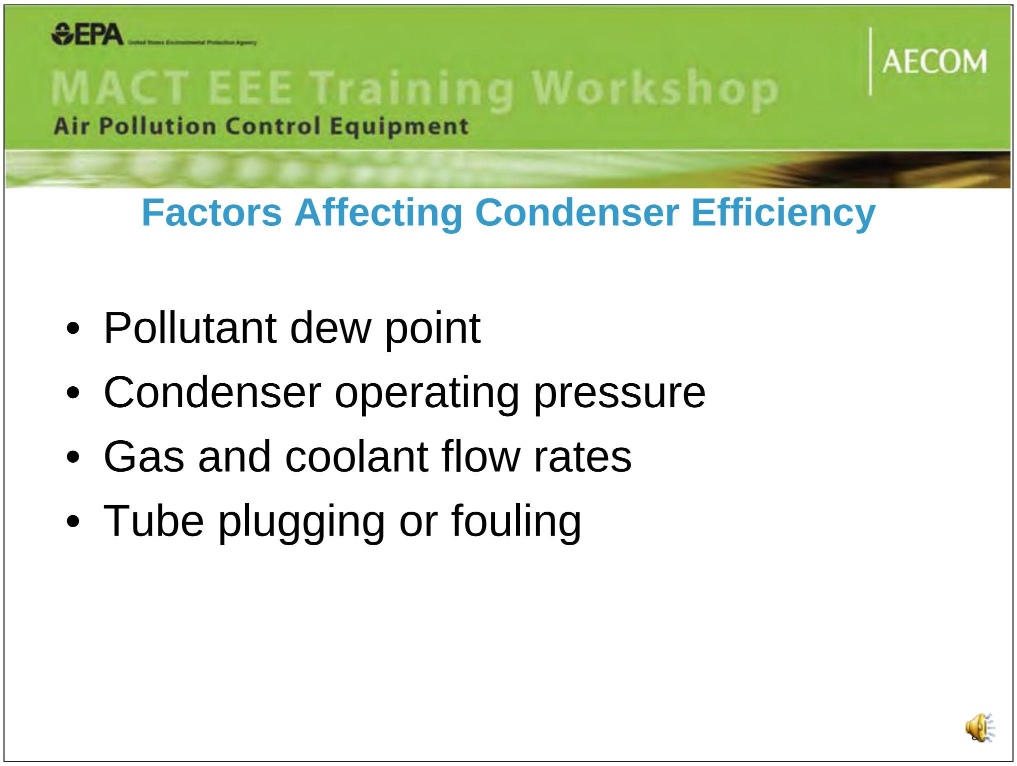
The disadvantages of a SNCR system are: its effectiveness is less at lower NOx levels, the combustion chamber must operate within SNCR temperature range, and an unacceptable ammonia slip may be produced.



Another simple control device that is not mentioned for MACT EEE use is a condenser. The condenser simply lowers the temperature of the gas so that specific contaminants will be condensed and, therefore, removed from the gas stream. This slide shows schematically the operation of the condenser.



Another variation of condensation is the direct contact condenser. In this schematic, water is injected into the gas stream, which lowers the temperature of the gas allowing contaminants to condense and exit with the water.



The factors that affect a condenser's efficiency are: the pollutant dew point, that is the temperature at which it condenses, the condenser operating pressure, the gas and coolant flow rates, and tube plugging or fouling.

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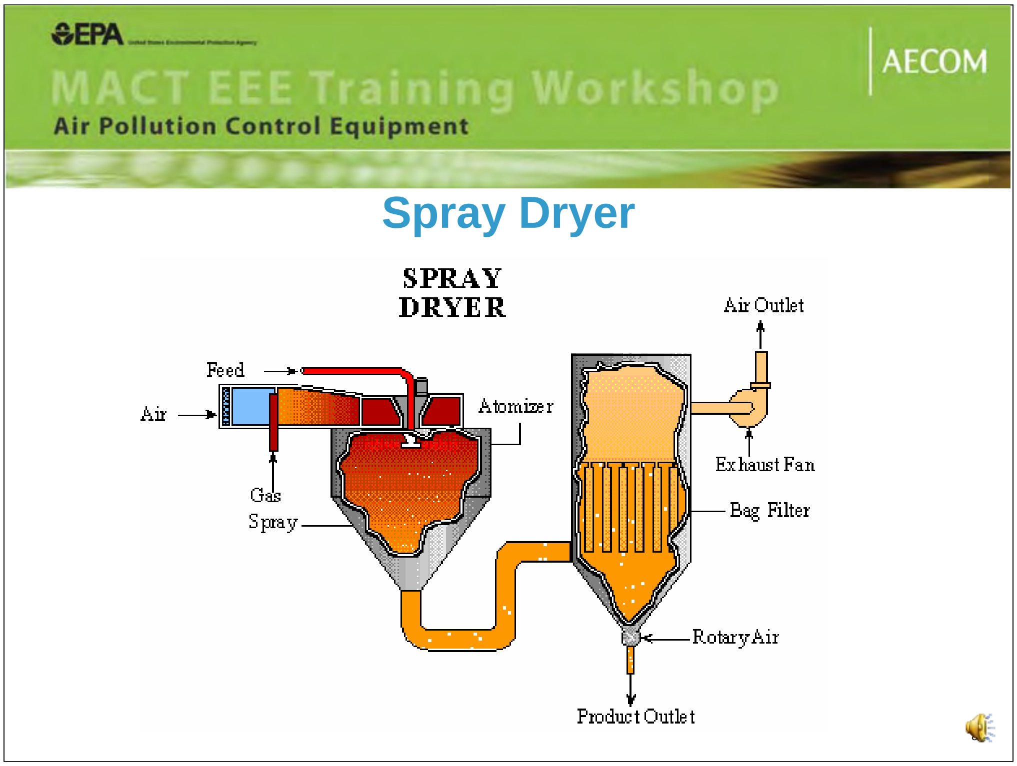
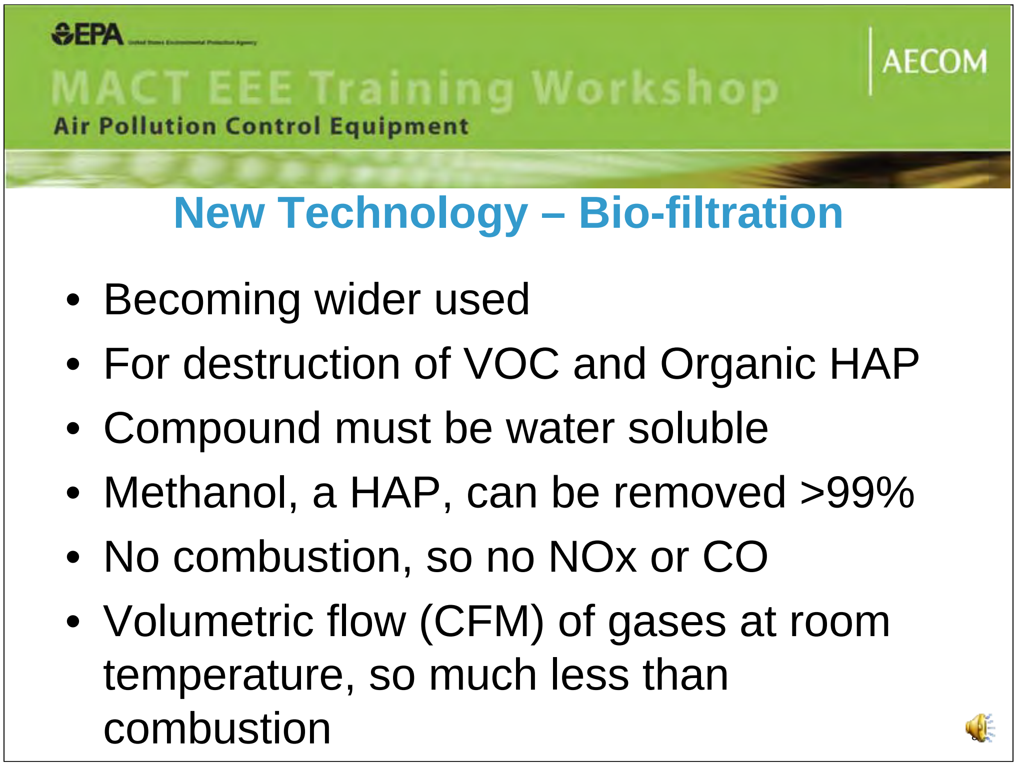
Condenser Performance Indicators

- Outlet VOC concentration
- Outlet gas temperature
- Coolant inlet temperature
- Coolant outlet temperature
- Exhaust gas flow rate
- Pressure differential across condenser
- Coolant flow rate
- Pressure differential across coolant refrigeration system
- Condensate collection rate
- Inspection for fouling or corrosion

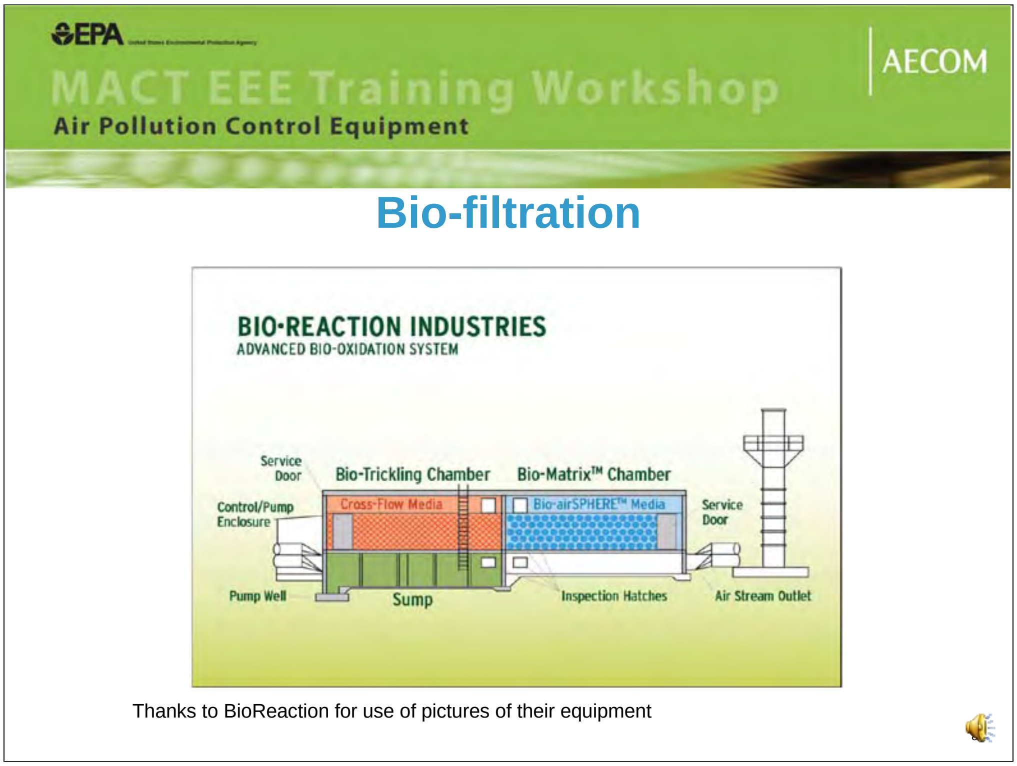
Indicators of performance of a condenser are: the outlet concentration of the contaminant, the outlet gas temperature, the coolant inlet and outlet temperature, the exhaust gas flow rate, the pressure differential across condenser, the coolant flow rate, the pressure differential across coolant refrigeration system, the condensate collection rate, and inspection for fouling or corrosion.



This slide is a schematic of a spray dryer.



A new technology that is becoming more widely used is a bio-filter. The bio-filtration system is good for destruction of VOC and Organic HAP. The contaminant must be water soluble, such as Methanol, a HAP, that can be removed at more than 99 percent. The process has no combustion, so no NOx or CO is generated. The volumetric flow (CFM) of exhaust gas is so much less than combustion systems.



This schematic shows how the bio-filter operates. Gas first passes through a trickling filter and then into a bio-media chamber before being exhausted to the atmosphere.

The bio-filter media is shown in this slide.

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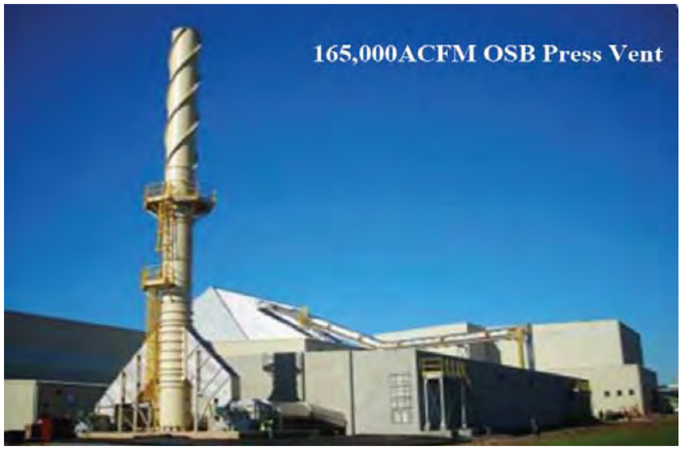
Biofilter Application



Thanks to BioReaction for use of pictures of their equipment

This slide shows a bio-filter installation.

Another bio-filter installation is shown in this slide.

This ends the presentation of this module.