



Biosolids Technology Fact Sheet

Use of Incineration for Biosolids Management

DESCRIPTION

Incineration is combustion in the presence of air. Incineration of wastewater solids takes place in two steps. The first is drying the solids, so that their temperature is raised to the point that water in the solids evaporates. The second step is the actual combustion of the volatile fraction of the solids. Combustion can only take place after sufficient water is removed.

Wastewater solids are dewatered to between 15 to 35 percent solids prior to incineration. The incineration process then converts biosolids into inert ash. Sixty-five to 75 percent of the solids are combustible, and thus the volume of ash is significantly lower than that of the original biosolids. This ash can be used or disposed of more readily due to its low volume and inert nature. If solids are dewatered to approximately 30 percent solids and their heat value is sufficient, the process can be self-sustaining, and supplemental fuel is not required to sustain combustion. Nonetheless, supplemental fuel is always needed during initial start-up operations and periodically throughout operations to accommodate fluctuation in feed solids characteristics.

Ash generated by incineration of wastewater solids is usually landfilled, but some facilities use other innovative methods to reuse the ash, including:

- Filler in cement and brick manufacturing.
- Subbase material for road construction.
- Daily landfill cover (must be pelletized first).
- Ingredient in footing at athletic facilities, including baseball diamonds, and equestrian facilities, such as race tracks and arenas.

Two types of incineration systems are commonly used for wastewater solids combustion - multiple hearth furnaces (MHFs) and fluidized bed furnaces (FBFs). Both use high temperatures to thermally process the solids in the presence of air. Because FBFs are generally better at meeting federal emission standards, most new installations use this technology. Some facilities with MHFs incorporate FBF technology to comply with more recent federal regulations. The following paragraphs describe the two systems in greater detail.

Multiple Hearth Furnace Technology

The multiple hearth technology has historically been the most common system used for wastewater solids incineration. MHF systems may be operated continuously or intermittently; however, the costs and energy requirements for start-up and standby are high, making continuous operation preferable. The furnace consists of a refractory-lined, circular steel shell with several shelves (or hearths) and a central, rotating hollow cast iron shaft from which arms extend. Solids are fed onto the top hearth and raked slowly to the center in a spiral path. The solids burn on the middle hearth, producing temperatures in excess of 482°C (900°F). Ash is cooled on the bottom zone prior to discharge.

Solids burning on the hearth release heat and generate a flow of hot gases that rise countercurrent to incoming solids. This countercurrent flow of air and solids is reused to optimize combustion efficiency - while most of the exhaust air is discharged through the hollow central shaft, a portion is piped to the lowest hearth where it is further heated by the hot ash and used to dry the incoming solids. Discharged air is sent through a scrubber to remove fly ash, and is then processed further to meet air permit requirements.

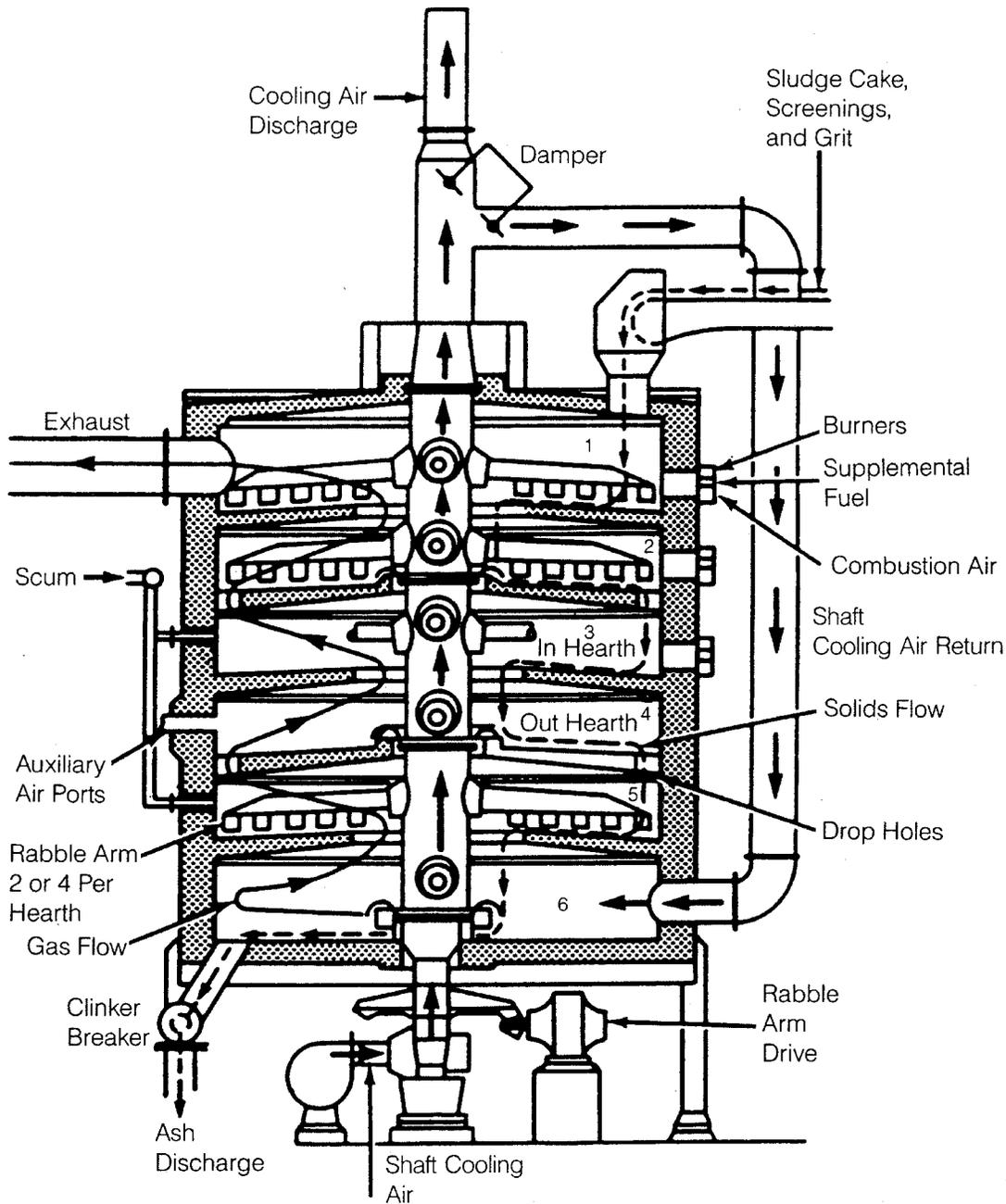
Ash removal at MHFs is accomplished by the rabble arms which push the hot ash on the lowest hearth through a drop out port. Conveyors or pneumatic equipment move the ash either into temporary on-site storage or directly into trucks for transport off-site.

A typical MHF has 5 to 12 hearths, is 1.8 to 7.6 m (6 to 25 ft) in diameter, and 3.6 to 19.8 m (12 to 65 ft) in height. Nine hearths are generally required

for complete combustion of wastewater solids that contain 75 to 80 percent moisture. Figure 1 shows a cross section of a typical MHF.

Fluidized Bed Furnace Technology

Most wastewater solids incineration installations over the past 20 years have been FBFs, which are more efficient, more stable, and easier to operate than are MHFs. Like MHFs, FBFs are vertically



Source: WEF, 1992a.

FIGURE 1 CROSS SECTION OF A TYPICAL MHF

oriented, refractory-lined, steel shell cylinders. The bottom layer is an inert granular material (usually sand) that is kept in fluid condition during operation by an upflow of air. The sand bed, typically between 0.8-1.0 m (2.5-3 ft) thick, serves as a heat reservoir to promote uniform combustion. The bed is preheated to approximately 649°C (1200°F) using fuel oil or gas before solids are introduced. Solids are fed through nozzles into the fluidized sand bed, where solids and heated sands mix. It is here that liquid is evaporated from the solids and the volatile fraction of the solids burns. Temperatures between 760-816°C (1400-1500°F) are maintained in the combustion zone. The overall combustion process occurs in the bed and in the freeboard area while the resulting ash and water vapor are carried out through the top of the furnace. A cyclonic wet scrubber is used to remove ash from the exhaust gases, after which it is separated from the scrubber water in a cyclone separator. Alternately, some plants use lagoons for long-term storage of wet ash and periodically dredge the solids from the lagoon. Plants with limited space use mechanical dewatering equipment, such as a multiclone or bag house, in combination with gas cooling equipment.

Figure 2 shows a cross section of a typical FBF, which is 2.7 - 7.6 m (9-25 ft) in freeboard diameter with a 0.8 m (2.5 ft) thick sand bed.

Air Pollution Control Equipment

Air pollution control is an integral part of any incineration facility. Equipment must be able to control particulate emissions, gases [such as nitrogen oxides (NO_x), sulfur oxides (SO_x) and carbon monoxide (CO)], and other characteristics such as opacity.

Particulates

Particulates, including trace metals, can be controlled through use of mechanical collectors, wet scrubbers, fabric filters, and electrostatic precipitators.

Mechanical collectors have a relatively low control efficiency and usually provide only partial control in a total particulate emissions control system. Mechanical collectors include settling chambers, which use gravity to induce particle

settlement; impingement separators, which cause particles to lose momentum and drop out of the gas; and cyclone separators, in which the incinerator exit gas is forced down a cone of decreasing diameter. The efficiency of mechanical collectors ranges from 50-95 percent for particles larger than 10 μm.

Wet scrubbers are commonly used to remove particulate matter and water soluble air contaminants such as hydrogen chloride, sulfur dioxide, and ammonia. There are several types, but the Venturi scrubber is the most widely used. These systems can remove 90-98 percent of particulate matter as small as 1 μm, depending on operating conditions.

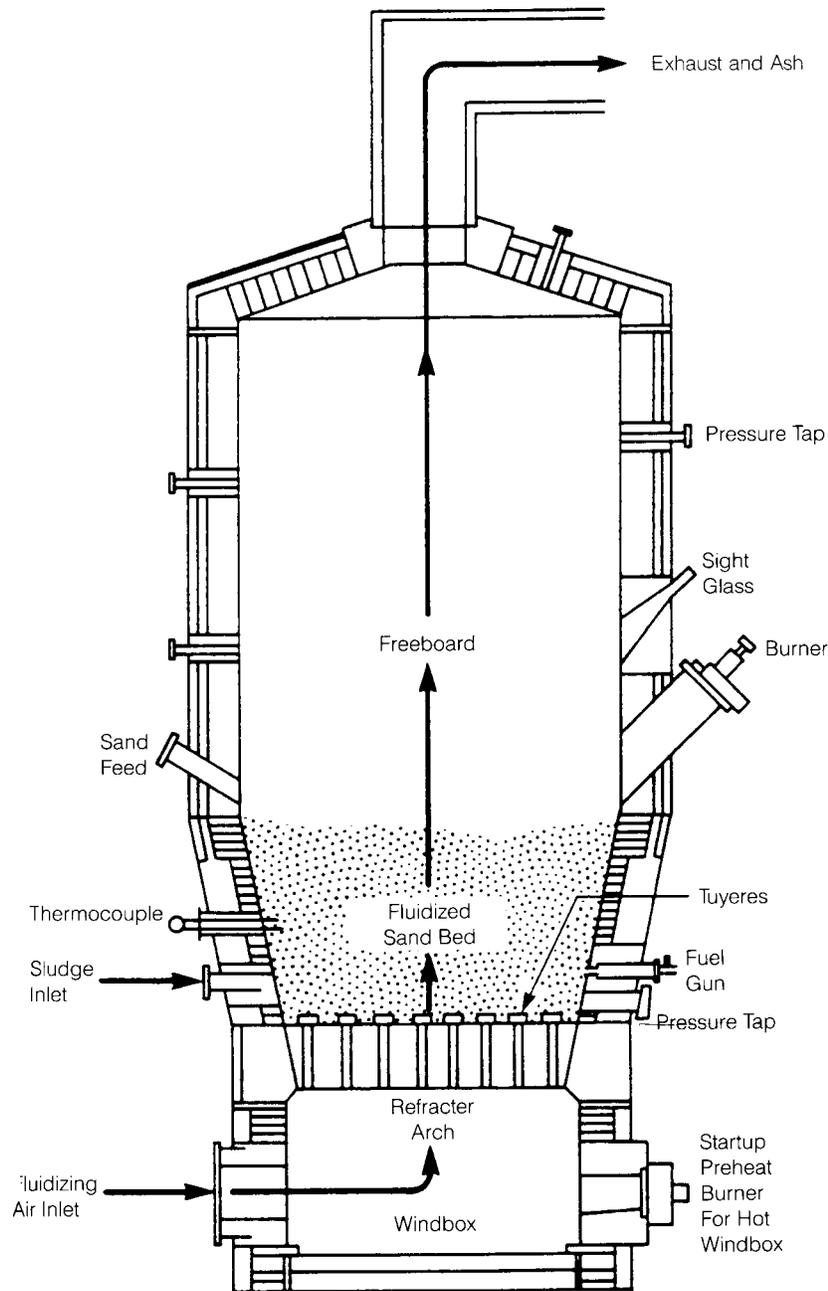
Fabric filters, or bag houses, pass the incinerator exhaust gas through a series of fabric filters. These can achieve removal efficiencies of 99 percent of particles at submicro sizes. Gas temperatures must be reduced to less than 149-177°C (300-350°F) before entry into the fabric filter.

Electrostatic precipitators negatively charge particles which are then attracted to positively charged plates. Electrostatic precipitators can be wet or dry. Wet systems contain a washing mechanism and generally achieve better removal efficiencies. Electrostatic precipitators are most effective when used in combination with mechanical collectors. Efficiencies of 99 percent or greater can be achieved (WEF, 1992a).

Gases

The emission of problematic gases can be reduced by controlling production of these gases. The formation of NO_x can be reduced through process adjustments such as operating the burners with low excess air, staging the combustion process, recirculating flue gas, and using low-NO_x burners which limit the exposure of fuel to oxygen in the combustion zone. Reducing agents such as ammonia and urea can also be used to limit NO_x emissions. Reduction of SO_x emissions can be accomplished through use of wet or dry scrubbers.

Results of a survey reported in *Design of Municipal Wastewater Treatment Plants* indicate that miscellaneous wet scrubbers, Venturi systems



Source: WEF, 1992a.

FIGURE 2 CROSS SECTION OF A TYPICAL FBF

and impingement and cyclone separators were the most common types of air pollution control equipment employed at MHF. Similar results were reported at FBF facilities (WEF, 1992).

FBFs generally achieve better removal of problematic gases due to their higher operating temperatures (temperatures in excess of 871°C [1600°F] for FBFs compared to temperatures between 316-482°C [600- 900°F] for MHFs). The

higher temperatures destroy odorous compounds and hydrocarbons, which helps to meet emission standards (WEF, 1992). Afterburners can be used on MHFs to raise exhaust gases to sufficient temperatures to destroy these problematic compounds. Afterburners are secondary burners that operate in a temperature range of 600-650°C (1,100-1,200°F) with efficiencies of 99 percent or greater. The need for afterburners on MHFs to reduce air emissions often gives FBFs an economic

advantage in comparing the technologies for specific applications.

APPLICABILITY

Incineration reduces wastewater solids volume by up to 95 percent. The technology is most applicable when landfill tipping fees are high, distances to alternative disposal or beneficial use sites are long, space at the treatment plant is limited and on-site treatment of solids is desired, or beneficial use options are not appropriate.

The composition and characteristics of wastewater solids are important when considering incineration. Standards regulate the metals content of incinerated solids. In addition, moisture content greatly impacts energy (supplemental fuel) usage. Incineration is most economical when solids are dewatered to more than 25 percent solids. In addition, wastewater treatment plants that find incineration to be most economical are those that produce more than 11 Mg dry solids/day (10 dry tons of solids/day). Usually, the larger the quantity of solids incinerated, the greater the economies of scale (i.e., the cost per dry ton goes down as capacity increases). Many incinerators even receive wastewater solids from other plants to improve the economics of the facility. Some wastewater solids producers generate additional revenues by serving as regional processing facilities, resulting in cost savings to both the incinerator operator/owner and the “customer” solids producers.

Changes in wastewater constituents or solids processing may impact the potential for energy recovery. It is generally preferable to burn raw rather than digested material due to heat values. The heat of combustion ranges from 18,624-30,264 kJ/dry kg of solids [8,000 to 13,000 BTU/dry lb] for primary wastewater solids to 11,640-23,280 kJ/dry kg of solids (5,000 - 10,000 BTU/dry lb) for combined primary and waste activated solids. By comparison, anaerobically digested primary solids have a heating value of approximately 12,804 kJ/dry kg of solids (5,500 BTU/dry lb). Because this incineration is less efficient, these facilities require more auxiliary fuel and have additional capital and annual operation and maintenance costs associated with the digestion process.

ADVANTAGES AND DISADVANTAGES

Advantages and disadvantages of using incineration systems for solids disposal, vs. disposing of solids in a landfill or through stabilization followed by use as a fertilizer or soil conditioner, are provided below.

Advantages

- Volume reduction.
- Generation of stable material. Ash is a stable, sterile material, effectively eliminating storage and handling problems.
- Potential energy recovery.
- Minimal land area required.

Disadvantages

- High capital investment.
- In most cases, annual operating costs depend on fuel costs.
- Consumption of non-renewable resources (oil and/or natural gas).
- Limited feasibility in nonattainment areas.
- Potential operating problems. Incinerators experience significant down time for routine maintenance and therefore require redundancy, backup, or storage. High technology instrumentation is required to comply with air pollution control permits.
- Potential for public opposition.

Modern incineration facilities generally do not present a significant health risk to the community if they are equipped with adequately maintained process control and air pollution control equipment and are operated by trained employees. An important goal of 40 CFR Part 503, Subpart E is to provide assurance that air pollution impacts are reduced to the maximum extent possible.

Dangtran, et al., 2000, conclude that design differences between the MFH and FBF technologies lead to the following advantages for FBF:

- Lower NO_x, CO, and total hydrocarbon (THC) formation.
- More suitable for intermittent operation.
- Allows feed variability and reduces chance of thermal shock.
- Ease of control and automation.
- Lower auxiliary fuel usage.
- Reduced maintenance cost.
- Smaller air pollution control system.
- Lower power requirements.
- Easier ash removal from off gases.

Table 1 presents a comparison of the MHF and FBF technologies.

DESIGN CRITERIA

The first step in designing an incineration system is development of a material balance. The total amount of solids to be processed, including the average (hourly, daily, monthly) and peak amounts, must be known. The specific characteristics of the feed solids, including moisture content, percent volatile solids, heat value, and concentration of specific inorganics, must also be known. Based on this information, a heat balance can be developed using the projected characteristics of the feed solids.

In addition to the furnace, the major physical components of an incineration system include:

- Conveyance of feed solids to the furnace.
- Ash handling, including removal from the furnace and final use or disposal.
- Air emission/pollution controls.
- Solids handling during peak production to equalize feed to the furnace.
- Supplemental fuel storage and availability.

Incineration systems are designed to handle a specific range in solids volume and characteristics as determined through the mass balance and heat balance performed in designing a system.

TABLE 1 COMPARISON OF MHF AND FBF

Parameter	Multiple Hearth Furnace	Fluidized Bed Furnace
Flow	Countercurrent	Intense back mixing
Heat Transfer	Poor	High
Solids Detention Time	½-3 h	1 to 5 min
Gas Detention Time at High Temperature	1 to 3 sec	6 to 8 sec
Combustion Temperature	1400 to 1800 ^E F	1400 to 1600 ^E F
Gas Exit Temperature	800 to 1400 ^E F	1500 to 1600 ^E F
Excess Air	75 to 100 percent	40 percent

Source: Dangtran, *et al*, 2000.

Provisions for temporary holding and storage help to even out the solids flow to the furnace. Feed volume should be maintained within the design range to ensure efficient operations. Incineration systems can handle routine fluctuations in solids characteristics, but fluctuations outside the established acceptable range may necessitate operational changes, such as increasing the amount of auxiliary fuel necessary to continue combustion.

Applicability of Windboxes

FBF systems can be designed to use air which is either preheated or at ambient temperature. With ambient air (cold windbox technology), no preprocessing of the air fed to the furnace is performed. With a hot windbox, combustion air is preheated to approximately 538^BC (1000^BF) before it is introduced to the furnace. This step serves to increase thermal efficiencies, and reduces fuel costs by about 60 percent. However, the addition of preheating equipment may increase system capital costs by as much as 15 percent (Bruner, 1980). An economic evaluation will determine the most cost effective option for a particular facility.

PERFORMANCE

In 1993, EPA estimated that 343 biosolids incinerators were in operation in the United States. Of these, approximately 80 percent were MHFs and 20 percent were FBFs. Siting and development of new incinerators to manage wastewater solids has been limited in recent years at least partly because of EPA's beneficial reuse policy for wastewater solids. Currently, approximately 254 incinerators for wastewater solids are operating in the United States. These facilities process an estimated 865,000 Mg (785,000 tons) per year (Dominak, 2001). Dangtran, et al., (2000) indicates that there have been 43 new incineration systems installed for managing wastewater solids since 1988, all of which use the fluid bed technology. Eleven of these replaced existing multiple hearth facilities.

Wastewater solids incinerators are regulated under Section 112 of the 1990 Clean Air Act Amendments (CAAA), which require incinerators classified as a major source of emissions (those that could emit 9 Mg [10 tons] or more per year of any of 189 identified pollutants or 23 Mg [25 tons] or more per year of any combination of the 189 pollutants) to meet technology-based standards. Incinerators that do not meet the definition as a major emissions source are still regulated for emission of 30 selected pollutants, including alkylated lead compounds, polycyclic organic matter, hexachlorobenzene, mercury, polychlorinated biphenyls, dioxins, and furans.

Specific regulatory limits for wastewater solids incinerators are as follows:

- Particulate emissions may not exceed 0.65 kg/Mg (1.3 lb/ton) of solids incinerated at 7 percent oxygen (40 CFR Part 60 Subpart O).
- Opacity (visible emissions) may not exceed 20 percent for a 6-min average period (40 CFR Part 60 Subpart O).
- Emissions of beryllium and mercury may not exceed 10 g and 1,200 g, respectively, in a 24-hour period (40 CFR Part 61 Subparts C and E).

- Average daily concentration of lead fed to an incinerator may not exceed a concentration calculated using the following equation (40 CFR Part 503 Subpart E):

$$\frac{0.1 \times \text{NAAQS} \times 86,400}{\text{DF} \times (1 - \text{CE}) \times \text{SF}}$$

where:

NAAQS = National Ambient Air Quality Standard for lead (F g/m^3).

DF = Dispersion factor as determined in accordance with 40 CFR Part 503.42(e) ($\text{F g/m}^3/\text{g/s}$).

CE = Incinerator control efficiency for lead determined through performance testing in accordance with 40 CFR Part 503.43(e).

SF = Solids feed rate (Mg/day, dry weight basis).

- Average daily concentrations of arsenic, cadmium, chromium and nickel fed to an incinerator may not exceed a concentration calculated using the following equation (40 CFR Part 503 Subpart E):

$$\frac{\text{RSC} \times 86,400}{\text{DF} \times (1 - \text{CE}) \times \text{SF}}$$

where:

RSC = Risk specific concentration (F g/m^3) provided in Tables 1 and 2 of 40 CFR Part 503.43.

DF = Dispersion factor as determined in accordance with 40 CFR Part 503.42(e) ($\text{F g/m}^3/\text{g/s}$).

CE = Incinerator control efficiency for lead determined through performance testing in accordance with 40 CFR Part 503.43(e).

SF = Solids feed rate (Mg/day, dry weight basis).

The monthly average concentration for THC emissions as propane (corrected for zero percent moisture and seven percent oxygen) may not exceed 100 ppm on a volumetric basis (40 CFR Part 503 Subpart E).

The National Ambient Air Quality Standards also apply to wastewater solids incinerators. Any source emitting more than 92 Mg (100 tons) per year must obtain a Title V operating permit. Facilities emitting between 23- 92 Mg (25-100 tons) of NO_x per year may be classified as a major source depending on area attainment classification.

Typically, MHFs have simple solids feed and ash handling equipment but produce high CO and NO_x emissions. FBFs have low CO and NO_x emissions but require complex solids feed and ash handling systems. The main contributor to the formation of NO_x is nitrogen in the wastewater solids, so operating MHFs at high hearth temperatures causes NO_x emissions to increase by 0.5-1 kg/Mg (1-2 lb/ton) of solids processed. Conventional external or top hearth afterburners also produce significantly higher NO_x emissions because they consume large amounts of fossil fuels.

OPERATION AND MAINTENANCE

The dry solids content in wastewater solids has a significant effect on the operation of thermal processes due to the high energy associated with evaporation. FBFs may be used for intermittent operation with a minimum amount of start-up time. FBFs will “warm up” at the beginning of the week from about 400°F and feed continuously. The week ends with a gradual cool down and a discontinuation of feed on Friday afternoon. Gradual heating and cooling minimizes maintenance of the refractory lining as well as downtime. FBFs also require less excess air and less fuel than MHFs.

Multiple Hearth Furnace

Two main operational problems associated with MHFs include:

- Frequent need for supplementary fuel to maintain the incineration process.
- Emission of volatile compounds or NO_x from the incinerator.

To overcome the NO_x emission problem, oxygen enrichment can be used to increase the waste combustion capacity when gas residence time, flue gas flow rate, or combustion air fan capacity are the limiting factors. This will provide more oxygen for combustion for a given amount of flue gas produced. A second effect of oxygen enrichment is that it displaces inert nitrogen, which is a heat sink. Oxygen injection for MHFs has been demonstrated successfully. The increased throughput and reduced auxiliary fuel consumption can be achieved and oxygen injection can be economically viable. This provides an additional tool for the furnace operator to respond rapidly to changes in the feed. A “troubleshooting guide” for multiple hearth furnaces is provided in Table 2.

Fluidized Bed Furnace

It is important to maintain a steady and consistent feed rate to a FBF in order to maintain low NO_x emissions. Emissions testing of the FBF confirms that low average NO_x concentrations can be achieved by maintaining the furnace oxygen concentration at less than 5.0 percent, keeping freeboard temperatures between 816°C and 843°C (1500°F-1550°F), and setting the fluidizing air blower at a minimum air flow rate (Sapienza et al., 1998). Table 3 provides a “troubleshooting guide” for fluidized bed incineration.

**TABLE 2 TROUBLESHOOTING GUIDE FOR INCINERATION - MULTIPLE HEARTH
INCINERATION**

Problem	Probable Cause	Solution
Furnace temperature too high	Excessive fuel feed rate	Decrease fuel feed rate
	Greasy solids	If fuel is off and temperature is rising, this may be the cause; raise air feed rate or reduce sludge feed rate
	Thermocouple burned out	If temperature indicator is off scale, this is likely the cause; replace thermocouple
Furnace temperature too low	Moisture content of sludge has increased	Increase fuel feed rate until dewatering system operation is improved
	Fuel system malfunction	Check fuel system; establish proper fuel feed rate
	Excessive air feed rate	If oxygen content of stack gas is high, this is likely the cause; reduce air feed rate or increase feed rate
Oxygen content of stack gas is too high	Sludge feed rate too low	Remove any blockages and establish proper feed rate
	Air feed rate too high	Decrease air feed rate
	Air feed excessive above burn zone	Check doors and peepholes above burn zone; close as necessary
Oxygen content of stack gas is too low	Volatile or grease content of sludge has increased	Increase air feed rate or decrease sludge feed rate
	Air feed rate too low	Check for malfunction of air supply, and increase air feed rate, if necessary
Furnace refractories have deteriorated	Furnace has been started up and shut down too quickly	Replace refractories and observe proper heating and cooling procedures in the future
Unusually high cooling effect from one hearth to another	Air leak	Check hearth doors, discharge pipe, center shaft seal, air butterfly valves in inactive burners, and stop leak
Short hearth life	Uneven firing	Check all burners in hearth; fire hearths equally on both sides
Center shaft drive shear pin fails	Rabble arm is dragging on hearth or foreign object is caught beneath arm	Correct cause of problem and replace shear pin
Furnace scrubber temperature too high	Low water flow to scrubber	Establish adequate scrubber water flow
Stack gas temperatures too low (260 to 320°C [500 to 600°F]; odors noted)	Inadequate fuel feed rate or excessive sludge feed rate	Increase fuel or decrease sludge feed rates
Stack gas temperatures too high (650 to 870°C [1,200 to 1,600°F])	Excessive heat value in sludge or excessive sludge feed rate	Add more excess air or decrease fuel rate

TABLE 2 (CONTINUED) TROUBLESHOOTING GUIDE FOR INCINERATION - MULTIPLE HEARTH INCINERATION

Problem	Probable Cause	Solution
Furnace burners slagging up	Burner design	Consult manufacturer and replace burners with newer designs that minimize slagging
	Air-fuel mixture is off	Consult manufacturer
Rabble arms are drooping	Excessive hearth temperatures or loss of cooling air	Maintain temperatures in proper range and maintain backup systems for cooling air in working condition; discontinue scum injection into hearth

Source: Modified from WEF, 1996.

COSTS

The cost of incineration is a function of many factors, including:

- Furnace type, size, and manufacturer.
- Solids content of the feed. The effect of solids content on fuel economics will vary as a function of the type of furnace and the temperature oxidation design used (i.e., temperature raised in the furnace itself or in an external unit before or after scrubbing of the gases).
- Volatile solids content and heating value of the feed.
- Various design considerations, such as energy efficiency of the system.
- Local labor costs.
- Air emission control requirements.

The economics of incineration should be evaluated as part of an overall system design incorporating dewatering, combustion, air pollution control, and ash management. Furthermore, the system should be analyzed on a sensitivity basis, specifically evaluating the effects of solids concentration on the capital and annual operation and maintenance (O&M) costs for each process train.

Due to additional requirements of Part 503 regulations, continuous monitoring of feed rate, stack gas oxygen content, and stack gas moisture

content have contributed to the increase of operational costs. These cost increases result in greater workload for facility operators. Retrofit costs associated with Part 503 risk reduction from metal emissions are based on exposure of the most exposed individual to the metals of concern, and the risk can be reduced by improving dispersion characteristics, reducing emissions, or a combination of both. These retrofitting adjustments, such as a THC monitor, have been the primary reason for operational cost increases. The cost of installing new stacks or extending the height of the existing stack is site specific and the cost of extensions or replacement stacks is dependent on the choice of material and configuration. Typical annual O&M costs quoted in one study range from \$83-\$269/dry Mg (\$76-\$245/dry ton) (adjusted using 2002 ENR values) (Walsh et al., 1990). The adjusted 2002 O&M costs for a multiple hearth facility retrofitted with additional air pollution control equipment to comply with the Part 503 Regulations are approximately \$270/dry Mg (\$244/dry ton) per day processed.

The results of a recent study of one wastewater solids facility estimated the annual operating costs (including amortization of capital costs) to be \$22/wet Mg (\$20/wet ton) including a \$7.39/wet Mg (\$6.70/wet variable nature of operating costs, this same report notes that actual O&M costs increased from \$17.26 -

**TABLE 3 TROUBLESHOOTING GUIDE FOR INCINERATION - FLUIDIZED BED
INCINERATION**

Problem	Probable Cause	Solution
Bed temperature is falling	Inadequate fuel supply	Increase fuel feed rate or repair any fuel system malfunctions
	Excessive rate of sludge feed	Decrease sludge feed rate
	Excessive sludge moisture	Improve dewatering system operation
	Excessive air flow	Reduce air rate if oxygen content of exhaust gas exceeds 6%
Low (<4%) oxygen in exhaust gas	Low air flow	Increase air blower rate
	Fuel rate too high	Decrease fuel rate
Excessive (>6%) oxygen in exhaust gas	Sludge feed rate too low	Increase sludge feed rate and adjust fuel rate to maintain steady bed temperature
Erratic bed depth readings on control panel	Bed pressure taps plugged with solids	Tap a metal rod into the pressure tap when reactor is not in operation Apply compressed air to pressure tap while the reactor is in operation after reviewing manufacturer's safety instructions
Preheat burner fails and alarm sounds	Pilot flame not receiving fuel	Open appropriate valves and establish fuel supply
	Pilot flame not receiving spark	Remove spark plug and check for spark; check transformer, replace defective part
	Pressure regulators defective	Disassemble and thoroughly clean regulators
	Pilot flame ignites but flame scanner malfunctions	Clean sight glass on scanner, replace defective scanner
Bed temperatures too high	Fuel feed rate too high through bed guns	Decrease fuel flow rate through bed guns
	Bed guns have been turned off but temperature still too high because of greasy solids or increased heat value of sludge	Raise air flow rate or decrease sludge feed rate
Bed temperature reads off scale	Thermocouple burned out or controller malfunction	Check the entire control system; repair as necessary
High scrubber temperature	No water flowing in scrubber	Open valves
	Spray nozzles plugged	Clean nozzles and strainers
	Water not recirculating	Return pump to service or remove scrubber blockage
Reactor sludge feed pump fails	Bed temperature interlocks may have shut down the pump	Check bed temperature
	Pump is blocked	Dilute feed sludge with water if sludge is too concentrated
Poor bed fluidization	During shutdowns, sand has leaked through support plate	Once per month, clean windbox

Source: Modified from WEF, 1996.

\$23.36/ wet ton when processing tonnage dropped from 82,600 wet Mg (91,000 wet tons) to 75,500 wet Mg (68,500 wet tons). No other system changes were noted during this time. In comparison, this same report estimates the comparable cost of landfilling in this geographic area to be almost \$55/wet Mg (\$50/wet ton) and the cost of land application to be between \$66-\$88 per wet Mg (\$60-\$80 per wet ton) (Dominak, 2001).

Since relatively few new incineration facilities are being constructed, accurate capital cost information is difficult to locate. Capital costs for a new FBF facility constructed in North Carolina in 1994 are quoted at \$6 million. This facility serves two plants with combined capacity of 136,000 m³/day (36 MGD). This figure does not include dewatering but does include some ancillary modification to existing plant buildings. The capital investment in terms of processing capacity is estimated at \$66/dry Mg (\$60/dry ton). In comparison, landfill disposal for the same situation was estimated to be \$127/dry Mg (\$115/dry ton). Land application costs are approximately \$15.40/dry Mg (\$14/dry ton [see EPA's fact sheet on Use of Land Application for Biosolids Management]).

Table 4 presents the capital costs of the various air pollution control strategies. This information was generated to address existing facilities that needed to be updated to address new regulatory requirements imposed by Part 503 Regulations.

REFERENCES

Other Related Fact Sheets

Other EPA Fact Sheets can be found at the following web address:
<http://www.epa.gov/owm/mtb/mtbfact.htm>

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TABLE 4 TYPICAL COSTS OF AIR POLLUTION CONTROL EQUIPMENT

Equipment	Costs (\$) *
Multiple Venturi Systems	100,000 - 200,000
Wet Electrostatic Precipitator	150,000 - 500,000
Internal Afterburner Retrofit	50,000 - 75,000
Top Hearth Afterburner Retrofit	50,000 - 75,000
Conventional External Afterburner	400,000 - 700,000
Side-Flue Afterburner Retrofit	300,000 - 400,000
Side-Exit Afterburner Retrofit	600,000 - 800,000
Post-Scrubber Afterburner	400,000 - 700,000

* Range based on size

Source: Baturay, 1999.

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The mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Environmental Protection Agency.

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Metropolitan Council
Dave Quast
Mears Park Center
230 East 5th Street
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Palo Alto Regional Water Quality Control Plant
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Office of Water
EPA 832-F-03-013
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