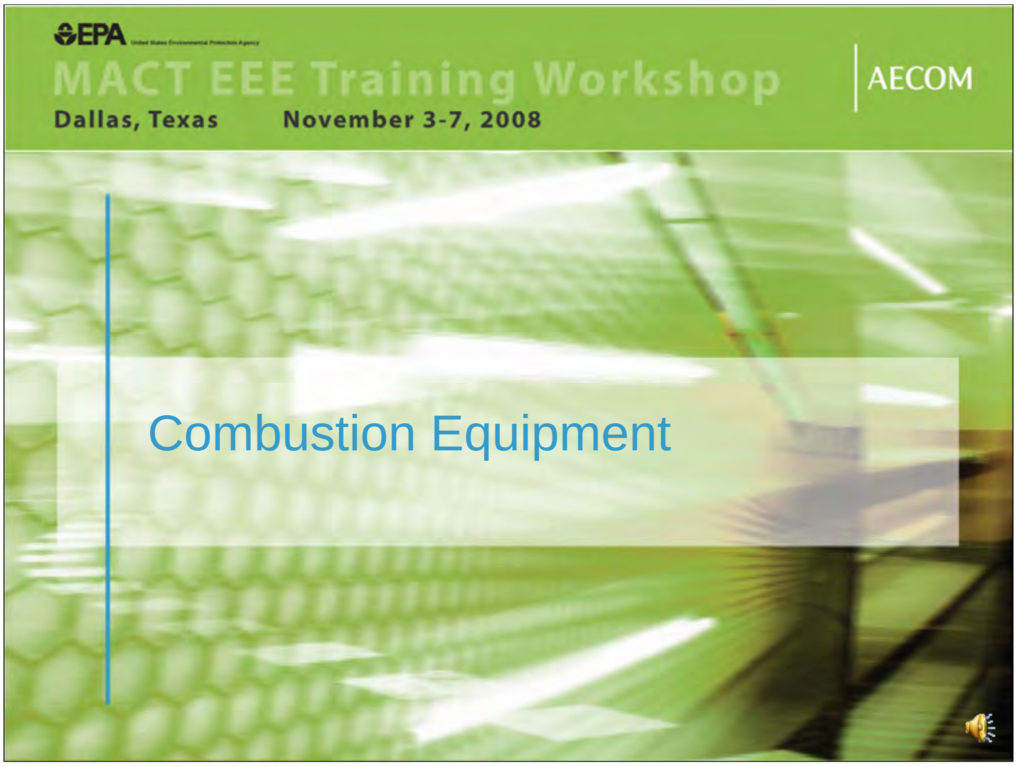


This module will take a more in-depth look at the combustion equipment that make up the technologies that were mentioned in the previous module.

MACT EEE Training Workshop

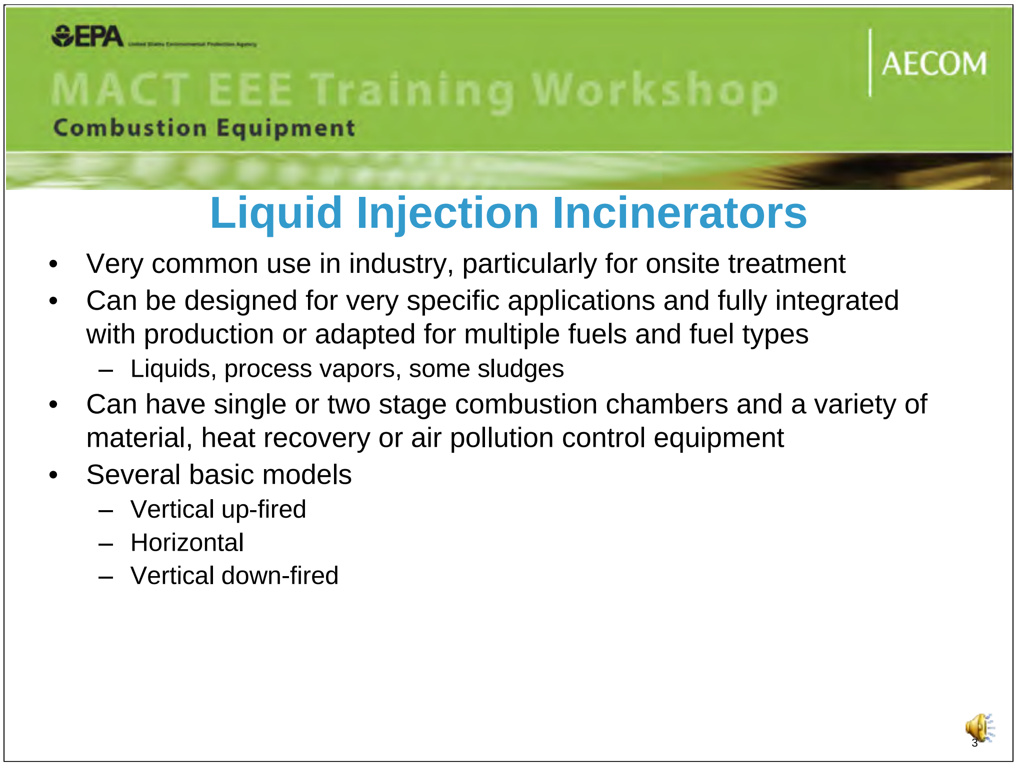
Combustion Equipment

AECOM

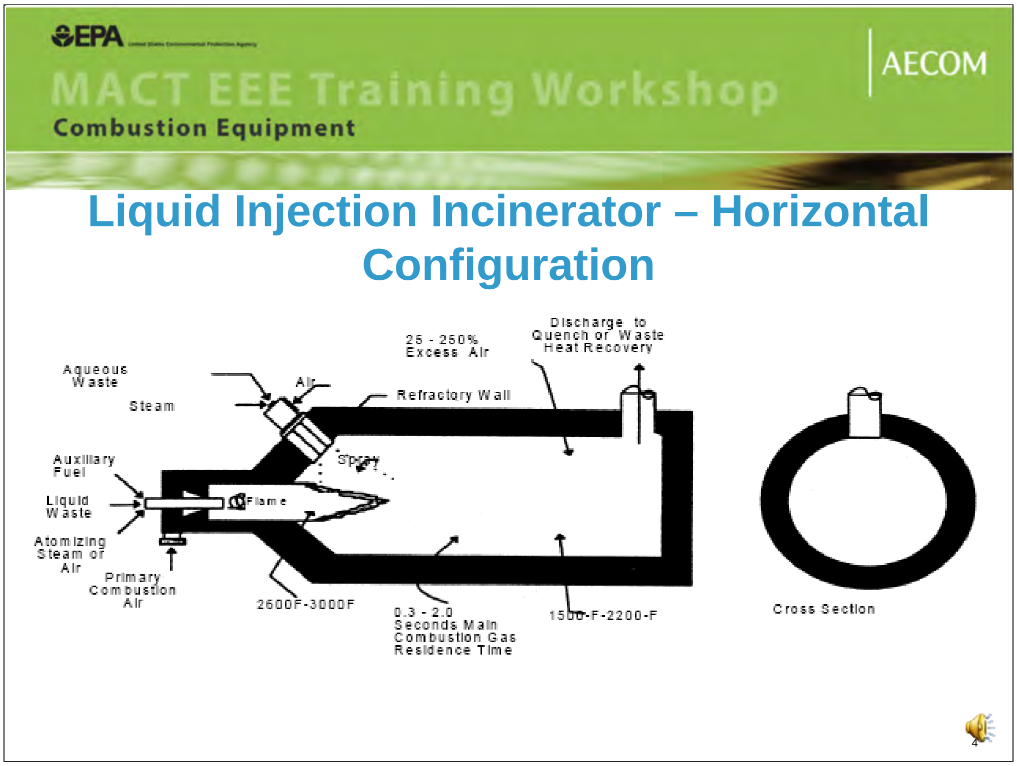
Presentation Overview

- Liquid injection incinerators
- Rotary kiln incinerators
- Starved air incinerators
- Fluidized bed incinerators
- Multiple hearth incinerators
- Boilers
- Cement and light weight aggregate kilns
- Other combustion systems

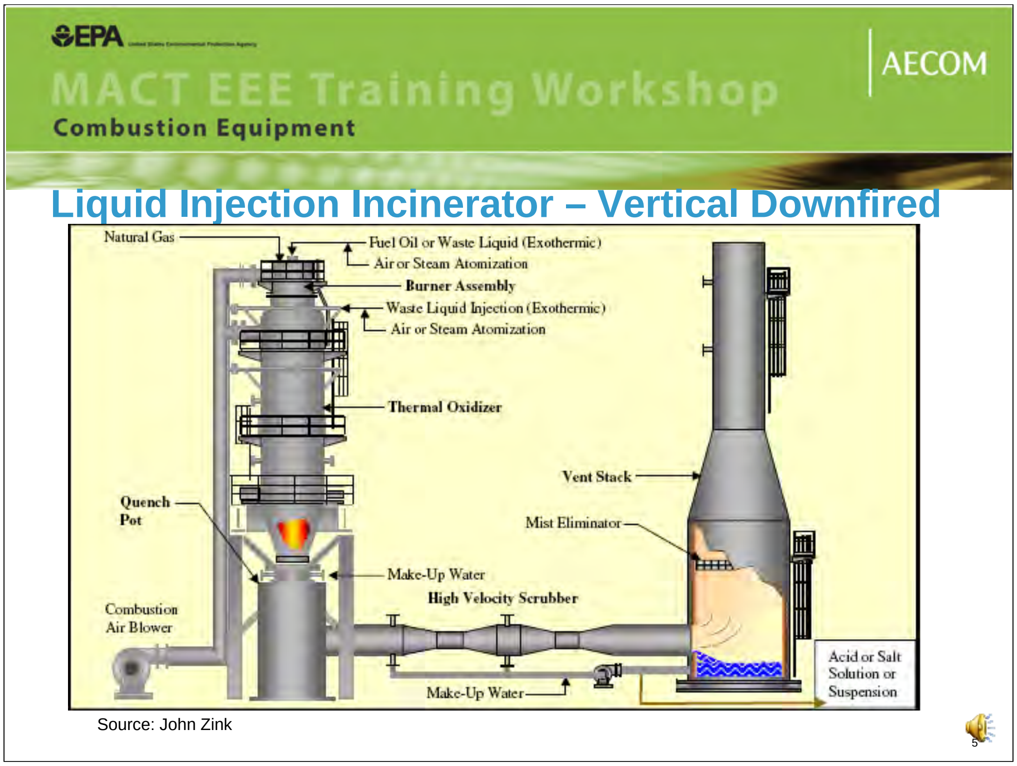
The technologies that will be discussed in this module are: Liquid injection incinerators; Rotary kiln incinerators; Starved air incinerators; Fluidized bed incinerators; Multiple hearth incinerators; Boilers; Cement and light weight aggregate kilns; and Other combustion systems.



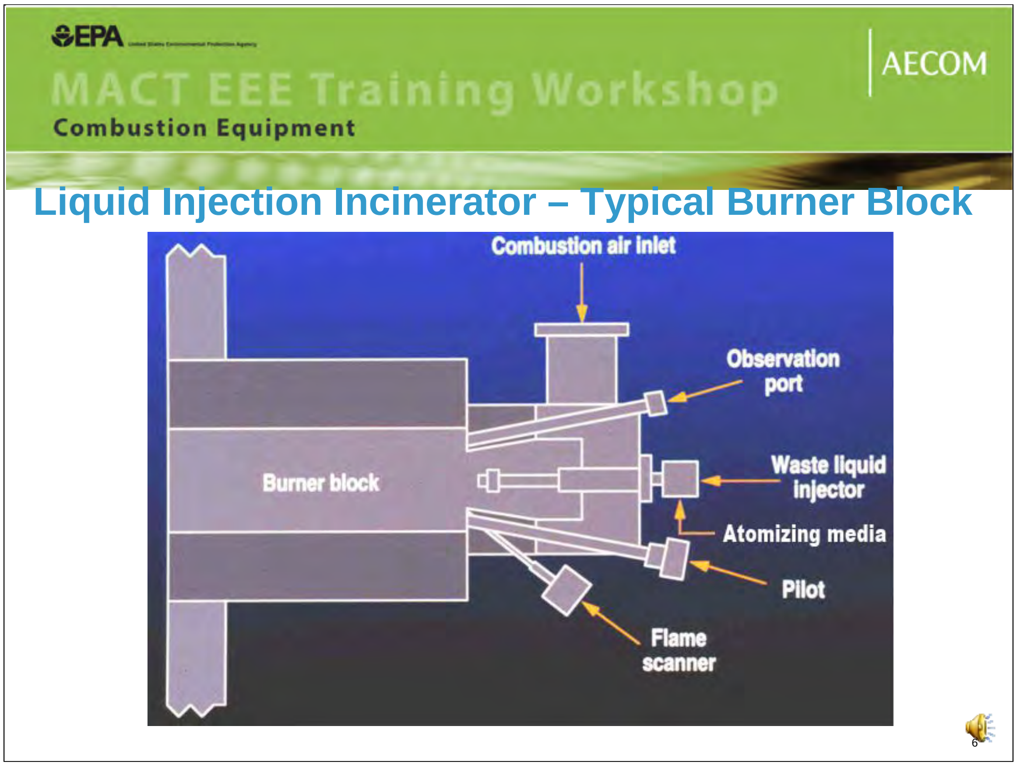
Liquid injection incinerators are very common across the industry and as discussed in the previous module, are typically designed for specific waste streams. They can have single or two stages of combustion, depending on the designed and be equipped with a variety of different material or energy recovery. There are three basic configurations of liquid incinerators. They can have vertical combustion chambers that are either fired from the bottom (up-fired) or fired from the top (down-fired) or their combustion chambers are horizontally oriented and are fired from one end.



This slide shows and example of a refractory lined, horizontally fired liquid injection incinerator. In this graphic, waste (generally organic waste) is shown being injected into the combustion chamber from the left side, along with auxiliary fuel and combustion air. Atomizing air or steam is injected along with the waste to break it up into droplets and combustion air is also provided. Wastes with higher water content are often injected into the combustion chamber at a point typically somewhat further down the combustion chamber so that they interact with the primary flame. Combustion chambers 10 to 20 feet in diameter and 20 to 30 feet in length are common with the primary flame often occupying a good portion of that volume and burning at temperatures of a couple thousand degrees Fahrenheit. Bulk gas temperature is generally 1,000 degrees less than flame temperature and residence time can vary depending on performance needs. Hot gases are discharged from the primary combustion chamber as shown and are either further treated in a secondary combustion chamber or they pass into the air pollution control section of the unit.

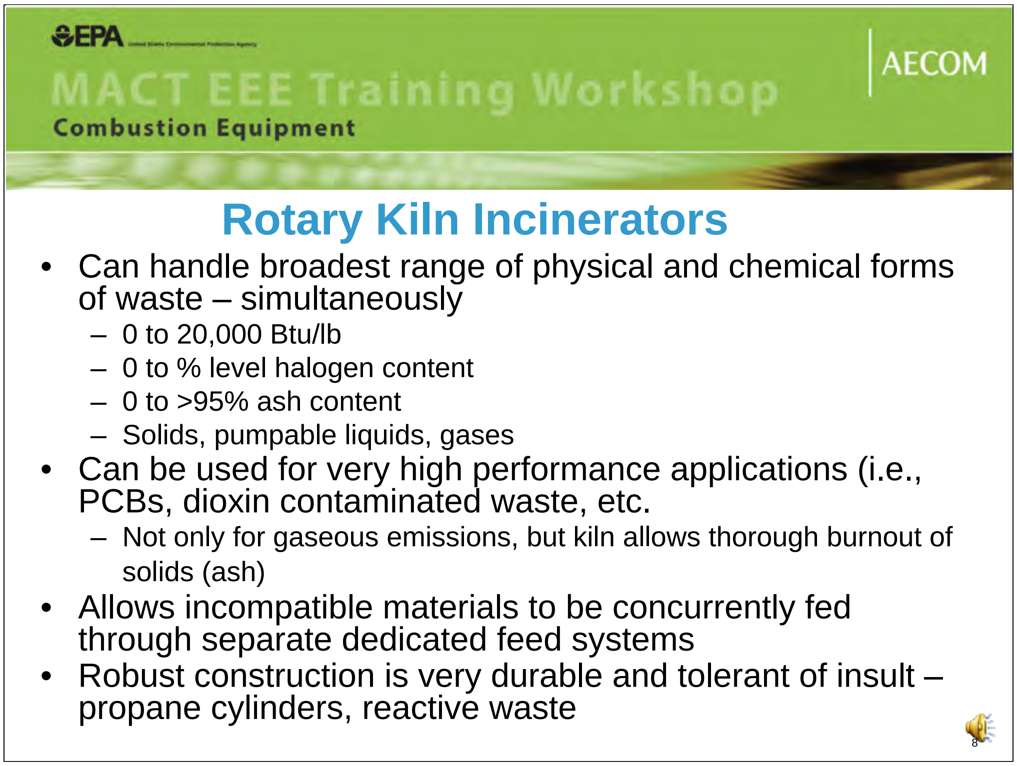


This slide depicts a liquid injection incinerator that has a vertically oriented combustion chamber that is down-fired. Wastes are fed in similar fashion as described in the previous slide except that the burner assembly is mounted on the top. These units are often configured with a quench chamber immediately below the combustion zone that rapidly cools the hot gas stream to around 200 degrees F. The location of the quench chamber right below the combustion chamber allows these units to treat waste that has a high salt and halogen content where the quench water can be used to separate out these materials from the flue gas stream to facilitate their treatment.

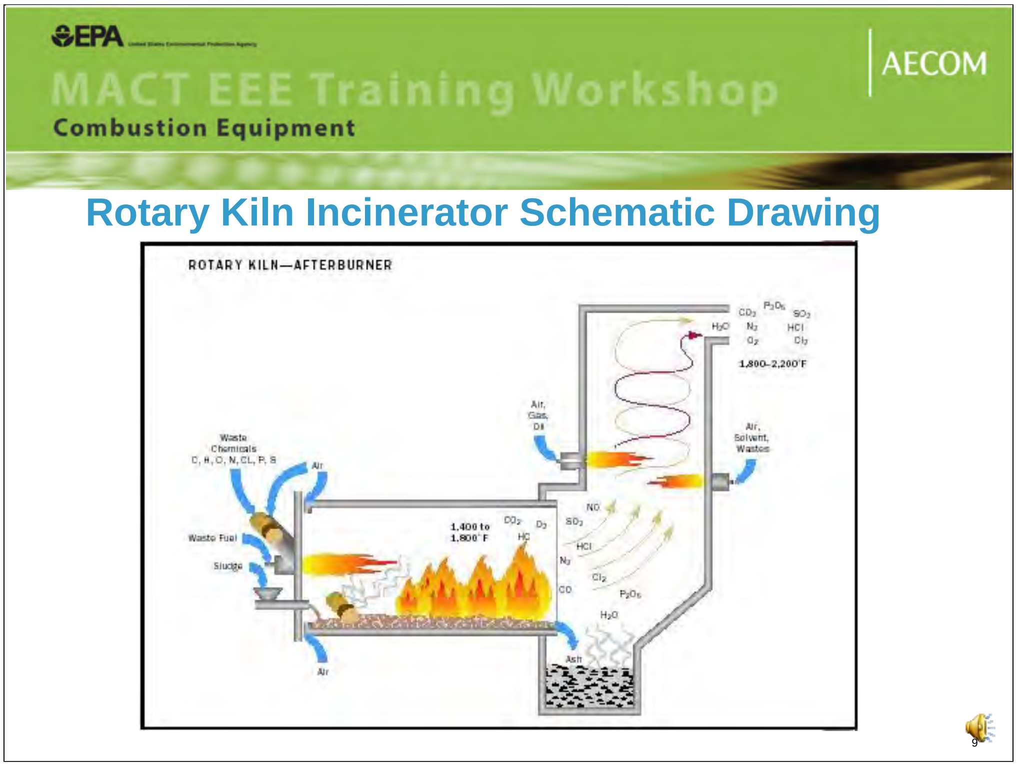


Virtually all combustion systems that fire liquid or gases are equipped with burner blocks similar to the one shown in this slide. This type of burner block is recessed in that the flame actually burns in a smaller chamber first and then flame enters the combustion chamber. Other types of burner blocks can be surface mounted so that the entire flame burns in the combustion chamber. Start-up begins by igniting a smaller pilot flame that is then used to ignite the main burner where the liquid waste is then fed. Combustion air is feed at the appropriate rates to sustain combustion. The flame would burn from right to left in this graphic. Once the burner and combustion chamber are operating properly and at the correct minimum temperature, the liquid waste can be fed. This is injected through an inner feed line that is inside a larger diameter atomizing pipe. The two concentric pipes come together at the “nozzle” (shown in about the center of the graphic) which has a center hole through which the waste is fed. The nozzle also has multiple slots or circular perforations around that center hole that allows the atomizing air or steam to be introduced into the liquid waste right at the nozzle’s tip. The slots or perforations are sized and oriented so that the atomizing air or steam discharges at a high pressure from the couple dozen holes in the nozzle and acts to break up the liquid stream into small droplets. This “atomization” is an essential to assure good combustion as the smaller droplets are more quickly vaporized in the flame than a single non-atomized stream would be. Burner blocks are also typically equipped with observation ports for direct viewing of the flame and with either infrared or ultraviolet wavelength flame scanners that are essential safety interlocks. Neither auxiliary fuels or waste fuels can be fed unless the flame scanner senses flame except for a pre-set period of time during initial light-offs. Typical burner management programs allow only a limited number of light-off attempts, which if unsuccessful, must be followed by an air purge cycle to assure that any build-up of gas or other fuel (from the failed attempts) is purged from the combustion chamber prior to attempting another sequence of light-off attempts.

Moving on to rotary kiln incinerators and as discussed in the previous module, these units are extremely versatile and robust. Capable of processing large quantities of a variety of wastes at the same time, these units also require extensive support infrastructure and staffing. Extensive waste receiving facilities are needed on the front end to properly receive, manage and feed the variety and volume of wastes for treatment. In addition, air pollution control systems can be extensive as well, since these units are designed to treat broad range of wastes. This in turn, depending on whether the APC equipment is wet or dry, may require fairly extensive supply (i.e., clean water treatment) and possibly wastewater treatment systems as well. It is not uncommon for units like these to require several dozen staff for round-the-clock operation. Rotary kiln systems also utilize a large induced draft fan, or possibly multiple ID fans to pull flue gases through the entire system and maintain a vacuum on all upstream equipment.



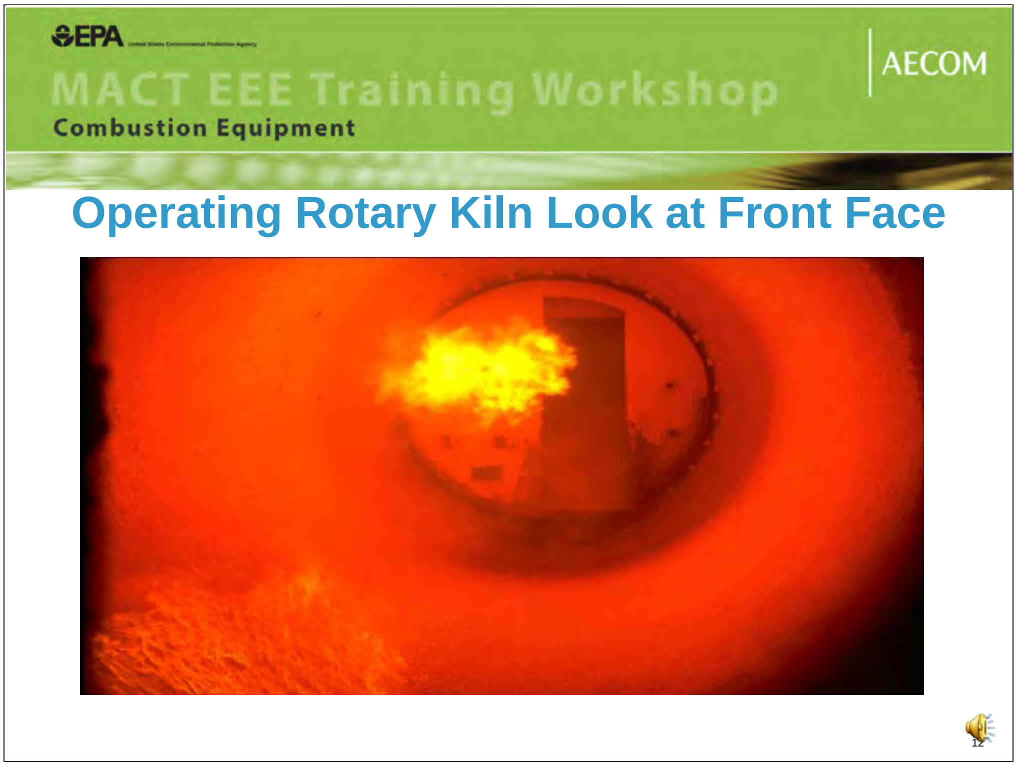
From a waste handling perspective, physical form and composition can vary broadly. It is not unusual for these facilities to have several thousand different approved waste streams and be receiving several dozen different wastes at any one time. Based on wastes received and cleared for processing, operations staff then feed multiple waste streams concurrently according to waste composition to maintain consistent operations and compliance with requirements. Rotary kilns can be used for treatment of PCBs and dioxin containing waste and with the kiln itself, can achieve meet not only emissions limits but also assure very thorough burn out of solids. In addition, wastes that would otherwise be incompatible if they were mixed together, can be fed concurrently through their own separate dedicated feed systems. And finally, due to their construction and design, rotary kilns can also handle difficult materials such as small propane cylinders and reactive lab waste.



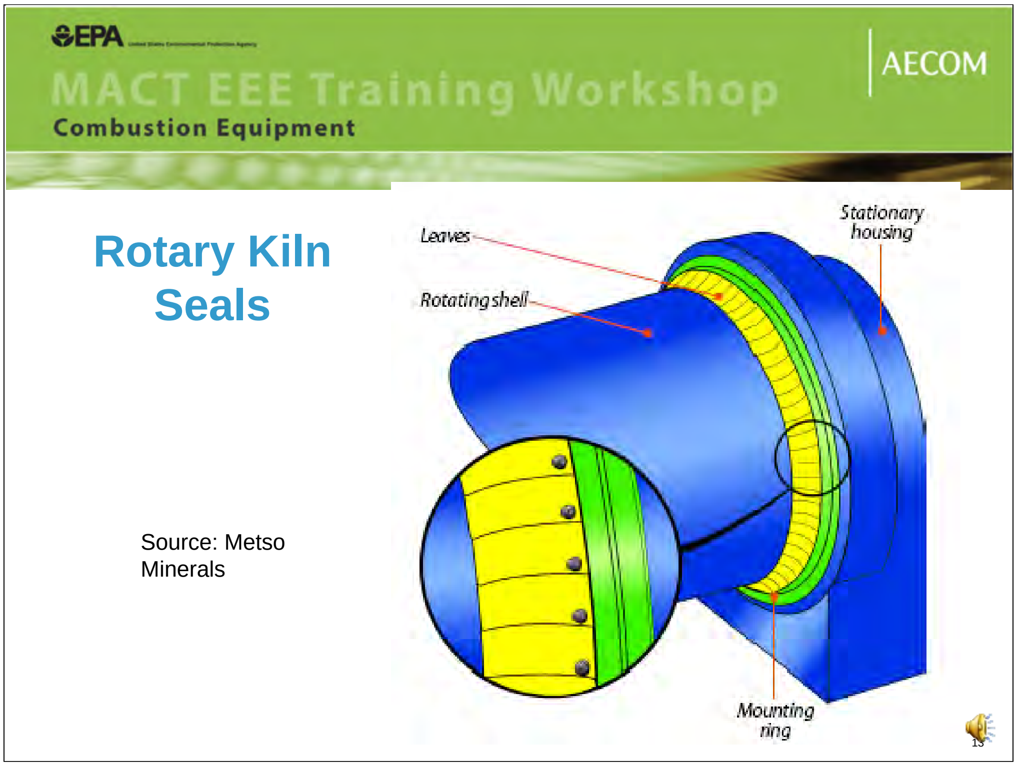
This graphic depicts a cross section of a typical rotary kiln on the left connected to a secondary combustion chamber or afterburner on the right. The kiln is the primary combustion chamber these are generally 10 to 15 feet in diameter and 40 feet or so long, although there are 60 foot long kilns. Wastes are fed in multiple locations to the front of the kiln on the left, solids are tumbled towards the discharge end of the kiln as the kiln rotates at several revolutions per minute. Organics are volatilized out of the solid waste and burned out ash falls off the end of the kiln into either a wet or dry ash handling system, while the volatilized organics pass into the afterburner where their combustion is completed using additional burners mounted in the afterburner that can fire waste and/or auxiliary fuels. Hot gases exiting the afterburner pas into the air pollution control section of the system for additional gas clean-up.

This slide actually depicts a transportable rotary kiln unit being used for a soil treatment project, but its configuration and features are common to many units of this type. The feed end is on the right just below the conveyor and the discharge end is on the left. In order for the kiln to rotate there are two "riding rings" that are affixed on the outside of the kiln itself. These roll on bearings located just underneath each riding ring. In addition, a large horsepower motor, shown in the center of the kiln on the front, drives the kiln rotation through the "bull gear", which goes entirely around the center of the kiln. Depending on how hot the kiln is actually operated, back-up ability to turn the kiln is often provided as in some units, particularly those that run in slagging mode at higher temperatures, must rotate to avoid overheating the crown of the kiln and possibly cause warping of the steel shell.

This picture is taken inside a rotary kiln just after it has been re-lined with new refractory. This shows the “front face” of the kiln, liquid nozzles and the feedchute for feeding solids, which is stationary, and the first several feet of the circular kiln on the right of the picture. Kiln re-bricking can take a week or more depending on how extensive the work is. Old, damaged refractory must first be removed, typically with jack hammers and intense manual labor once the unit has cooled sufficiently to allow workers inside. Then, once old materials is cleaned out, new brick or other types of refractory (like gunnite or castable refractory) can be installed. As can be seen here, brick shapes vary widely and are purchased that way, and also typically, many installations must custom cut the bricks to shape. The different color brick in this picture is indicative of differences in composition. It is not unusual for several different refractory materials to be used in a single unit based on different physical and chemical resistance properties that need to be addressed.

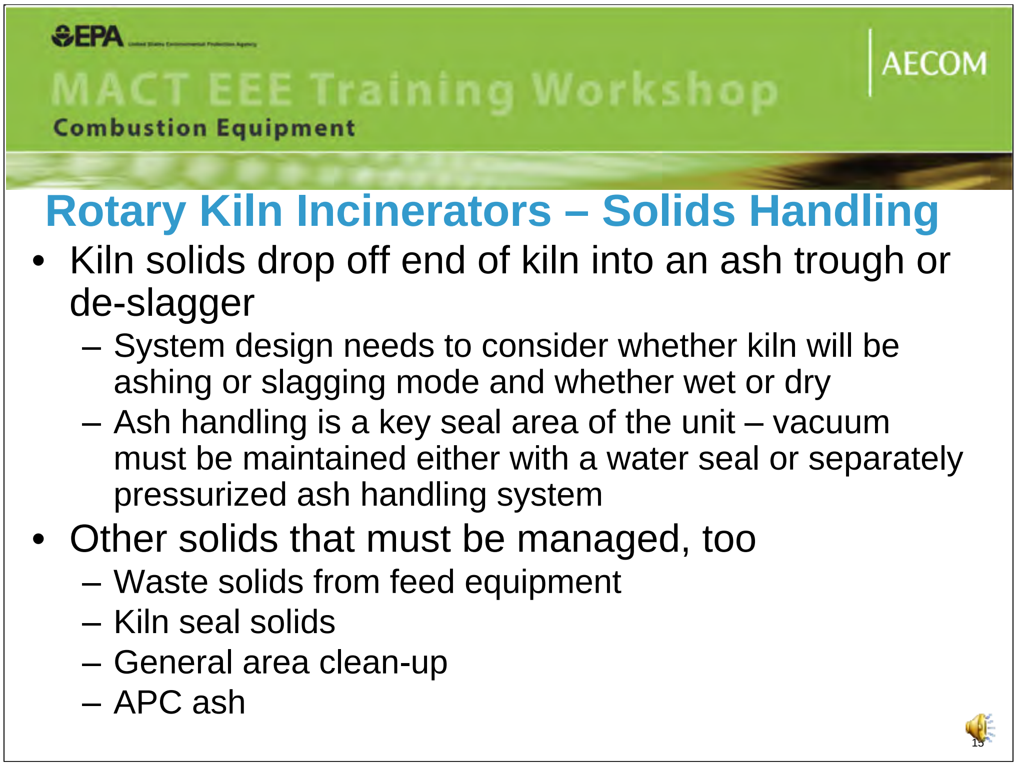


This picture is taken through a viewing port located just beyond the discharge end of a rotary kiln looking at the front face. The flame on the left is from a main front face mounted burner and for a sense of scale is approximately 4 to 5 feet in diameter and 10 to 20 feet long. Front face features can also be seen – the feed chute just to the right of center, two liquid waste nozzles on the right and a rectangular combustion air duct on the lower left.



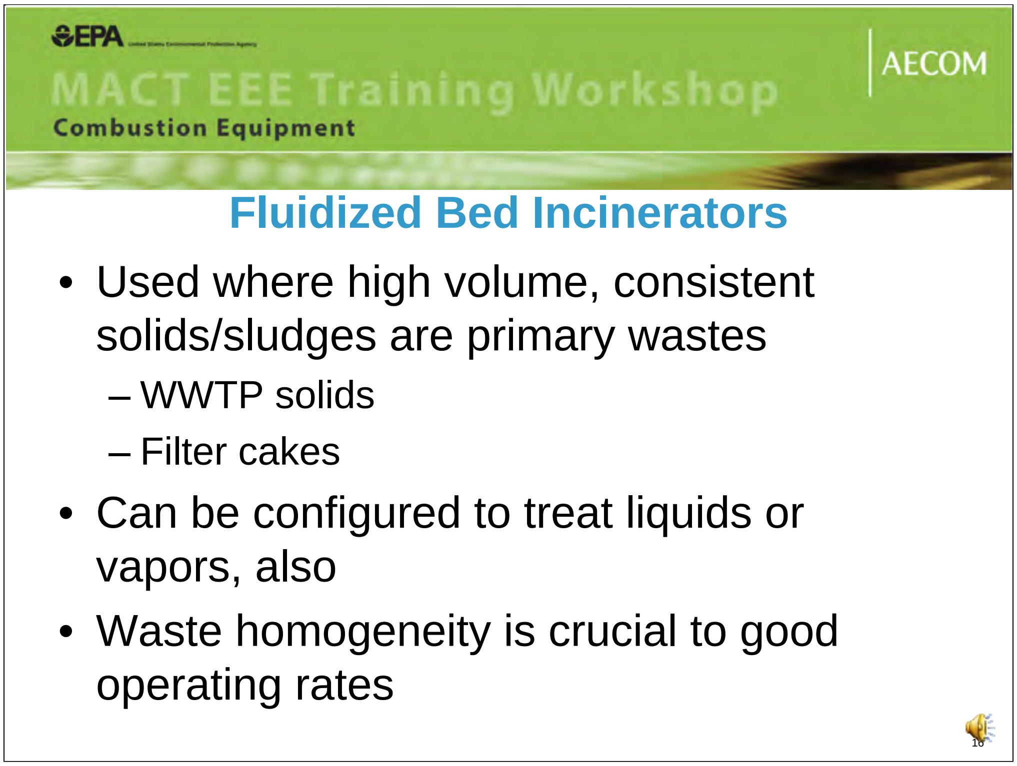
Another important feature of proper operation of a rotary kiln is the ability to minimize and control fugitives at the feed and discharge ends of the kiln where the rotating kiln meets the stationary structures at either end. This is typically accomplished with some type of kiln seal system such as is shown here. The leaves show in yellow are overlapping steel plates mounted on the stationary wall adjacent to where the kiln meets up with it. The leaves are flexible and installed so that they exert pressure on the outside shell of the kiln. This system provides a good mechanical seal around the kiln at each end. There are also other seal systems in use in the industry that are equally effective.

Switching now to summarize waste feed systems, this slide shows and typical container feed system. In this example, 55 gallon steel drums are being fed, but containers can vary in size and shape (typically from several gallon up to 85-gallon overpacks) depending on the availability of containers, incinerator packaging requirements and handling limits. This picture shows a roller type conveyor that is moving the drums from right to left. The caged area is a lift system where the containers are lifted to the top of the feed chute to then be fed. Typically, drums are fed through a double door air lock or similar one at a time so that proper vacuum can be maintained in the kiln. Facilities either utilize bar code systems and scanners or manually record waste information so that adequate records can be maintained for feed documentation and compliance.

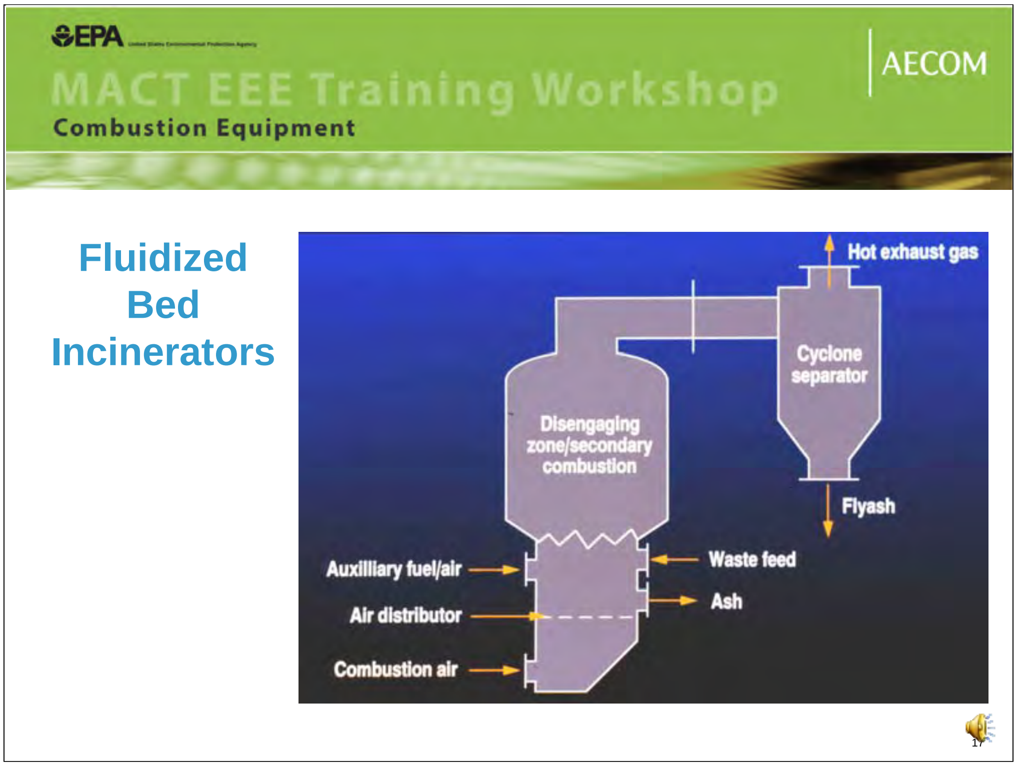


Rotary Kilns can generate several different types of solids streams that must be properly managed and are typically landfilled in Subtitle C landfills. Generally, the largest solids stream that is generated is incinerator ash that is generated from the kiln itself. This hot ash falls off the end of the kiln and is collected in either a dry or wet ash handling systems. Kilns can be operated in either "ashing" or "slagging" mode and that typically dictates the type of ash handling equipment used. Ash discharge systems must be designed so that they maintain a vacuum around where the ash exits the system. "Ashing" mode is a cooler kiln temperature that allows solids to be adequately burned out prior to disposal, but stays below the melt point of the ash. Dry ash systems can be used in this case so long as the design ensures that vacuum is maintained around the ash discharge equipment. This is typically don with some type of airlock arrangement on the ash discharge. We de-slagging systems are often used when the kiln operates in slagging mode – that is above the melt point of ash. In this situation, the ash liquifies and discharges off the end of the kiln as a hot, molten stream. Use of a water bath directly below this discharge point allows the slag to be quickly quenched and also provides a water seal to maintain vacuum in the combustion unit.

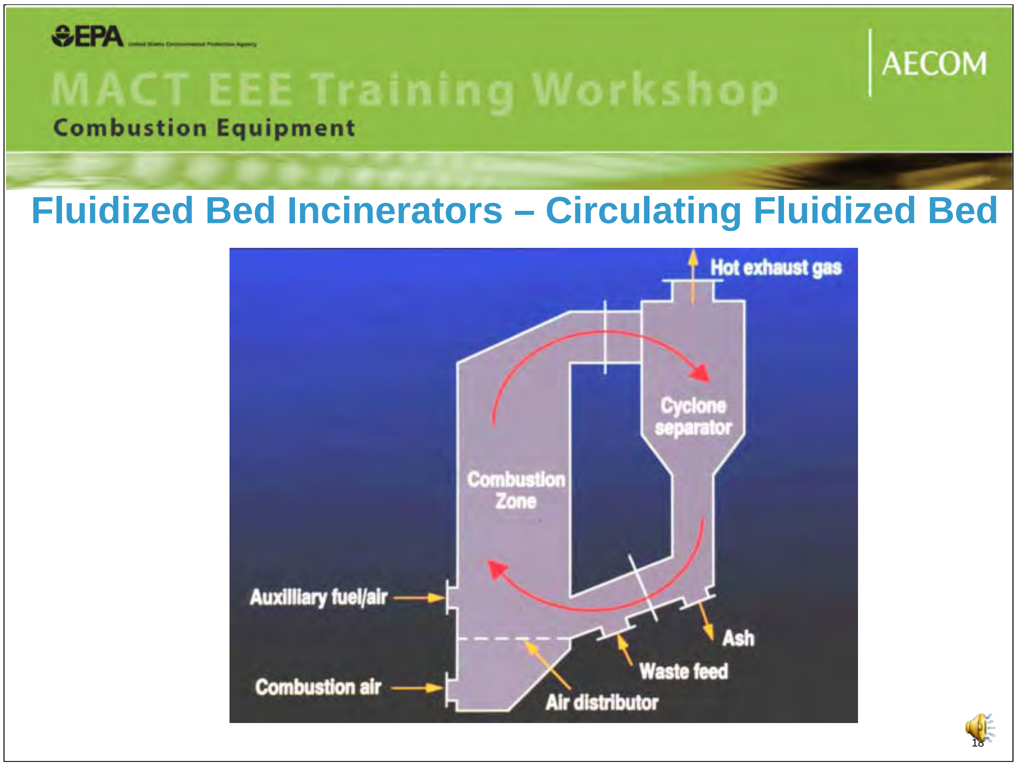
Rotary kilns also typically generate additional solids from several different areas of the unit. Bulk solids must be manage carefully to minimize fugitives and tracking out of these materials from handling areas by the heavy equipment used in moving it around. In addition, even with well designed and operated kiln seal systems, provisions for solids handling around the front and discharge kiln ends needs to be make. Also, some type of ash (e.g., fly ash) is typically generated in the various APC devices used for emissions control. And finally, good housekeeping is always important at an operating Subpart EEE rotary kiln and general area clean-up is an ongoing activity.



The next several slides discuss fluidized bed incinerators. As the name implies, a fluidized bed incinerator utilizes a high volume, high velocity air stream which is blown in from the bottom of the unit to suspend or fluidize waste in the combustion zone where it is combusted. Fluidized bed incinerators are an excellent technology for handling predominantly solid or sludge type waste streams that are relatively consistent and homogenous physically and that will lend themselves to this fluidizing process. In situations where waste composition varies, it must first be blended and processed so that a relatively consistent stream can be fed to the unit. Besides processing solids, liquid wastes and gases or vapors can also be configured to be treated in this technology.



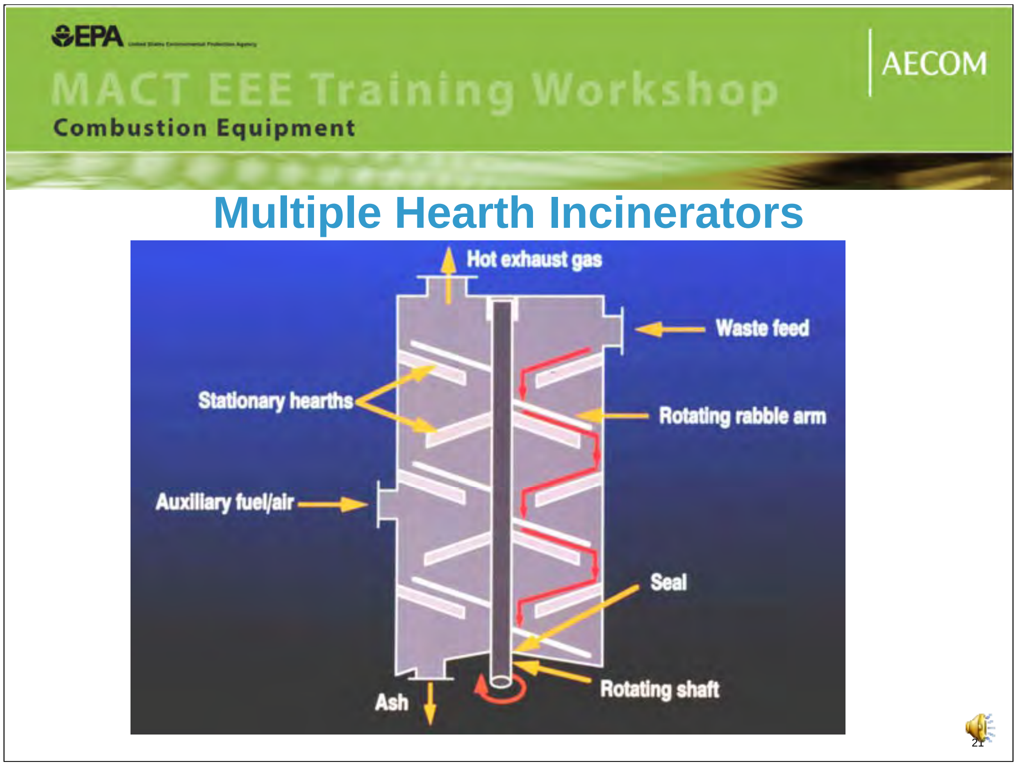
This slide shows a graphic of a typical fluidized bed unit. Combustion air is forced upwards through a distribution system the creates a high velocity stream capable of suspending waste in the combustion zone shown above. Although not shown in this graphic, burners are mounted in the combustion zone to maintain the temperatures needed for the bed itself to burn. Flyash is carried over into either a recirculating chamber (see the next slide) or removed as shown above in a cyclone type incinerator. Hot combustion gases are then processed further in the downstream air pollution control equipment.



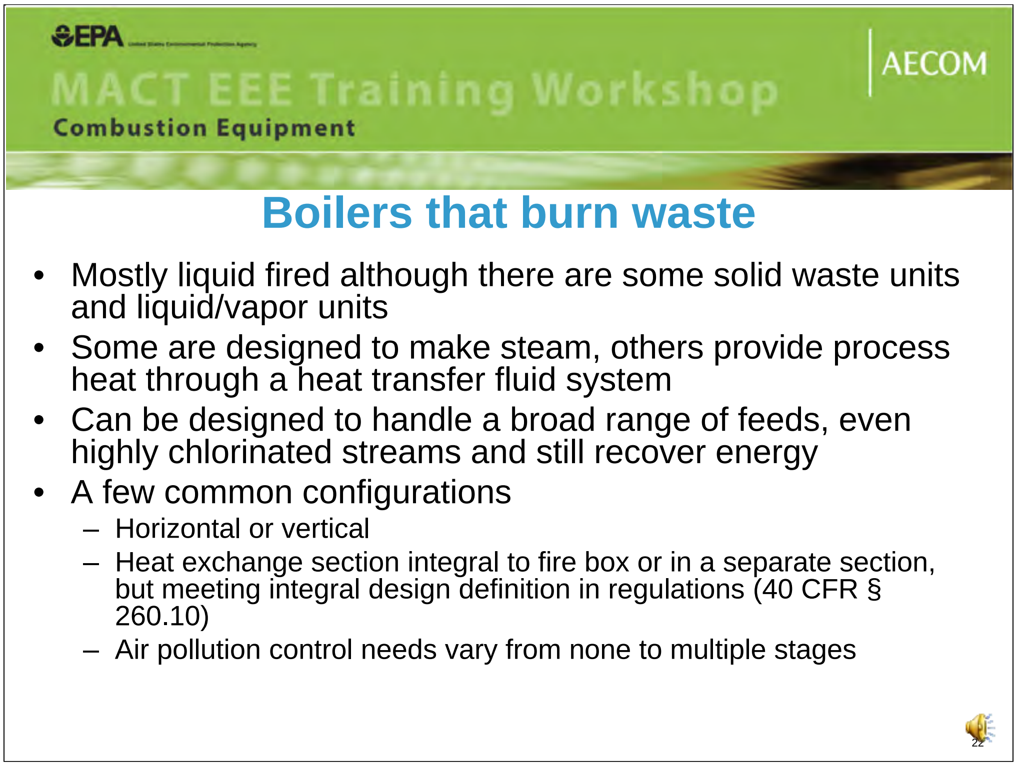
As mentioned in the previous slide, this graphic depicts a recirculating type fluidized bed.

This graphic depicts a cross section of a fluidized bed system showing its air distribution system. Combustion air enters the unit at the very bottom and is forced through the many small diameter pipes or "tuyeres" where the air then increases significantly its velocity as it enters the main chamber, enabling the combustible bed above it to be suspended or fluidized.

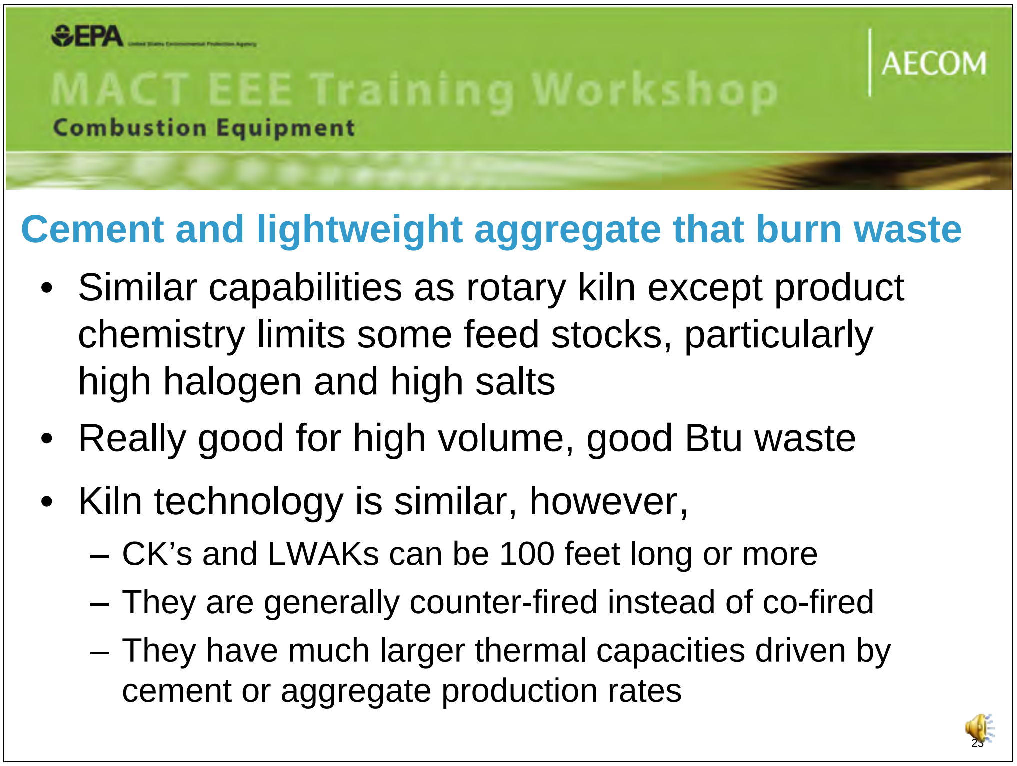
This graphic shows a close-up of the tuyere arrangement.



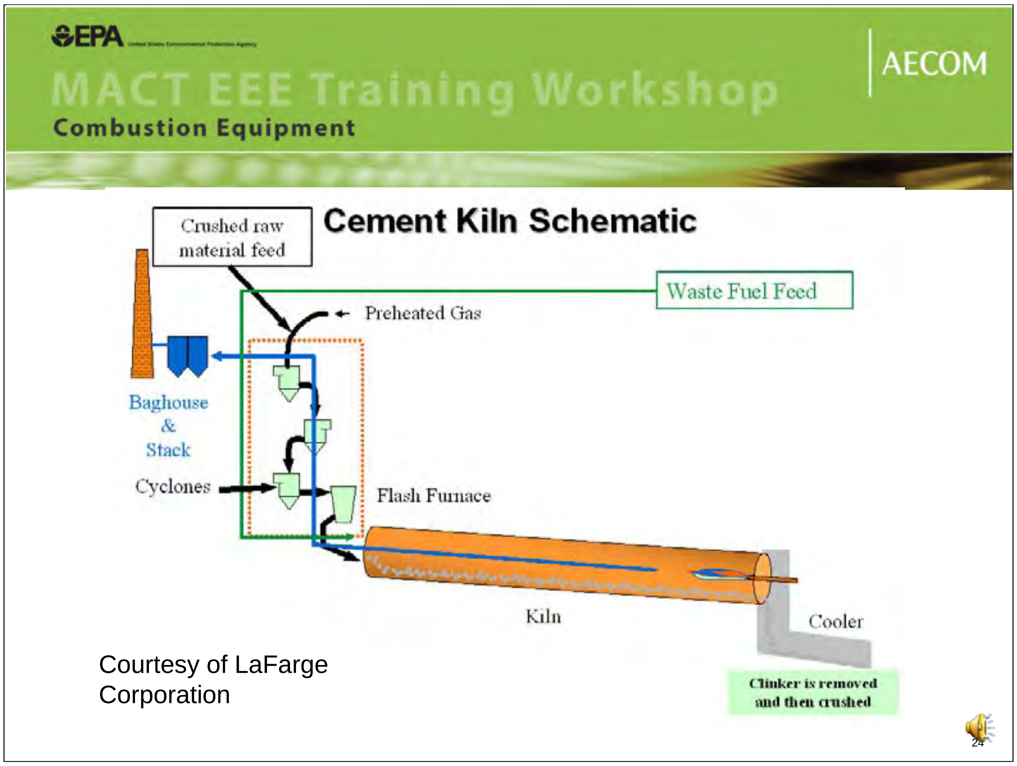
Another type of combustion technology that may be used to handle solid wastes under Subpart EEE is a multiple hearth incinerator. In this technology, waste is introduced ate the tope where it is raked with a rotating rabble arm and tumbles down from hearth to hearth. Hot combustion gases flow in a countercurrent fashion to burn the waste or volatilize organic components is it moves downward. Hot exhaust gases exit from the tope and depending on their organic composition, can be further combusted in a secondary combustion chamber or can be treated in the APC.



As discussed in the previous module, many types of boilers can be configured to burn waste in addition to traditional fossil fuels to produce steam or provide process energy through a heat transfer fluid. There are two primary types of boilers – water tube boilers and fire tube boilers. Both have a combustion chamber where fuels or waste are burned to generate hot flue gas. Both types have a heat exchange section typically comprised of a series of piping or “tubes” to heat the water or transfer fluid. The difference between the two is that in a water tube boiler, water is carried inside the tubing while in the heat exchange section of a fire tube boiler, the hot flue gas is carried inside the tubing and heats the water in the steam drum around it. Most units operating today are liquid fired however, there are solid waste processing boilers and some that burn a combination of liquid waste and process vapors. Units can be both horizontally or vertically oriented with heat exchange sections adjacent to or mounted above the actual combustion chamber. Waste fuels being burned must generally have reasonable heat content although some chlorinated streams with only moderate heat content can still be used for energy recovery.

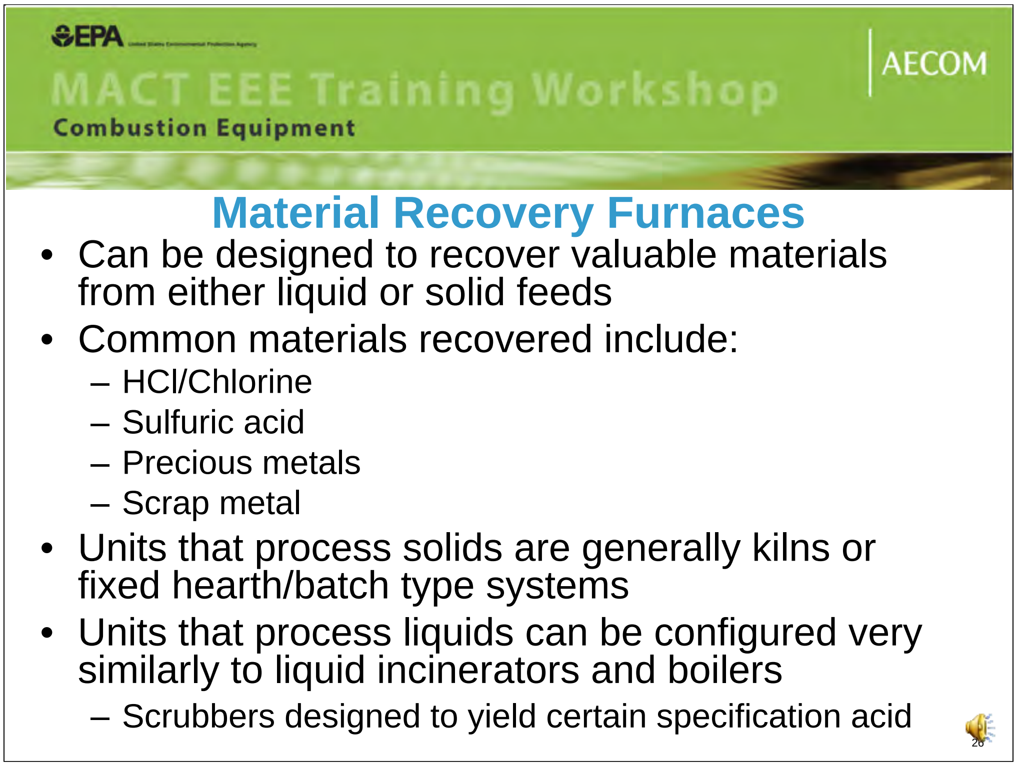


Cement kilns and light weight aggregate kilns look very similar to rotary kilns but are often larger, occupy bigger foot prints and are more costly to build and operate. Also, operating temperatures in the kilns themselves can be as much as 2,000 degrees F hotter in order for the product chemistry to occur. Because of the large fuel demands for manufacturing the cement clinker or aggregate, high volume, high Btu waste streams are very desirable for combustion in these type of units and this can actually offset or reduce their operating costs. These types of units are generally limited in their ability to handle halogenated wastes and high salt containing waste due to impacts on refractory and product quality.



This graphic depicts a typical cement kiln. These units are typically counter fired, that is raw material and sometimes certain solid waste is fed into the "cold" upper end of the kiln and makes its way down towards the hot fired end. Liquid wastes are typically fed along with other fossil fuel into the hot end. Combustion gases pass from right t left in this picture and are treated in the APC.

In addition to feeding waste at the hot end and sometimes, the cold end, technology has been developed to introduce containerized waste mid kiln where is fed directly into the hot solids bed. This graphic shows a cross section of that injection system which is permanently mounted on the kiln and as it rotates, it collects a container which is then injected through an air lock door when this system is at the top of its rotation.

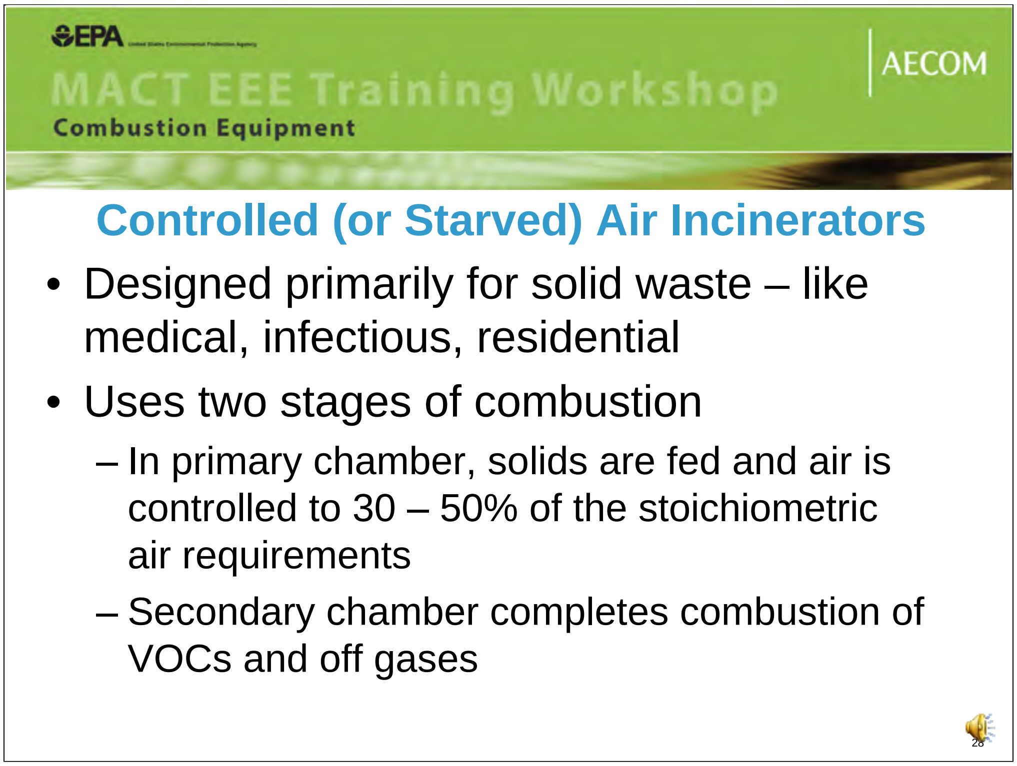


Material recovery technologies are another application the utilize combustion to recover valuable materials from either solid or liquid hazardous wastes. Acids, metals, such as silver and lead and other scrap metal like steel scrap are examples of materials that can all be recovered. Kilns and batch type fixed hearth units can process waste materials where recovered materials are generally collected from the bottom ash from their combustion. Liquid injection incinerators processing wastes containing sufficiently high concentrations of chlorine and sulfur can utilize wet scrubbing technologies after the combustion chamber(s) to absorb either compound in generally an acid form in water. Recovered acids can then be further concentrated to yield saleable grades of acid.

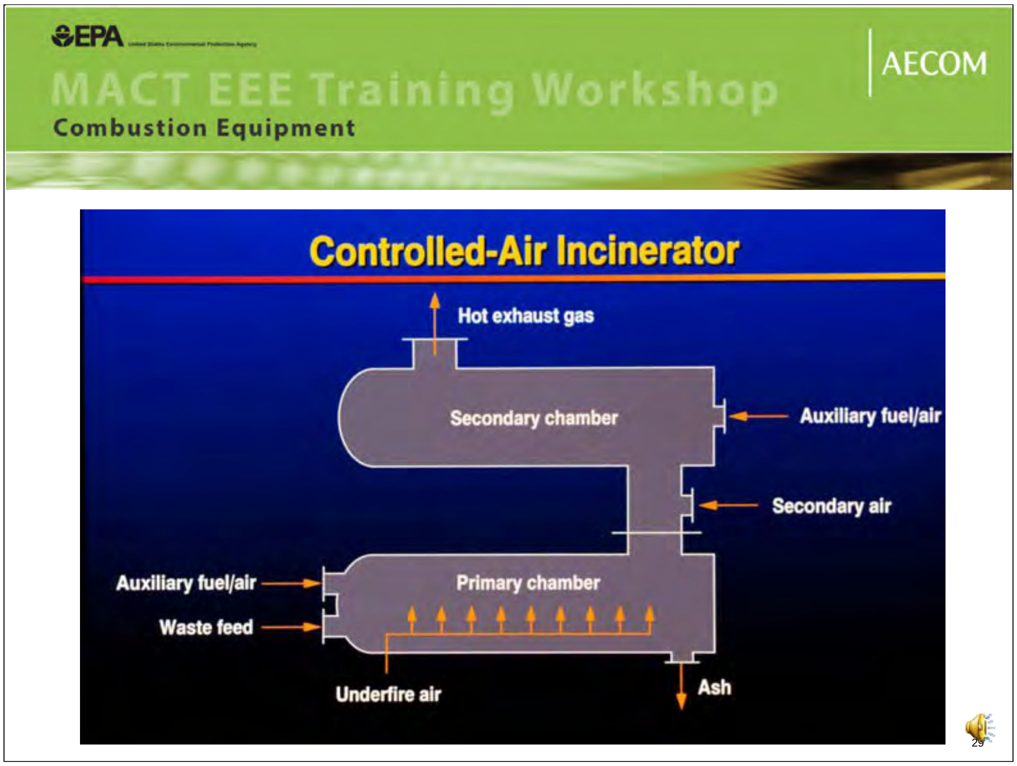
Specialty Incinerators

- Designed and constructed specifically for certain feed types
  - Munitions and energetics
  - Chemical agent
  - Compressed gases
- Material handling of feeds is the greatest challenge from safety standpoint

Traditional incinerator designs can also be adapted for specialized use to manage several different unique waste streams such as munitions, energetics, chemical agent and difficult to handle compressed gases. The general incinerator types used in these applications can include rotary kilns, liquid injection units and fixed hearth type units. This topic will be addressed in greater detail in module D.4., however, it is important to note that material handling of the incoming waste materials themselves generally poses the greatest challenge from a personnel safety standpoint.



Another type of specialty incinerator is a starved air incinerator which utilizes a primary combustion chamber where less than the stoichiometric amount of air is fed in with the waste. Units like this are often used for medical, infectious or residential waste and therefore are not common in Subpart EEE units, but are worth a mention. Organics are volatilzed off the waste in the primary combustion chamber and a secondary combustion chamber is used to complete combustion.



This slide shows a graphical depiction of a starved air/controlled air incinerator.

Vapor/Fume Incinerators

- Designed for vapor or gas streams – feed systems usually operated to minimize condensate
- Feed concentrations can range from -
  - Fairly dilute (several hundred ppmv)
  - Percent levels
- Sources can include process vapors/gases, tank farm losses, remediation site or landfill offgas
- Several designs, depending on performance requirements and operating (mostly auxiliary fuel) costs
  - Traditional fire box – rich streams, more stringent performance
  - Catalytic oxidizer
  - Regenerative thermal oxidizers

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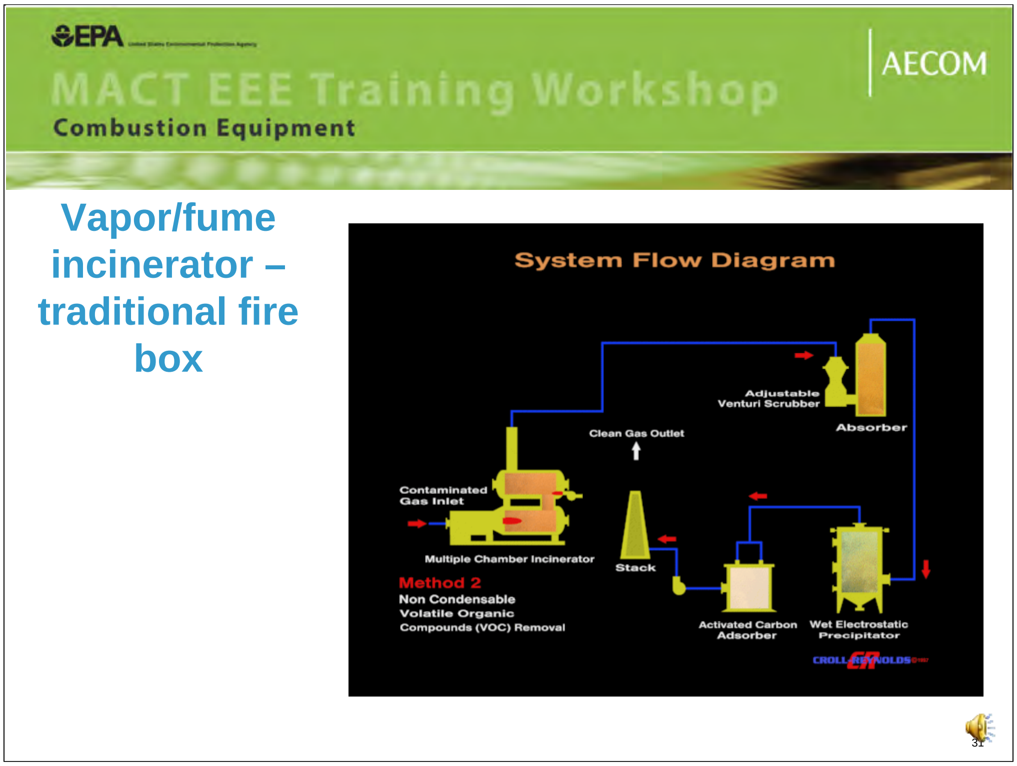
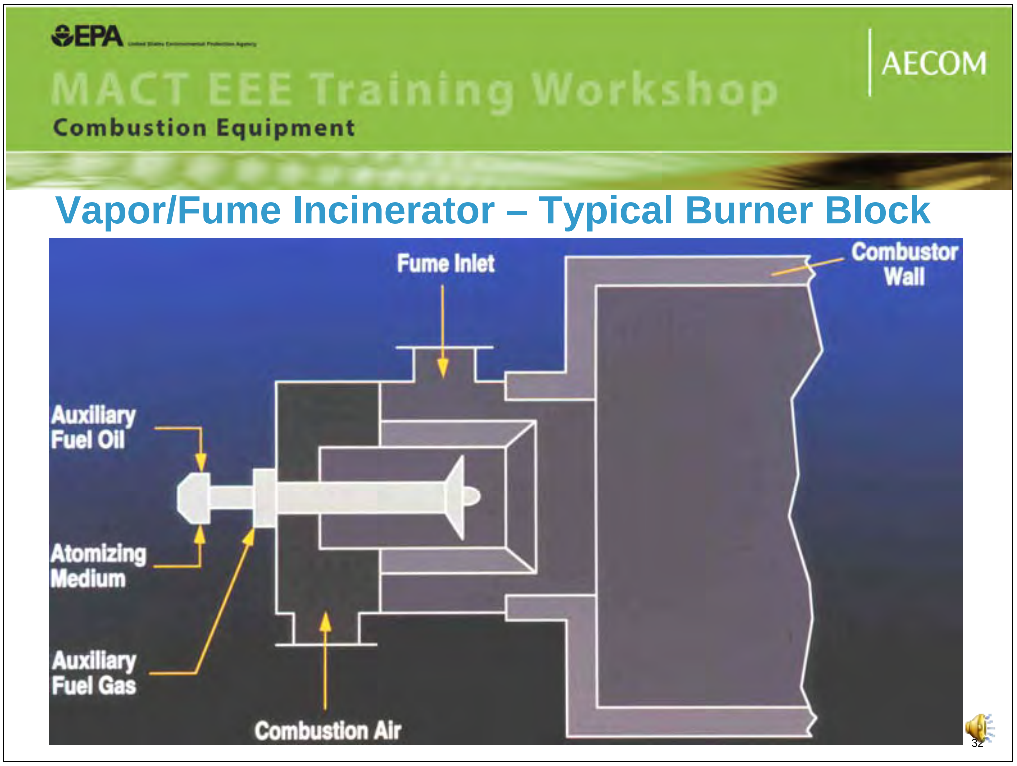
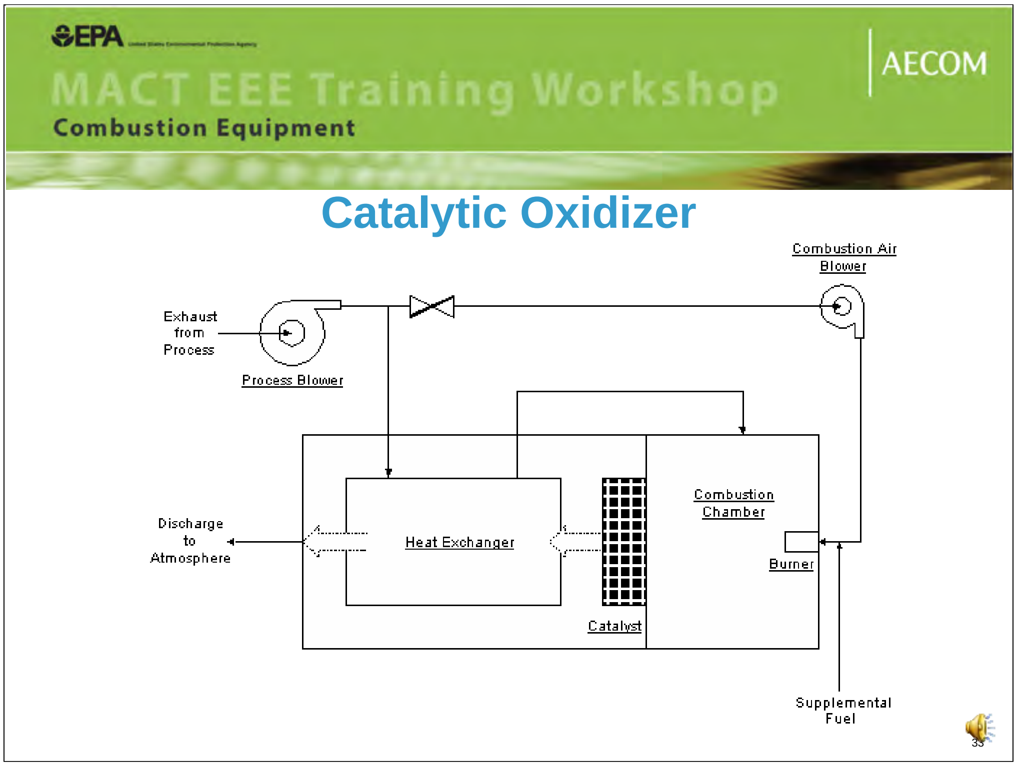
Combustion technologies are also used for non-Subpart EEE use to burn process vent streams from a variety of sources. These units can have a lot of similarities to Subpart EEE, but are typically regulated under other NESHAP or air quality regulations.



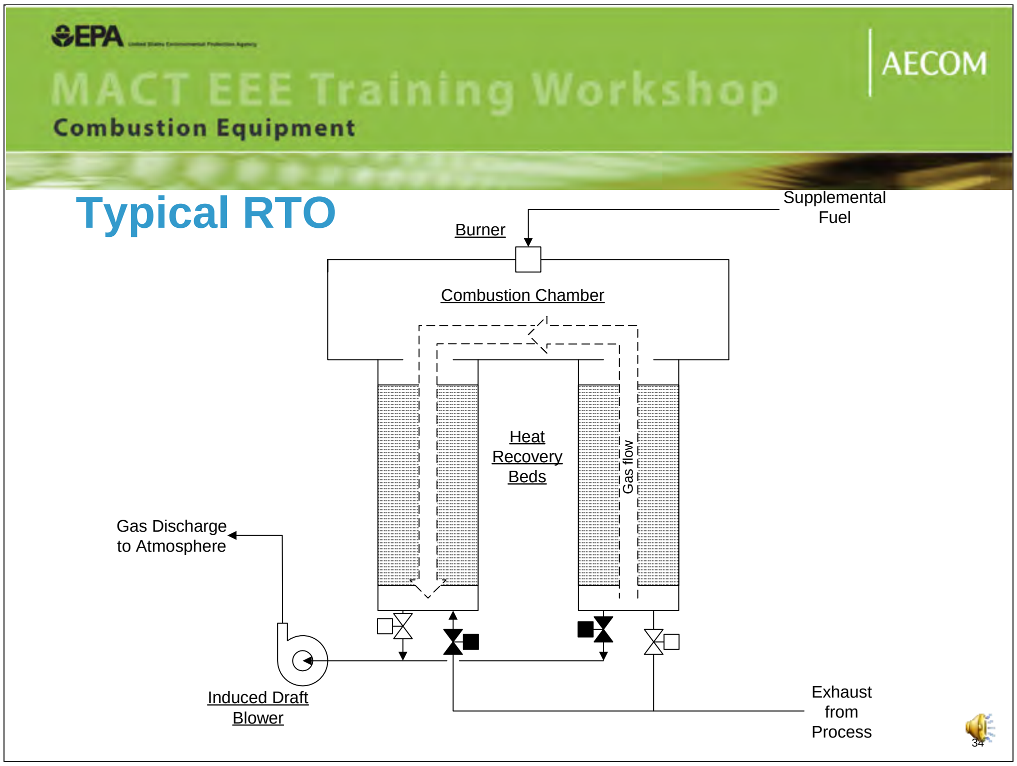
This slide shows a graphic of a traditional fire box design used for vapor/fume incineration.



Burner block designs for vapor/fume combustion can be very similar that used for a liquid waste. This example shows a fuel oil being employed as the auxiliary fuel and as can be seen, atomizing air or steam is being utilized to assure effective combustion of this fuel.



Catalytic oxidizers are another type of vapor/fume incinerator where a catalyst bed is used downstream of the combustion chamber to promote effective oxidation at lower costs than traditional combustion. A heat recovery section allows the process fumes to be preheated as another cost controlling feature of this technology.



Regenerative Thermal Oxidizers or RTOs are another type of combustion unit that is very energy efficient for treating process vapors or fumes. This graphic shows a two chamber design where process vapors enter right chamber and pass through the combustion zone at the top where they are burned. As the hot gases flow through the left chamber, the heat recovery bed is also heated. The white colored valves then close and the black colored valves open allowing the process vapors to then pas up through the heated bed on the left, through the combustion zone and down the right chamber where that heat recovery bed is heated. This cycle is repeated during regular operation so that the process vapors are always preheated, thus conserving energy.

This picture shows and actual two chamber RTO.