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LOCATING AND ESTIMATING AIR TOXICS EMISSIONS FROM MUNICIPAL WASTE COMBUSTORS

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LOCATING AND ESTIMATING AIR TOXICS EMISSIONS FROM MUNICIPAL WASTE COMBUSTORS

By

Radian Corporation
Research Triangle Park, North Carolina 27709

EPA Project Officer: William B. Kuykendal

U. S. ENVIRONMENTAL PROTECTION AGENCY
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1. PURPOSE OF DOCUMENT

This document is designed to assist Federal, State, and local air pollution agencies in inventorying air emissions of potentially toxic substances. It is one of a series the Environmental Protection Agency (EPA) is preparing to compile information on sources and emissions of these pollutants. Specifically, this document deals with emissions from municipal waste combustors (MWCs).

The emissions information in this document will be most useful in making preliminary estimates of air emissions and should not be used in exact assessments of emissions from any particular facility. The reason for this is that insufficient data are available to estimate the statistical accuracy of these emission factors. In addition, variability in waste composition contributes to variations in emission factors. In fact, the difference between actual and calculated emissions could be as great as orders of magnitude in extreme cases. The size of error would depend on differences in source configurations, variability of waste composition, control equipment design and operation, and overall operating practices. A source test is the best way to determine air emissions from a particular source. However, even when a source test is used for a specific facility, variability of waste composition could change the composition of emissions, especially for metals.

2. OVERVIEW OF DOCUMENT CONTENTS

This section briefly outlines the contents of this report.

Section 3.0 is an overview of the municipal waste combustion (MWC) industry, describing the major types of MWCs in the existing population: mass burn, modular, and refuse-derived fuel (RDF)-fired combustors. Included is a process description for each type of combustor, as well as current and planned facility lists. In addition, this section describes the air emission control technologies currently in use at MWC facilities, including electrostatic precipitators, fabric filters, wet scrubbers, dry sorbent injection, spray dryers, and combustion control.

Section 4.0 focuses on the emissions from MWCs. Emission factors are given in tabular format for acid gases, organics, and metals.

Section 5.0 discusses the EPA reference methods and generally accepted methods of sampling and analysis for each pollutant.

Appendix A contains a list of the existing facilities in the MWC population and Appendix B contains a list of planned MWC facilities.

This document does not discuss health or other environmental effects of emissions from MWCs, nor does it discuss ambient air levels or ambient air monitoring techniques for emissions associated with MWCs.

Comments on this document are welcome, including information on process descriptions, operating practices, control measures, and emissions information that would enable EPA to improve the contents. All comments should be sent to:

Chief, Pollutant Characterization Section (MD-15)
Noncriteria Pollutant Programs Branch
U. S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

3. BACKGROUND INFORMATION

Incineration is a means of disposing of municipal solid waste (MSW) discarded from residential, commercial, and industrial establishments. When compared to landfilling, incineration has the advantages of reducing solid mass approximately 90 percent and the potential for recovering energy through combustion of waste products. Disadvantages include the necessity of ash disposal and the potential for air emissions of toxic pollutants.

Section 3 provides background information on the current status of MSW incineration. In Section 3.1, the municipal waste combustion industry is briefly overviewed. Combustor and emission controls are described in detail in Sections 3.2 and 3.3, respectively.

3.1 CHARACTERIZATION OF THE INDUSTRY

There are currently 161 municipal waste combustion (MWC) facilities known to be operating in the United States (U.S.). Major types of combustors include:

(1) Mass burn
(2) Modular
(3) Refuse-derived fuel (RDF) - fired (including co-firing)

Of the 161 known facilities, 70 (43 percent) are modular, 59 (37 percent) are mass burn, 19 (12 percent) are RDF-fired, and the remaining 13 (8 percent) are either fluidized-bed combustors or of unknown configuration.

It is estimated that the total U.S. MWC capacity is about 68,300 tons of MSW per day (tpd). Of this capacity, about 39,300 tpd (58 percent) is in mass burn facilities, 19,800 tpd (29 percent) is in RDF-fired facilities, 6,400 tpd (9 percent) is in modular facilities, and 2,800 tpd (4 percent) is in other types of MWCs.

Facilities are comprised of between one and eight individual combustors. Unit capacities range from 5 to 1,000 tpd, and total facility capacities range from 5 to 3,000 tpd. The oldest facility in the existing population was constructed in 1955.

Figure 3-1 shows the geographic distribution of the existing MWC population. New Hampshire has the greatest number of existing facilities (15), followed by New York (13), Texas (11), and Minnesota (9). In terms of total capacity, however, Florida is the leader with a capacity of about 9,200 tpd of MSW. Massachusetts is second at 8,960 tpd, and New York is third at 8,765 tpd.

Lists of the existing facilities are in Appendix A.[1] Table A-1 is sorted by combustor technology, and Table A-2 is sorted by state. These tables also show combustor type, unit capacity, year of facility start-up, whether heat recovery is used, and type of air pollution control device.

There are at least 111 facilities currently in the planning stages that will commence construction by the end of 1989. The majority of these plants are mass burn waterwall designs (79). The remaining planned facilities are either modular (15), RDF-fired (14), or of unknown design (12).

The majority of planned facilities are being built in the Northeast and in California. New York and Pennsylvania each have 15 planned facilities, followed by New Jersey with 11. California has nine facilities in the planning stages.

Lists of planned facilities that will commence construction by 1989 are in Appendix B.[1] Table B-1 lists these facilities sorted by combustor technology, and Table B-2 lists them sorted by state. These tables also show combustor type, number of units, total plant capacity, whether heat recovery is used, and the projected year of facility start-up.

3.2 COMBUSTOR PROCESS DESCRIPTIONS

As mentioned in Section 3.1, there are three major categories of combustor: mass burn, modular, and RDF. Other types of combustors, such as fluidized-bed combustors, comprise a much smaller percentage of the population than these categories. Detailed descriptions of the three major categories of MWCs are contained in the following sections.

3.2.1 Mass Burn Combustors

Mass burn combustors are used to combust MSW that generally has not been pre-processed except to remove items too large to go through the feed system. Processed waste can be combusted in these units. These combustors are usually

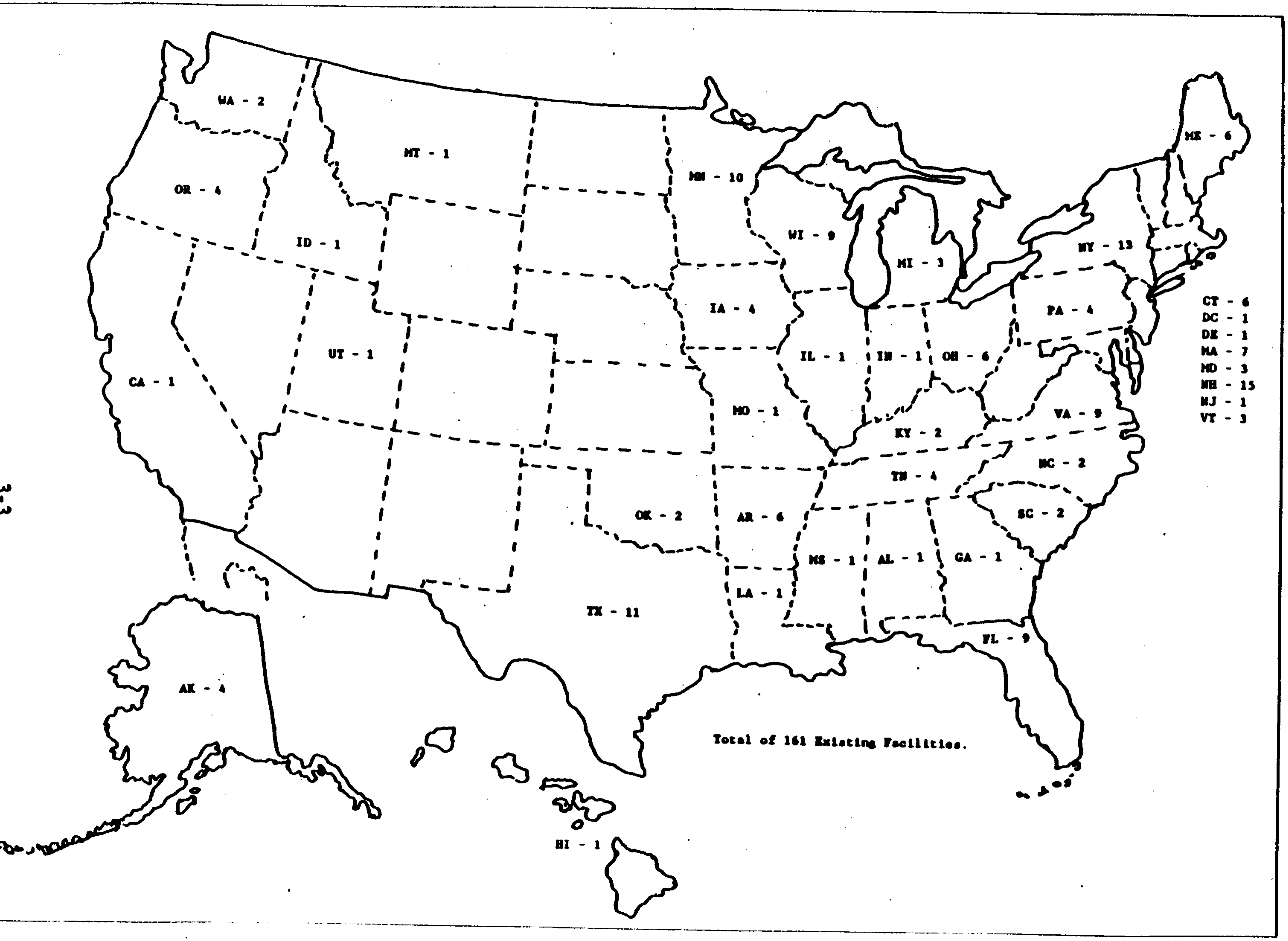

Figure 3-1. Geographic Distribution of Municipal Waste Combustion Facilities[1]

field-erected and range in size from 50 to 1,000 tpd MSW per unit. Many mass burn facilities have two or more combustors and have site capacities of greater than 1,000 tpd. The mass burn category can be further divided into waterwall and refractory-wall designs. Most refractory-wall combustors were built prior to the early 1970s. These units may incorporate separate waste heat recovery boilers, but most do not. Newer units are mainly waterwall designs used to recover heat for production of steam and/or electricity.

Refractory-wall mass burn combustors have at least three distinct combustor designs. The first design is a batch-fed upright combustor, which may be cylindrical or rectangular in shape. Figure 3-2 shows the typical configuration of a batch-fed rectangular combustor. This type of combustor was prevalent in the 1950's, but no additional units of this design are expected to be built.

A second, more common design consists of rectangular combustion chambers with traveling, rocking, or reciprocating grates. This type of combustor is continuously fed and operates in an excess-air mode with both underfire and overfire air provided. The primary distinction between plants with this design is the manner in which waste is moved through the combustor. The traveling grate moves on a set of sprockets and does not agitate the waste bed as it advances through the combustor. A schematic of a traveling grate combustor is shown in Figure 3-3. Rocking and reciprocating grate systems agitate and aerate the waste bed as it advances through the combustion chamber, allowing more waste surface area to be exposed to combustion air and increasing burnout of combustibles. The system generally discharges the ash at the end of the grate to a water quench pit for collection and disposal.

The third major design type in the mass burn refractory-wall population is a system which combines grate burning technology with a rotary kiln. Figure 3-4 shows a schematic of this design. Two grate sections (drying and ignition) precede a refractory-lined rotary kiln, where combustion is completed.

Refractory-wall combustors typically operate with high excess air levels (150 to 300 percent). These high levels are used to prevent excessive temperatures which can lead to refractory damage, slagging, fouling, and corrosion problems.

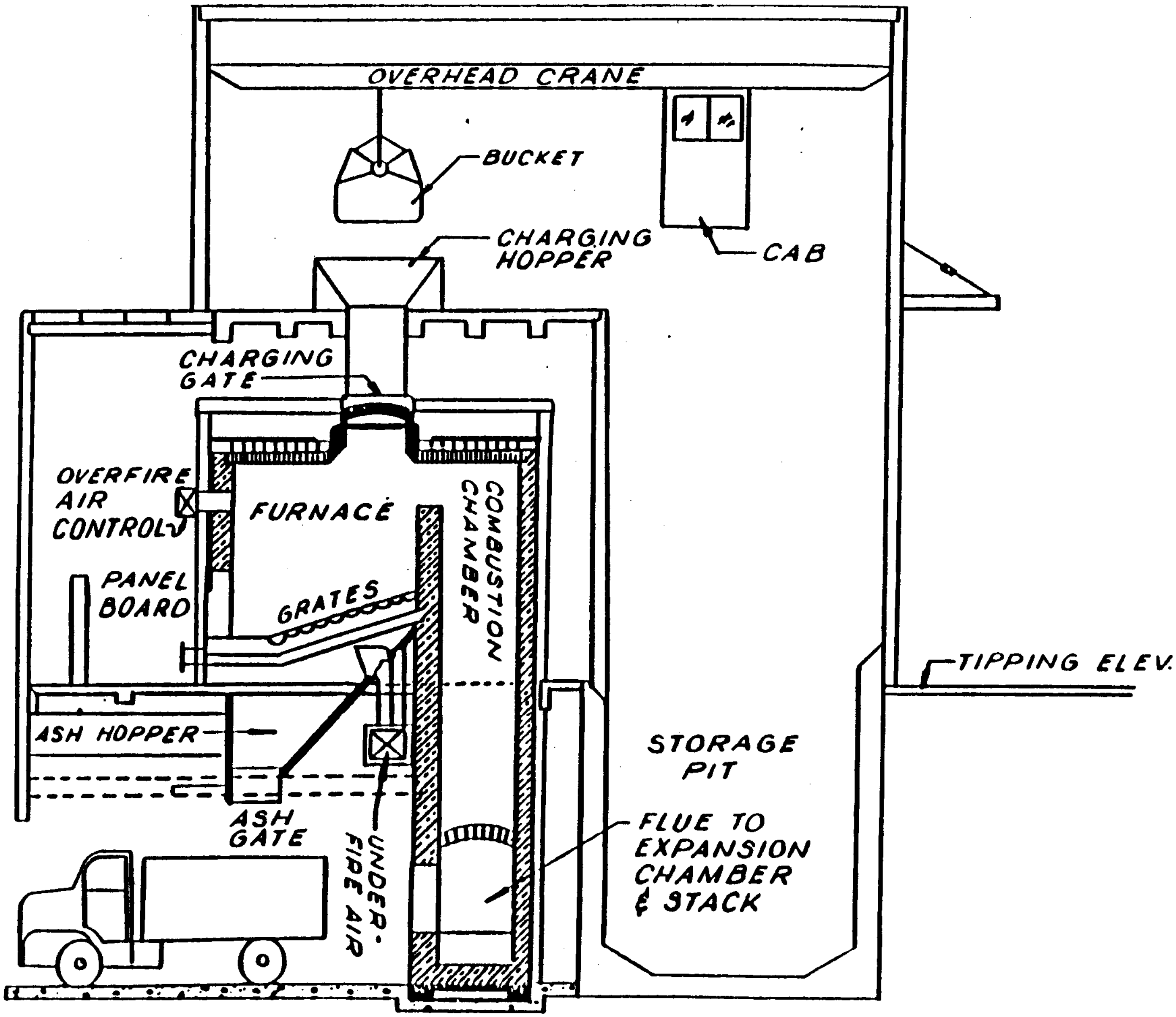

Figure 3-2. Refractory-Wall Batch Combustor[2]

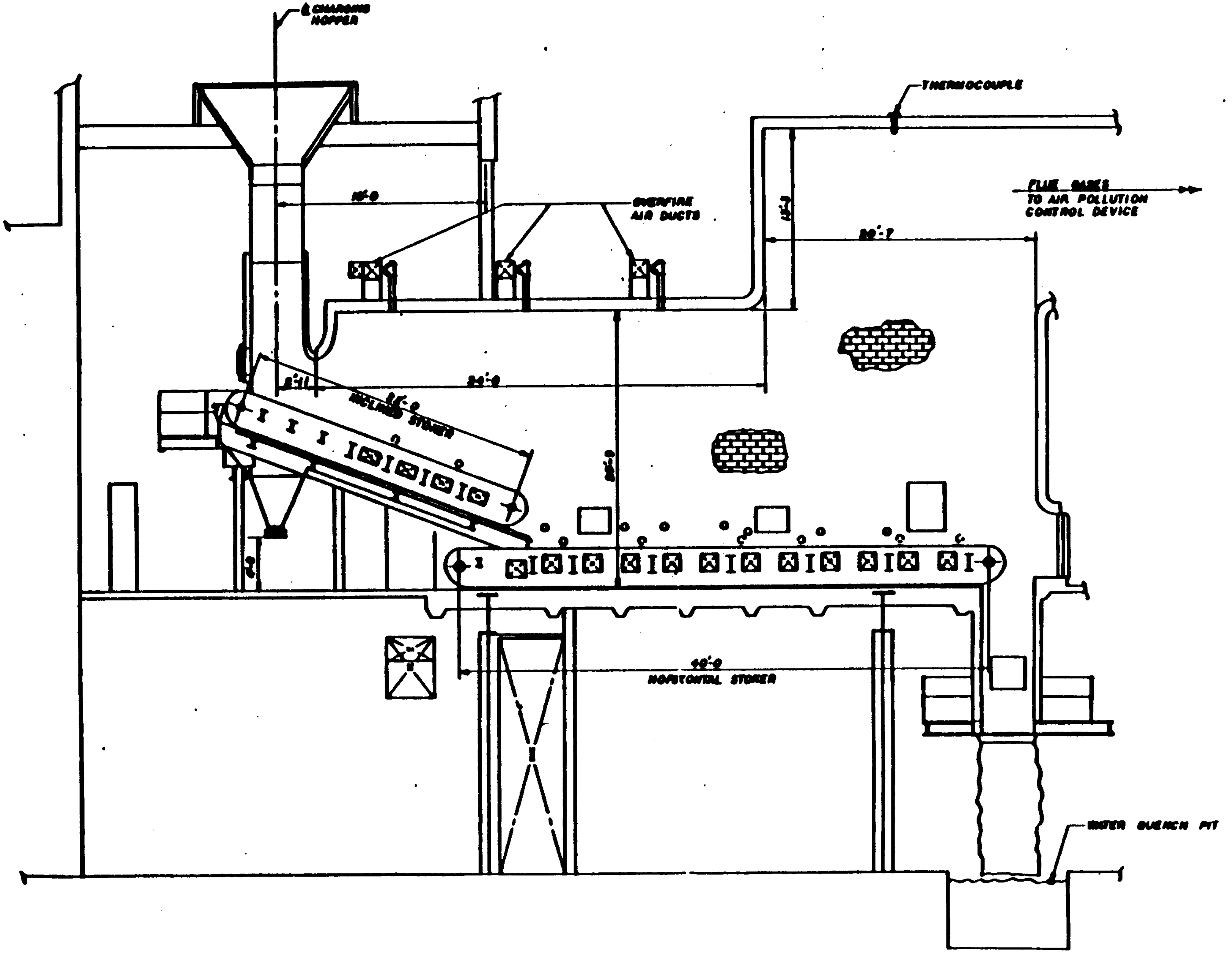

Figure 3-3. Typical Mass Burn Refractory-Wall Combustor with Traveling Grate

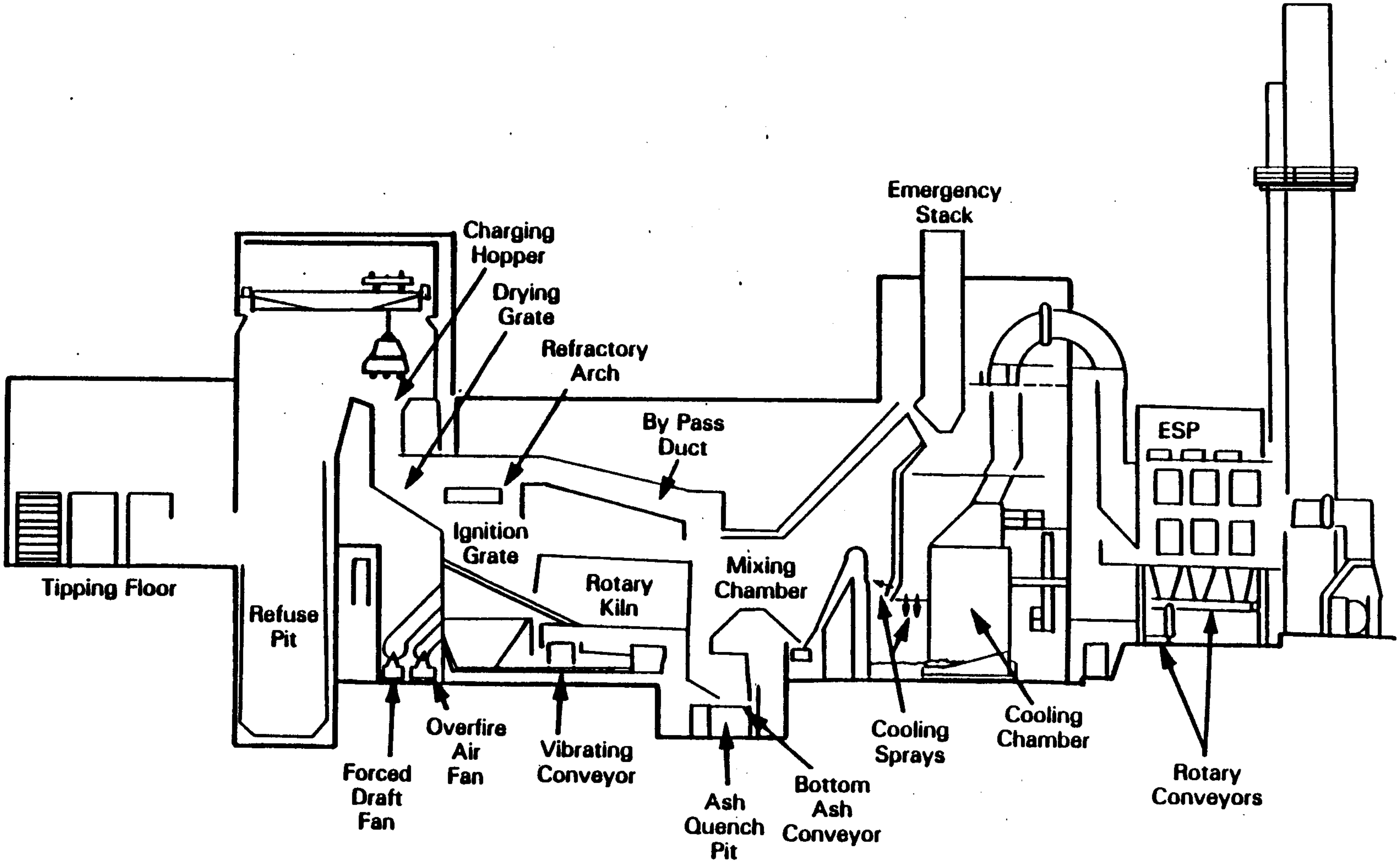

Figure 3-4. Typical Mass Burn Refractory-Wall Combustor with Grate/Rotary Kiln

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A typical mass burn waterwall system is shown in Figure 3-5. Unprocessed waste (with large, bulky, noncombustibles removed) is delivered by an overhead crane to a feed hopper from which it is fed into the combustion chamber. Earlier mass burn designs utilized gravity feeders, but it is more typical today for feeding to be accomplished by single or dual hydraulic rams that operate on a set frequency.

Nearly all modern conventional mass burn facilities use reciprocating grates to move waste through the combustion chamber. The grates typically include two or more separate sections where designated stages in the combustion process occur. For example, the initial grate section is referred to as the drying grate, where moisture is removed prior to ignition. The second grate section is the burning grate, where the majority of active burning takes place. The third grate section is referred to as the burnout or finishing grate, where remaining combustibles are burned. Smaller units may include two rather than three individual grate sections. In a typical mass burn waterwall system, bottom ash is discharged from the finishing grate into a water-filled quench pit. Dry ash systems have been used in some designs, but are not widespread.

Combustion air is added to the waste from beneath the grate by way of underfire air plenums. Most mass burn waterwall systems supply underfire air to the individual grate sections through multiple plenums. As the waste burns, additional air oxidizes fuel-rich gases and completes the combustion process. This additional air, referred to as overfire air, is injected through rows of high-pressure nozzles (usually two to three inches in diameter) located above the grate.

Typically mass burn waterwall MWCs are operated with 80 to 100 percent excess air. Normally 25 to 40 percent of total air is supplied as overfire air and 60 to 75 percent as underfire air. These are nominal ranges that may vary between specific designs.

Rotary waterwall combustors, another type of mass burn combustor, are of a single design. A schematic of a facility with a rotary waterwall combustor is shown in Figure 3-6. The waste is conveyed to a charge chute and ram fed to the rotary combustion chamber. The rotary combustion chamber sits at an angle and rotates at about 10 revolutions per hour causing the waste to

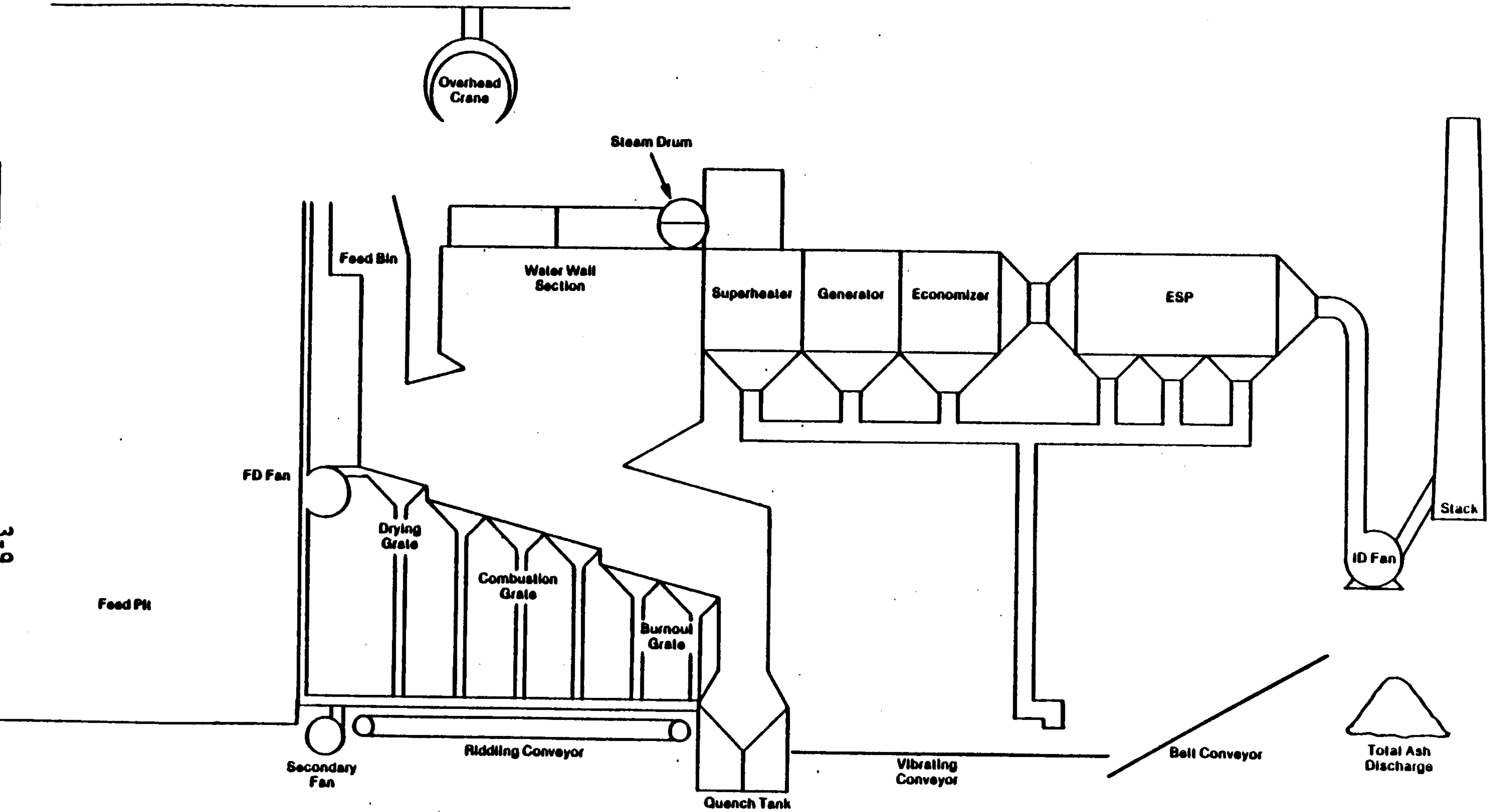

Figure 3-5. Typical Mass Burn Waterwall Combustor

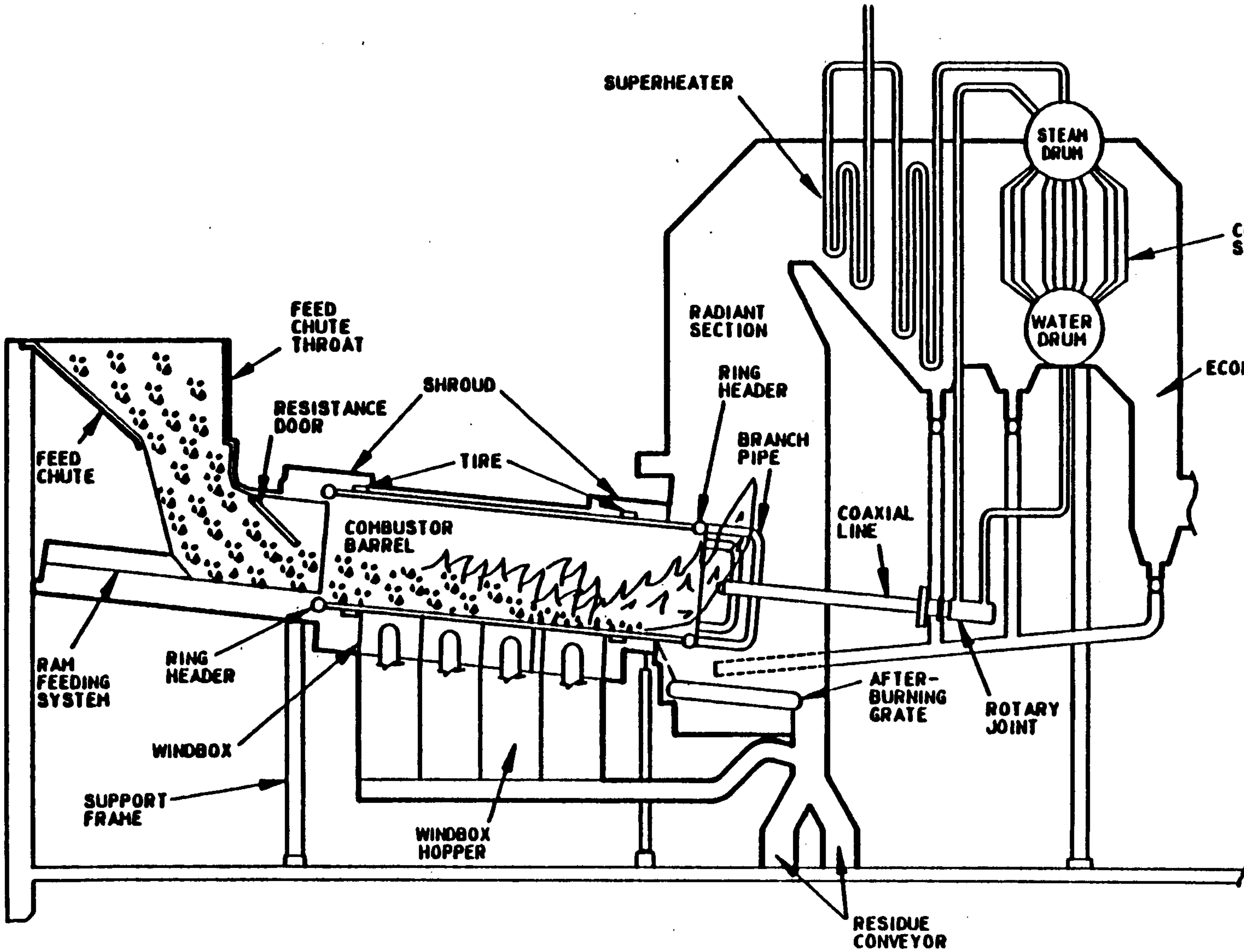

Figure 3-6. Simplified Process Flow Diagram, Gas Cycle for a Rotary Waterwall Combustor[3]

advance and tumble as it burns. Bottom ash is discharged from the rotary combustor to an after-burning grate and then into a wet quench pit or ram extractor.

Underfire air is injected through the waste bed and overfire air is provided directly above the waste bed, as shown in Figure 3-7. Approximately 80 percent of the combustion air is provided along the combustion chamber length with most of this provided in the first half of the length. The rest of the combustion air is supplied to the afterburner grate and above the rotary combustor outlet in the boiler chamber. As shown in Figure 3-6, this type of system uses preheated combustion air. Combustion air is drawn from the tipping floor and passes through the air heater, where heat from the flue gas preheats the combustion air to 450^{o}F. Water flowing through the tubes in the rotary chamber recovers heat from combustion. Additional heat recovery occurs in the boiler waterwall, superheater and economizer.

Mass burn combustors have a variety of emission controls. Most mass burn combustors have electrostatic precipitators (ESPs) for control of particulate matter (PM). Some older refractory-wall units have wet PM control devices such as wet scrubbers. Several newer units have acid gas control devices and PM control. The types of acid gas controls used include wet scrubbers, spray dryers and dry sorbent injection. The PM control devices used with acid gas control include ESPs and fabric filters. These emission control technologies are described in detail in Section 3.3.

3.2.2 Modular Combustors

Modular combustors are similar to mass burn combustors in that they burn waste without pre-processing. However, they are typically shop-fabricated and generally range in unit size from 5 to 120 tpd of MSW throughput. The most common type of modular combustor is the starved-air or controlled-air type. Another type of modular combustor, which is functionally similar from a combustion standpoint to the larger mass burn waterwall systems described above, is referred to as an excess-air combustor.

A typical modular starved-air MWC is shown in Figure 3-8. The basic design includes two separate combustion chambers (referred to as the "primary" and "secondary" chambers). Waste is batch-fed to the primary chamber by a

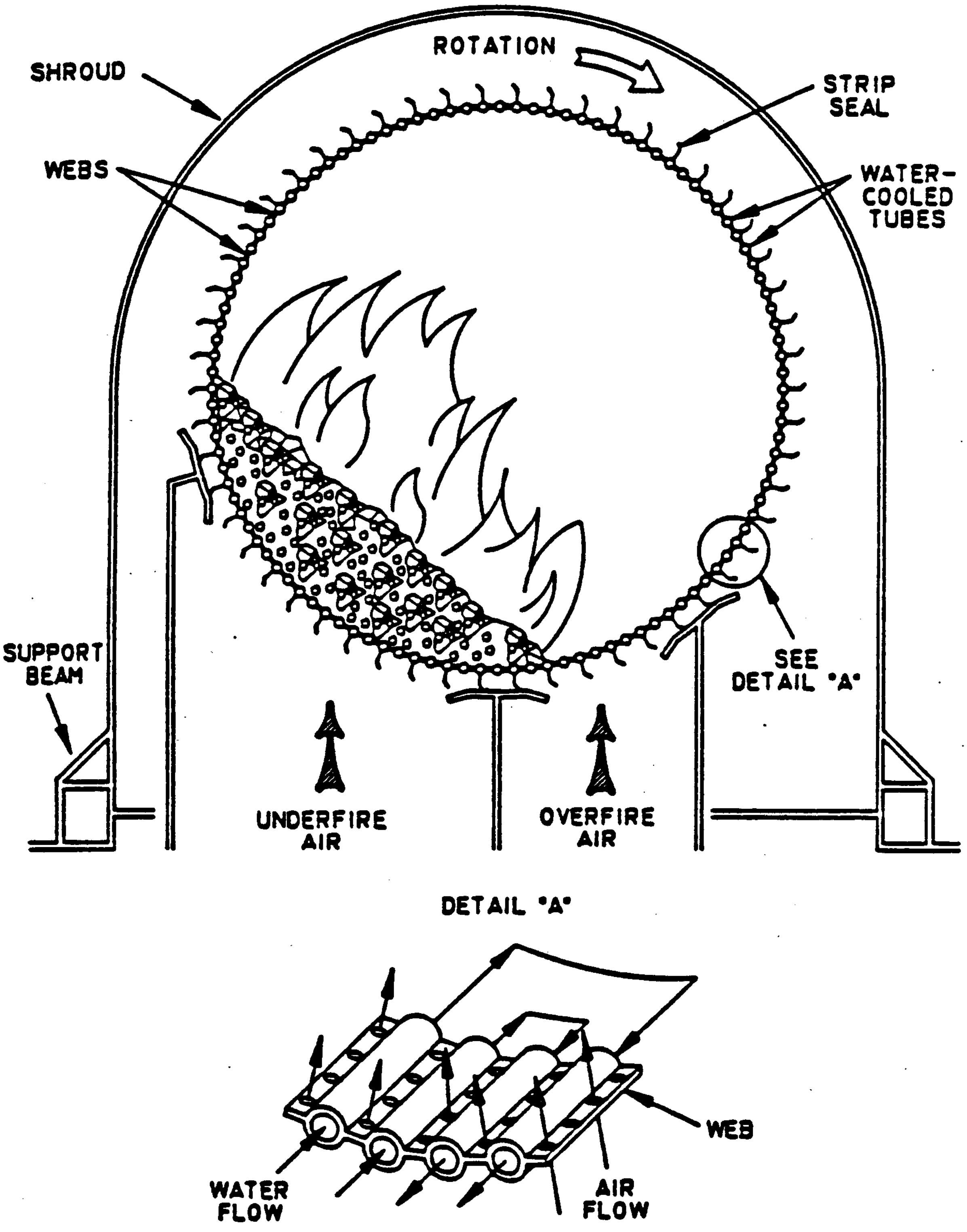

Figure 3-7. Cross-Section of a Waterwall Rotary Combustor[4]

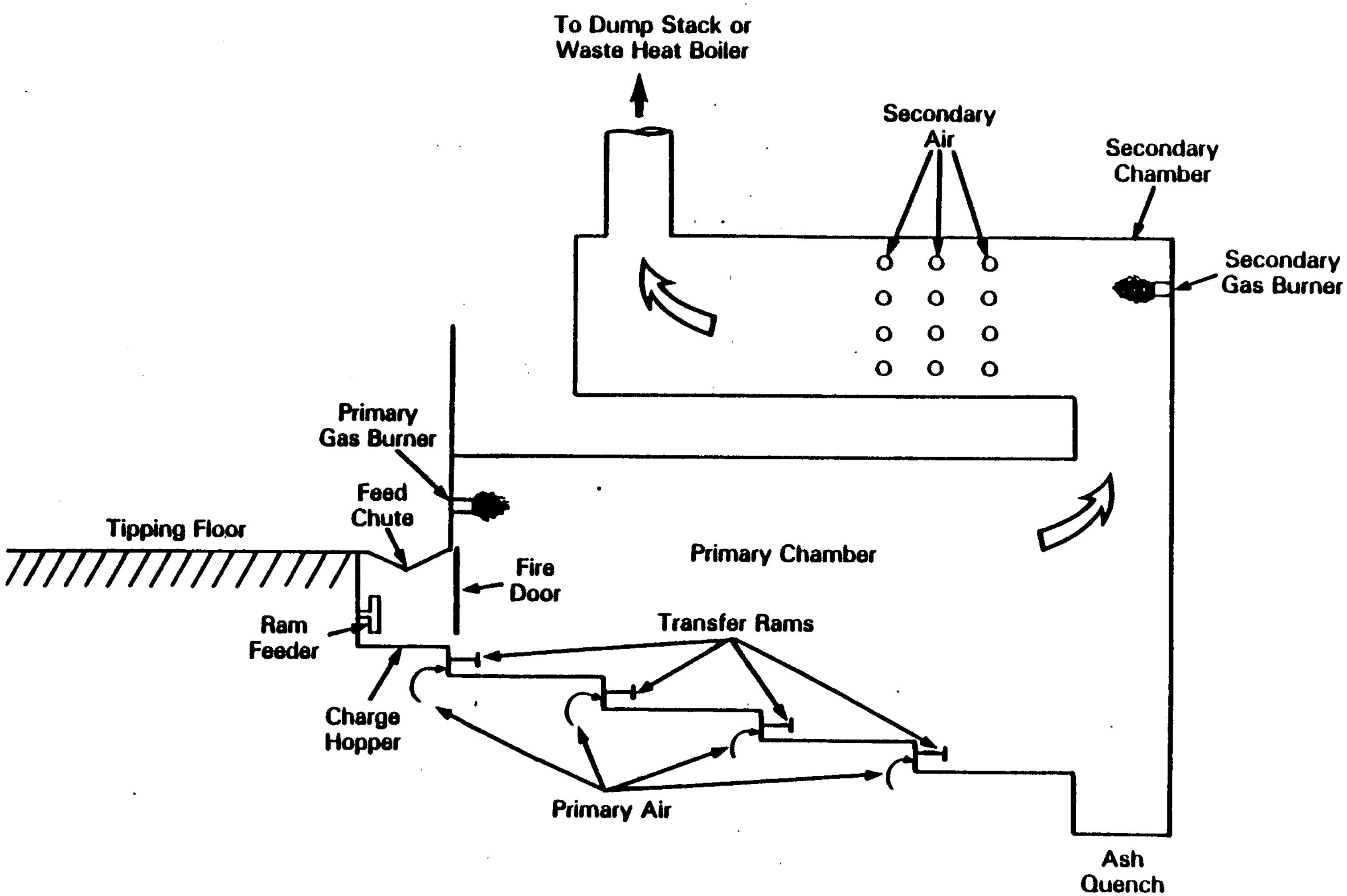

Figure 3-8. Typical Modular Starved-Air Combustor with Transfer Rams

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hydraulically-activated ram. The charging bin is filled by a front-end loader. Waste feeding occurs automatically on a set frequency (generally 6 to 10 minutes between charges).

Waste is moved through the primary combustion chamber by either hydraulic transfer rams or reciprocating grates. Systems using transfer rams have individual hearths upon which combustion takes place. Grate systems generally include two separate grate sections. In either case, waste retention times in the primary chamber are long (up to 12 hours). Bottom ash is usually discharged to a wet quench pit.

Combustion air is introduced in the primary chamber at substoichiometric levels, causing the primary chamber to essentially function as a gasifier. The combustion air flow rate to the primary chamber is controlled to maintain an exhaust gas temperature set point (generally 1,200 to 1,400^{o}F), which normally corresponds to about 40 percent theoretical air. Other system designs operate with a primary chamber temperature between 1,600 and 1,800^{o}F, which requires 50 to 60 percent theoretical air.

As the hot, fuel-rich gases flow to the secondary chamber, they are mixed with excess air to complete the burning process. The temperature of the exhaust gases from the primary chamber is above the autoignition point. Thus, completing combustion is simply a matter of introducing air to the fuel-rich gases. The amount of air added to the secondary chamber is controlled to maintain a desired flue gas exit temperature, typically 1,800 to 2,200^{o}F. Approximately 80 percent of the total combustion air is introduced as secondary air, so that excess air levels for the system are about 100 percent. Typical operating ranges vary from 80 to 150 percent excess air.

The walls of both combustion chambers are refractory-lined. Early starved-air modular combustors did not include heat recovery, but a waste heat boiler is common in newer facilities, with two or more combustion modules manifolded to a common boiler. Combustors with heat recovery capabilities also maintain dump stacks for use in an emergency, or when the boiler is not in operation.

Most modular starved-air MWCs are equipped with auxiliary fuel burners located in both the primary and secondary combustion chambers. Auxiliary fuel can be used during startup or when problems are experienced maintaining desired combustion temperatures. In general, the combustion process is self-sustaining through control of air flows and feed rate, so continuous co-firing of auxiliary fuel is normally not necessary.

A typical modular excess-air MWC is shown in Figure 3-9. The design is similar to that of the starved-air units. The basic design includes primary and secondary combustion chambers. Waste is batch-fed to the refractory-lined primary chamber and moved through the primary chamber by hydraulic transfer rams, oscillating grates, or revolving hearth. Bottom ash is discharged to a wet quench pit.

Unlike the starved-air type, and similar to mass burn units, the modular excess-air combustor is operated with up to 200 percent excess air in the primary chamber. Excess-air modular combustors also use recirculated flue gas for combustion air to maintain desired temperatures in the primary, secondary, and tertiary chambers. Flue gas burnout occurs in the secondary chamber, which is also refractory-lined. Heat is typically recovered in a waste heat boiler.

Most modular systems do not have air emission control devices. This is especially true of the smaller, starved-air facilities. Those facilities which use PM control devices typically have ESPs, although other controls such as cyclones, electrified gravel beds, and fabric filters have been used. Descriptions of the major types of control devices are provided in Section 3.3.

3.2.3 Refuse-Derived Fuel-Fired Combustors

Refuse-derived fuel-fired combustors burn processed MSW which may vary from shredded waste to finely divided fuel suitable for co-firing with pulverized coal. Combustor sizes range from 320 to 1,400 tpd. Most RDF facilities have two or more combustors, and site capacities range up to 3,000 tpd. Refused-derived fuel facilities typically recover heat for production of steam and/or electricity.

In an RDF facility, raw MSW is processed to RDF before combustion, raising the heating value of the waste. A set of standards for classifying RDF types has been established by ASTM and is presented in Table 3-1. The type of RDF used is dependent on the boiler design. With few known

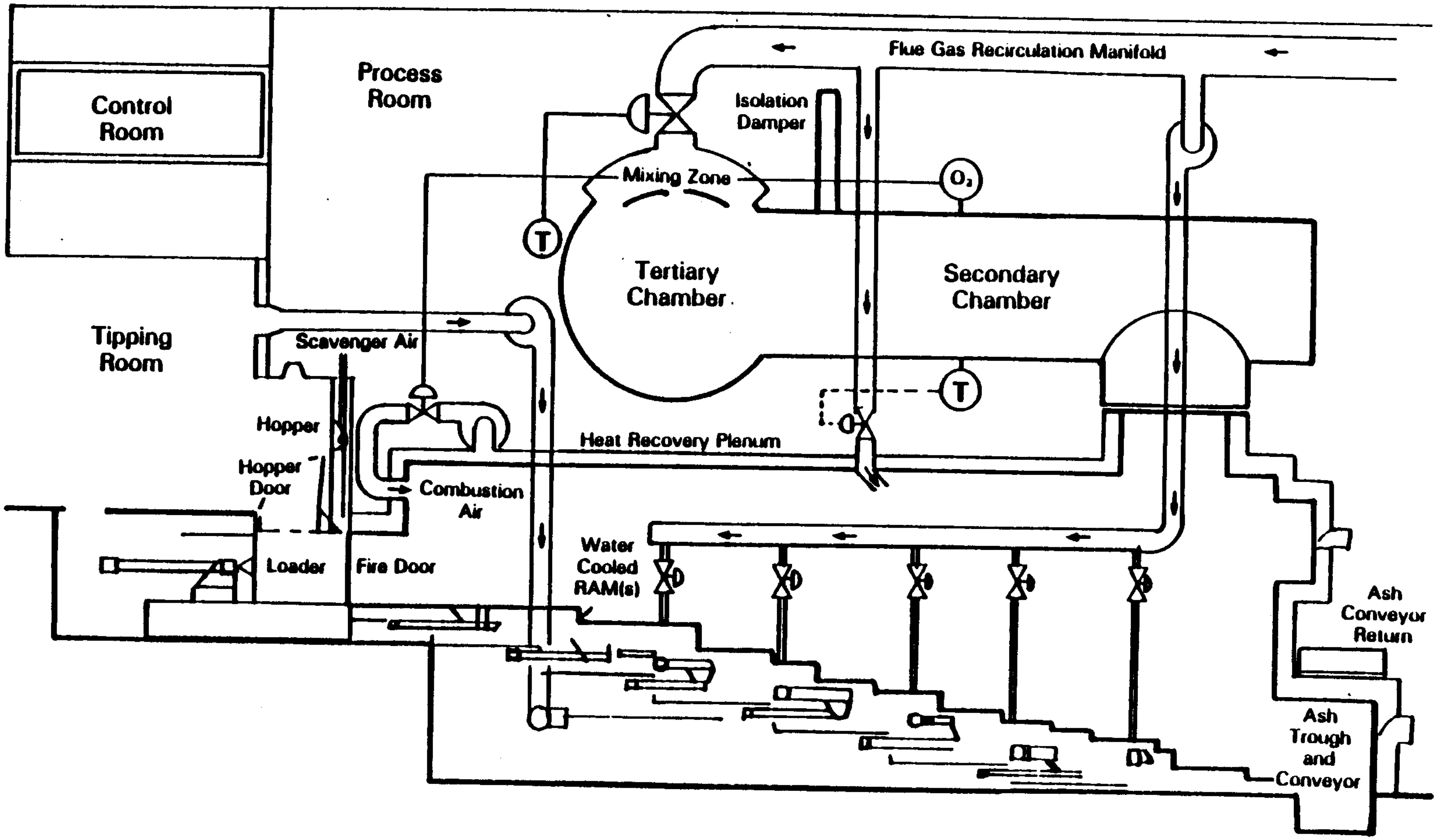

Figure 3-9. Typical Modular Excess-Air Combustor

TABLE 3-1. ASTM CLASSIFICATION OF REFUSE-DERIVED FUELS

Type of RDF	Description
RDF-1 (MSW)	Municipal solid waste used as a fuel in as-discarded form, without oversize bulky waste (OBW).
RDF-2 (c-RDF)	MSW processed to coarse particle size, with or without ferrous metal separation, such that 95 percent by weight (wt %) passes through a 6-inch square mesh screen.
RDF-3 (f-RDF)	Shredded fuel derived from MSW and processed for the removal of metal, glass, and other entrained inorganics. The particle size of this material is such that 95 wt % passes through a 2-inch square mesh screen. Also called "fluff RDF."
RDF-4 (p-RDF)	Combustible-waste fraction processed into powdered form, 95 wt % passing through a 10-mesh (0.035 inch square) screen.
RDF-5 (d-RDF)	Combustible waste fraction densified (compressed) into the form of pellets, slugs, cubettes, briquettes, or some similar form.
RDF-6	Combustible-waste fraction processed into a liquid fuel.
RDF-7	Combustible-waste fraction processed into a gaseous fuel.

exceptions, boilers that are designed to burn RDF as a primary fuel utilize spreader stokers and fire RDF-3 (fluff, or f-RDF) in a semi-suspension mode. This mode of feeding is accomplished by using an air-swept distributor, which allows a portion of the feed to burn in suspension and the remainder to be burned out after falling on a horizontal traveling grate. A schematic of a typical RDF spreader stoker boiler is shown in Figure 3-10.

Suspension-fired RDF boilers, such as pulverized coal (PC)-fired boilers, can co-fire RDF-3 or RDF-4 (powered or p-RDF). If RDF-3 is used, the fuel processing must be more extensive so that a very fine fluff results. Currently, several PC boilers co-fire fluff with pulverized coal. Suspension firing is usually associated with larger boilers due to the increased boiler height and retention time required for combustion to be completed in total suspension. Smaller systems firing RDF in suspension require moving or dump grates in the lower furnace to handle the falling material that is not completely combusted in suspension. Boilers co-firing RDF in suspension are generally limited to 50 percent of total heat input by RDF alone.[5]

The emission controls for RDF systems are typically ESPs alone, although spray dryer systems for acid gas control have been used with particulate control devices.

3.2.4 <u>Other Combustor Types</u>

Although the vast majority of municipal waste combustors are mass burn, modular, or RDF units, other technologies are available. The other significant technology used is fluidized-bed combustion (FBC). Fluidized-bed combustors have typically been used for combustion of other materials, but are beginning to be used with MSW. Fluffed or pelletized RDF (see RDF classifications in Table 3-1) is combusted on a turbulent bed of heated noncombustible material such as limestone, sand, silica, or aluminum. The bed is suspended or "fluidized" through introduction of underfire air at a high flow rate. Overfire air is used to complete combustion.

There are two basic types of FBC systems: bubbling bed combustors and circulating bed combustors. With bubbling bed combustors, most of the fluidized solids are maintained near the bottom of the combustor by using relatively low fluidization velocities. This helps prevent the entrainment of solids from the bed into the flue gas, minimizing recirculation or reinjection

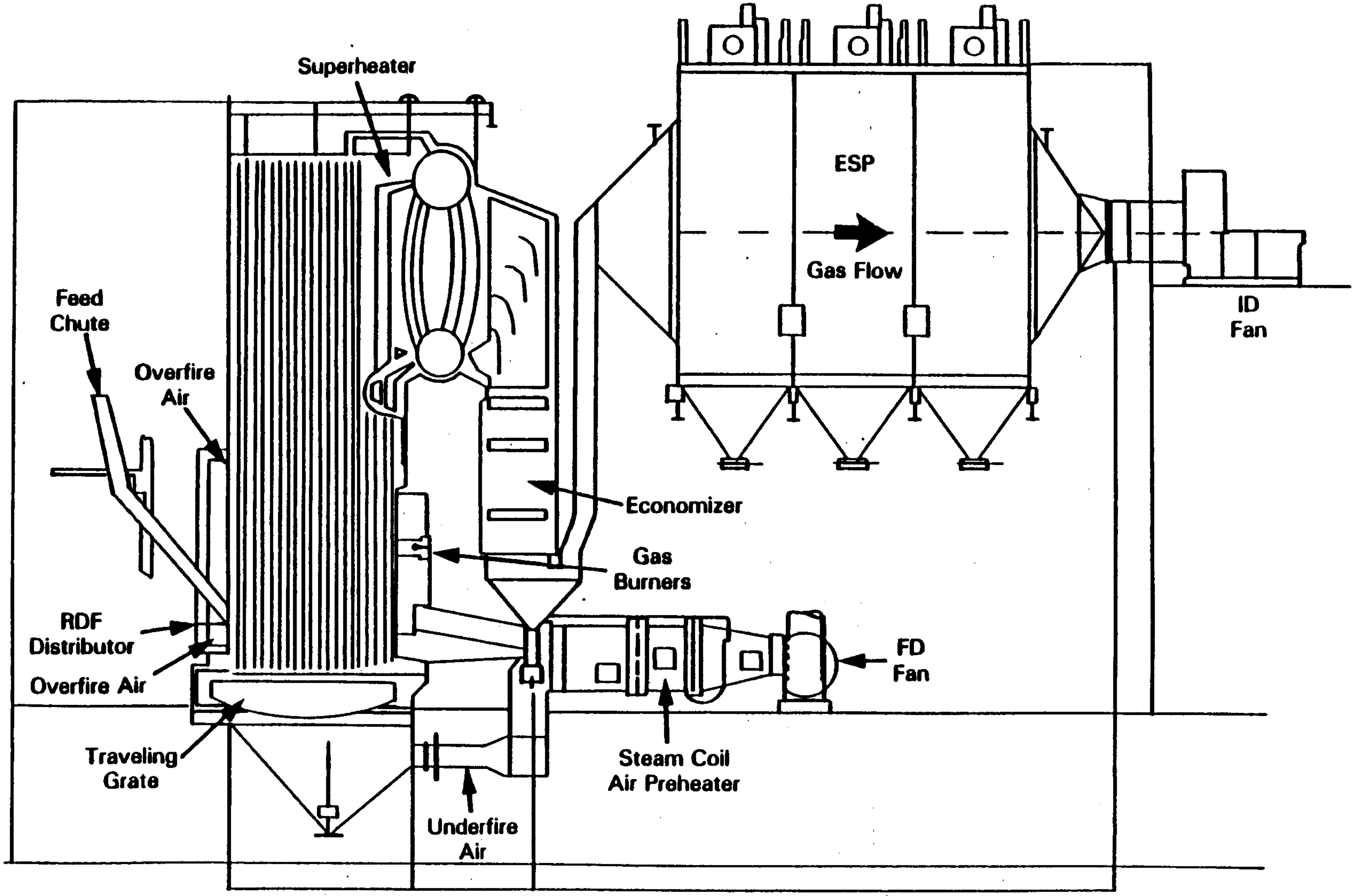

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Figure 3-10. Typical RDF-Fired Spreader Stoker Boiler of bed particles. Circulating bed combustors operate at relatively high fluidization velocities to promote carry-over of solids into the upper section of the combustor. Combustion occurs in both the bed and upper section of the combustor. By design, a fraction of the bed material is entrained in the combustion gas and enters a cyclone separator which recycles unburned waste and inert particles to the lower bed.

3.3 EMISSION CONTROL SYSTEMS

Refuse combustors have the potential to emit pollutants to the atmosphere at rates above EPA defined significant levels. One of these pollutants is particulate matter (PM), which is emitted because of the turbulent movement of the combustion gases with respect to the burning refuse and resultant ash. Particulate matter is also produced when metals that are volatilized in the combustion zone condense in the exhaust gas stream. The particle size distribution and concentration of the particulate emissions leaving the incinerator vary widely, depending on the composition of the refuse being burned and the type and operation of the combustion process.

Combustion of refuse under improper combustor design or operating conditions can result in emissions of intermediate products (e.g., volatile organic compounds, toxic organic compounds and carbon monoxide). Other potential emissions include hydrogen chloride (HCl), sulfur dioxide (SO_2), nitrogen oxides (NO_x), metals, and other acid gases. Acid gas and SO_2 emissions are a result of reaction of sulfur, chlorine, and fluorine in the feed. Metals are emitted when they are volatilized by the heat of combustion. Nitrogen oxides are formed during any combustion process and depend largely on combustion temperature and the nitrogen content of the fuel.

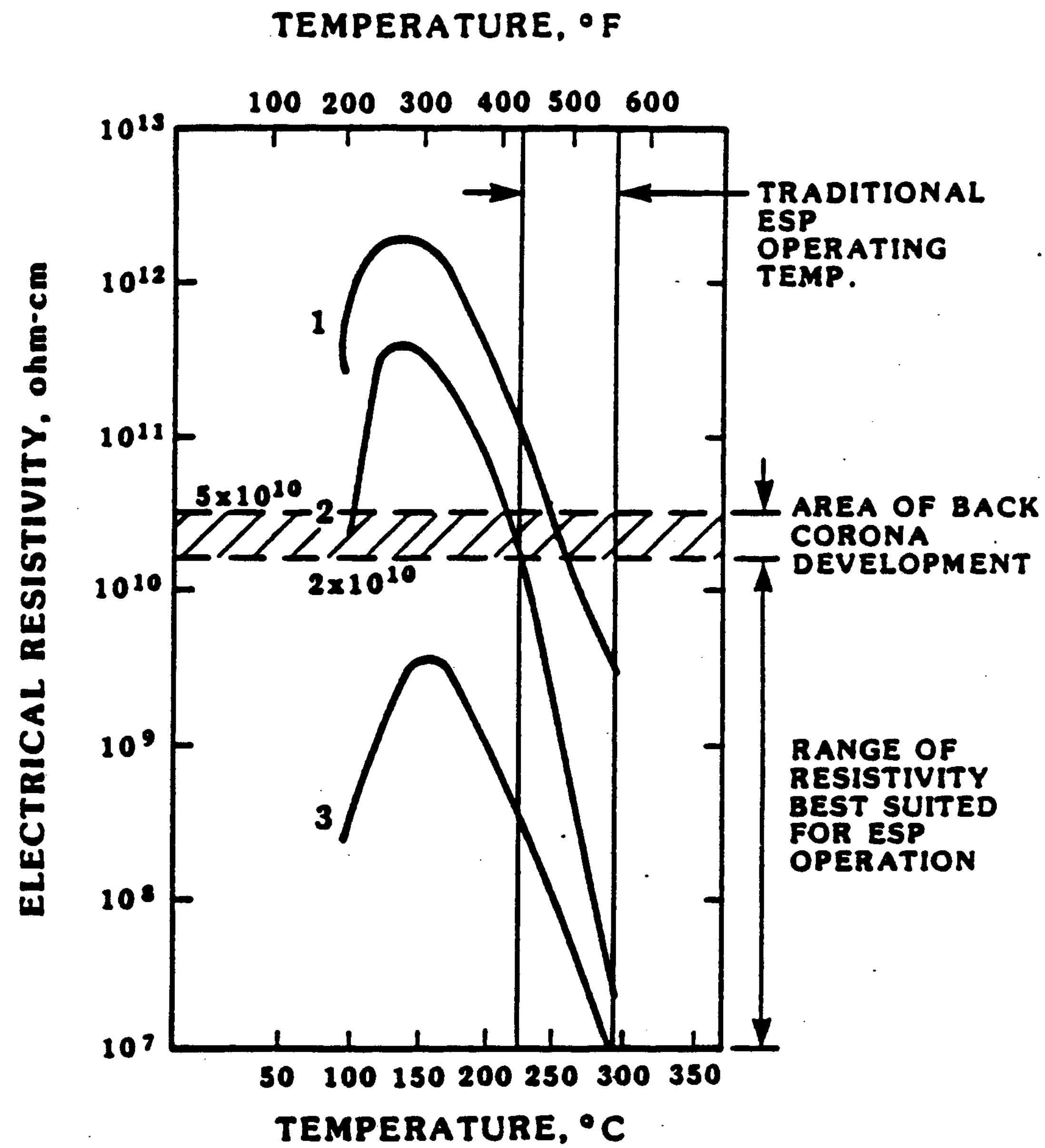
A wide variety of control technologies are used to control emissions from MWCs. For PM control, electrostatic precipitators are most frequently used, although other PM control devices (including fabric filters, cyclones, electrified gravel beds, and venturi scrubbers) are also used. Processes used for acid gas control include wet scrubbing, dry sorbent injection and spray drying (or semi-dry scrubbing). Both fabric filters and ESPs are used in combination with acid gas control devices for particulate removal.

3.3.1 PM Control Technologies

The most frequently used PM control devices are electrostatic precipitators and fabric filters. Although other PM control technologies (such as cyclones, electrified gravel beds, and venturi scrubbers) are used, they are infrequently used on systems currently installed and it is anticipated they will not be frequently used in future MWC systems. Therefore, the following discussion focuses on ESPs and fabric filters.

In electrostatic precipitators, flue gas flows between a series of high voltage (20 to 100 kv) discharge electrodes and grounded metal plates. Negatively charged ions formed by this high voltage field (known as a "corona") attach to PM in the flue gas, causing the charged particles to migrate toward the grounded plates. Once the charged particles are collected on the grounded plates, the resulting dust layer is removed from the plates by rapping, washing, or some other method and collected in a hopper. When the dust layer is removed, some of the collected PM becomes reentrained in the flue gas. To assure good PM collection efficiency during plate cleaning and electrical upsets, ESPs have several fields located in series along the direction of flue gas flow that can be energized and cleaned independently. Particles reentrained when the dust layer is removed from one field can be recollected in a downstream field.[6]

In general, fly ashes with resistivities between 1×10^8 and 5×10^{10} ohm-cm are most efficiently collected in ESPs. If the resistivity of the collected dust layer increases above roughly 2×10^{11} ohm-cm, the electrical charge of the collected dust layer is sufficient to create a "back corona" that significantly reduces collection efficiency by interfering with the migration of charged fly ash particles to the collecting electrode. At resistivities below 10^8 ohm-cm, the electrical charge of individual particles is so low that reentrainment of collected dust during electrode cleaning or by scouring from moving flue gas can become severe.[7] A graph of resistivity versus temperature for three MSW fly ashes is shown in Figure 3-11. As indicated in the figure, most ESPs on MWCs have traditionally operated at 440 to 550^{o}F (225 to 290^{o}C) to avoid potential problems with ash resistivity and acid gas corrosion.[8] However, individual ESPs with temperatures as low as



1 Samples taken at furnace outlet on a 250 ton/day municipal incinerator using a dry separation chamber for particulate control.

2 Samples taken at furnace outlet and exhaust stack inlet on a 250 ton/day municipal incinerator using a wet baffle cooling chamber for particulate control.

3 Samples taken at furnace outlet and exhaust stack outlet on a 120 ton/day municipal incinerator using a vertical wetted baffle particulate collection device.

Source: Walker, A.B. and Schmitz, Characteristics of Furnace Emissions from Large Mechanically-Stoked Municipal Incinerators, Research-Cottrell

Figure 3-11. Electrical Resistivity of Municipal Incinerator Dust[8]

$250^{o}F$ are currently operating in the U.S. as a result of being coupled with acid gas control. In addition, operating temperatures high as $600^{o}F$ are also found on individual units.

Small particles generally have lower migration velocities than large particles, and are therefore more difficult to collect. This factor is especially important to MWCs because of the large amount of total fly ash less than one micron. As compared to pulverized coal-fired combustors, in which only 1 to 3 percent of the fly ash is generally less than 1 micron, 20 to 70 percent of the fly ash at the ESP inlet for MWCs is reported to be less than 1 micron.[9] As a result, effective collection of PM from MWCs requires greater collection areas and lower flue gas velocities than many other fuels.

The most common types of ESPs used by MWCs are (1) plate-wire units in which the discharge electrode is a bottom-weighted or rigid wire and (2) flat plate units which use flat plates rather than wires as the discharge electrode. A typical plate-wire ESP is shown in Figure 3-12. Plate-wire ESPs generally are better suited for use with fly ashes with large amounts of small particulate and with large flue gas flow rates (>200,000 acfm). Flat plate units are less sensitive to back corona problems and are thus well suited for use with high resistivity PM.[10] Both of these ESP types have been widely used on MWCs in the U.S., Europe, and Japan.

The theoretical efficiency of PM removal by ESPs can be predicted using the Deutsch-Anderson equation:

$$\text{Collection Efficiency (\%)} = (1 - \exp(-Aw/V))100$$

where exp is the natural log (2.718...), A is the surface area of the collecting electrodes (ft^2), w is the effective migration velocity of individual PM particles toward the collecting electrode (ft/sec), and V is the actual flue gas flow rate (acfm). However, because of variations in the size and resistivity of individual particles in the flue gas, the effective migration velocity of bulk fly ash is not easily defined.

To account for these variations in PM characteristics, the modified Deutsch-Anderson equation is used:

$$\text{Collection Efficiency (\%)} = (1 - \exp(-Aw/V)^{k})100$$

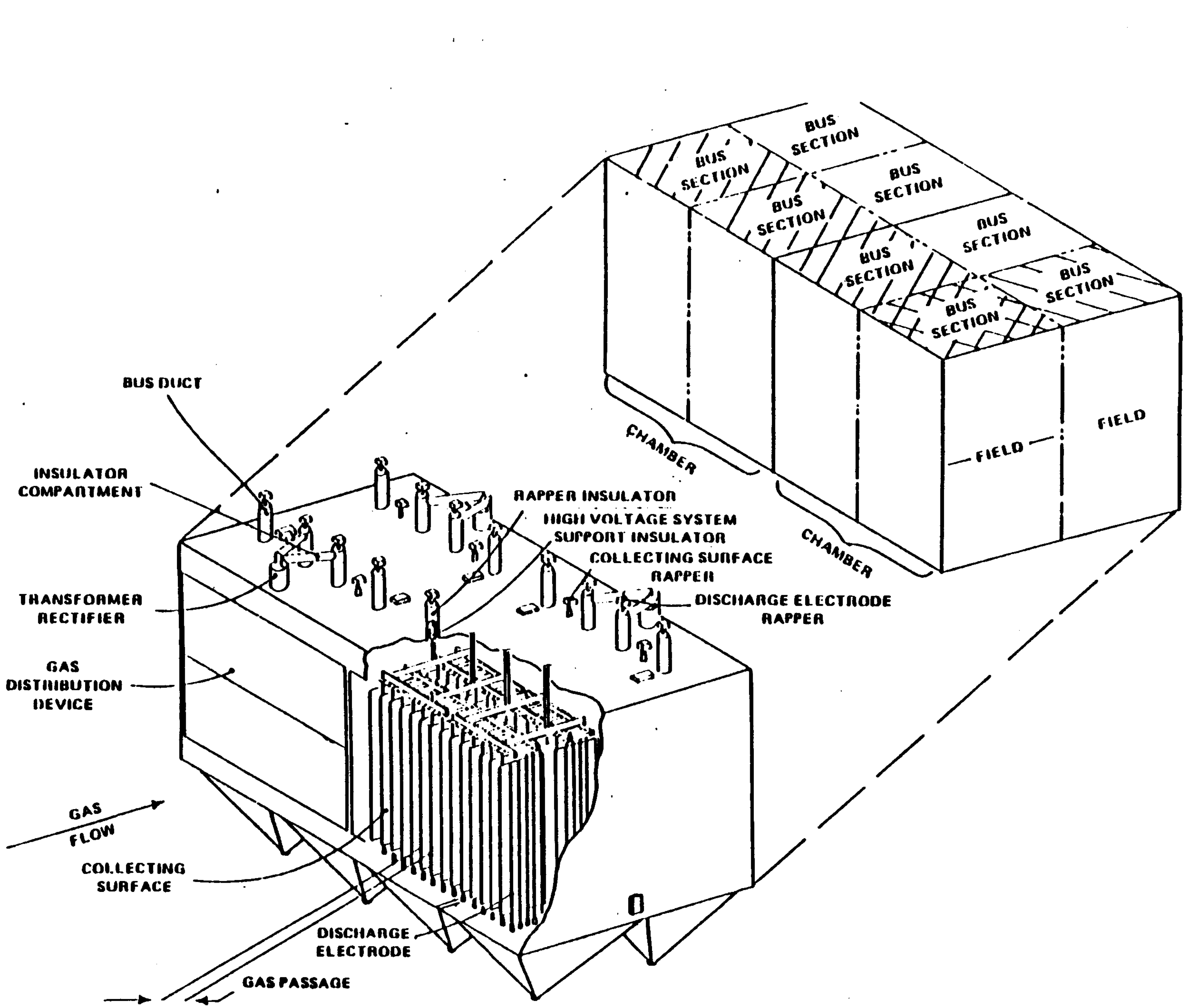


Figure 3-12. Typical Precipitator Cross-Section

where k is an empirically derived constant (generally around 0.5, but can vary between 0.4 and 0.8) that depends on the electrical resistivity and particle size of the fly ash.

As an approximate indicator of collection efficiency, the specific collection area (SCA) of an ESP is frequently used. The SCA is calculated by dividing the collecting electrode plate area by the actual flue gas flow rate (A/V in the Deutsch-Anderson equation) and is expressed as square feet of collecting area per 1,000 acfm of flue gas. In general, the higher the SCA, the higher the collection efficiency. Other factors that effect ESP efficiency include sneakage control, gas flow distribution, control of rapping losses, and electrical charging methods.

Fabric filters are also used for particulate control. They are frequently used in combination with acid gas control. When used following acid gas controls, fabric filters typically achieve greater than 99 percent removal of particulate. Additionally, the filter cake on fabric filters following acid gas controls can provide secondary acid gas removal because of the presence of unreacted sorbent.

Removal of particulate matter from the flue gas by fabric filters is achieved through five basic mechanisms: 1) inertial impaction, 2) Brownian diffusion, 3) direct interception, 4) electrostatic attraction, and 5) gravitational setting. The dominant collection mechanism is inertial impaction. As the particulate matter is collected on filter media, a particulate filter cake is formed, increasing the pressure drop across the filter. Once excessive pressure drop across the filter cake is reached, the filter is cleaned.

The effectiveness of the fabric filter depends on flue gas and filter characteristics, including 1) the air-to-cloth ratio (ratio of flue gas flow to filter surface area), and 2) the filter cleaning mechanism. The air-to-cloth ratio is optimized to give increased surface area without excess pressure drop. Collection efficiency increases for decreased air-to-cloth ratio. Two main filter cleaning mechanisms are used: reverse-air and pulse-jet. In a reverse-air fabric filter, flue gas flows through unsupported filter bags, leaving the particulate on the inside of the bags. The bags are cleaned by blowing air through the filter in the opposite direction of the flue gas flow, causing the filter bag to collapse. The filter cake falls off and is collected in the hopper located below the filter bags. In a pulse-jet fabric filter, flue gas flows through supported filter bags, leaving particulate on the outside of the bags. Compressed air is introduced at the top of the bag, causing the bag to expand and the filter cake to fall off. Because pulse-jet fabric filters remove more filter cake than reverse-air units during the cleaning cycle, pulse-jet filters can be operated at higher air-to-cloth ratios with equal removal efficiencies.

3.3.2 Acid Gas Control Technologies

The three most frequently used acid gas control technologies are wet scrubbing, dry sorbent injection, and spray drying. It is anticipated that all three of these technologies will be used on future MWC systems. A description of each of the technologies is provided in this section.

Spray drying is the most frequently used acid gas control technology for MWCs in the U.S. A typical spray drying system is shown in Figure 3-13. In the spray drying process, lime slurry is injected into the spray dryer (SD) through either two-fluid nozzles or a rotary atomizer; the water in the slurry evaporates to cool the flue gas and the lime reacts with acid gases to form salts that can be removed by a PM control device. The simultaneous evaporation and reaction increases the moisture and particulate content in the flue gas. The particulate exiting the SD contains fly ash plus calcium salts, water, and unreacted lime.

The key design and operating parameters that significantly affect SD performance are SD outlet temperature and lime-to-acid gas stoichiometric ratio. The SD outlet temperature is controlled by the amount of water in the slurry that is injected into the SD. More effective acid gas removal occurs at lower temperatures, but the temperature must be kept high enough to ensure the slurry and reaction products are adequately dried prior to collection in the PM control device. For MWC flue gas containing significant chlorine, a minimum SD outlet temperature of around 240^{o}F is required to control agglomeration of PM and sorbent by calcium chloride.[11] The stoichiometric ratio is the molar ratio of calcium fed to the theoretical amount of calcium required to react with the inlet hydrogen chloride (HCl) and SO_2. Sufficient lime is fed to react with the peak acid gas concentrations expected without

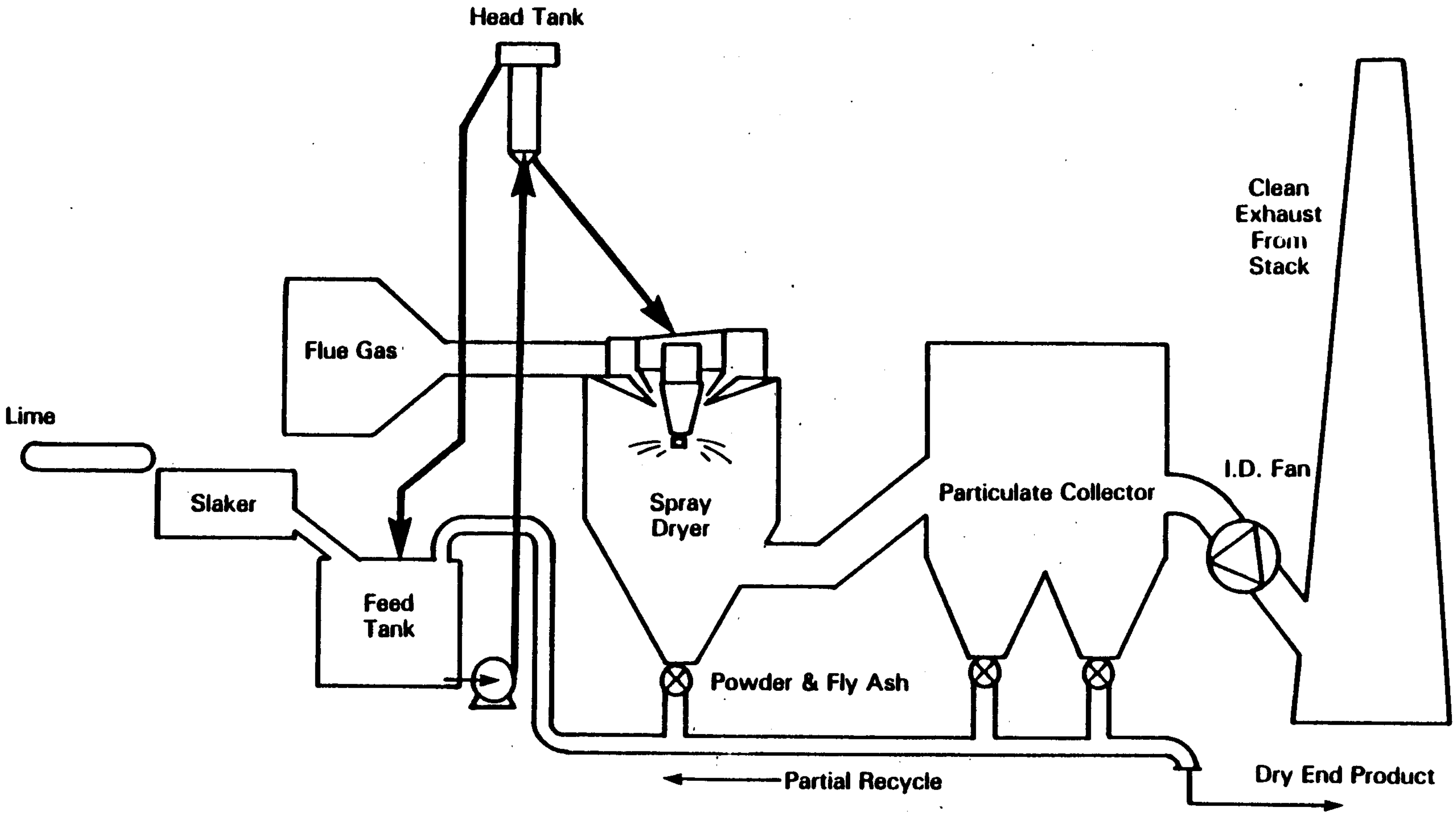


Figure 3-13. Typical Spray Dryer and Particulate Control System

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severely decreasing performance. The lime content in the slurry is generally about 10 percent by weight, but cannot exceed roughly 30 percent by weight without the lime slurry feed system and spray nozzles clogging.

Spray drying can be used in combination with either a fabric filter or an ESP for PM control. Both combinations have been used for MWCs in the U.S., although SD/fabric filter systems are more common. Removal efficiencies range from 50 to 90 percent for SO_2 and for 70 to 95 percent for HCl, with typical values of 70 percent for SO_2 and 90 to 95 percent for HCl. These removal efficiencies are based on stack tests using a grab sample approach. These tests are typically performed for compliance demonstration when the system is operated in an optimum fashion.

Many types of wet scrubbers have been used for controlling acid gas emissions from MWCs. These include spray towers, centrifugal scrubbers, and venturi scrubbers. No new MWCs are being built with wet scrubbers, however. In these devices, the flue gas enters the absorber where it is contacted with enough alkaline solution to saturate the gas stream. The alkaline solution, typically containing calcium hydroxide [$Ca(OH)_2$], reacts with the acid gas to form salts, which are generally insoluble and may be removed by sequential clarifying, thickening, and vacuum filtering. The dewatered salts or sludges are then landfilled. A schematic of a typical wet scrubbing system is shown in Figure 3-14.

Two dry sorbent injection technologies exist. The more widely used of these systems, referred to as duct sorbent injection (DSI), involves injecting dry alkali sorbents into flue gas downstream of the combustor outlet and upstream of the particulate control device. The second approach, referred to as furnace sorbent injection (FSI), injects sorbent directly into the combustor.

In DSI, powdered sorbent is pneumatically injected into either a separate reaction vessel or a section of flue gas duct located downstream of the combustor economizer. Alkali in the sorbent (generally calcium or sodium) reacts with HCl, SO_2, hydrogen fluoride (HF), and sulfur trioxide (SO_3) to form alkali salts (e.g., calcium chloride [$CaCl_2$], calcium fluoride [CaF_2], and calcium sulfite [$CaSO_3$]). By lowering the acid content of the flue gas, downstream equipment can be operated at reduced temperatures while minimizing

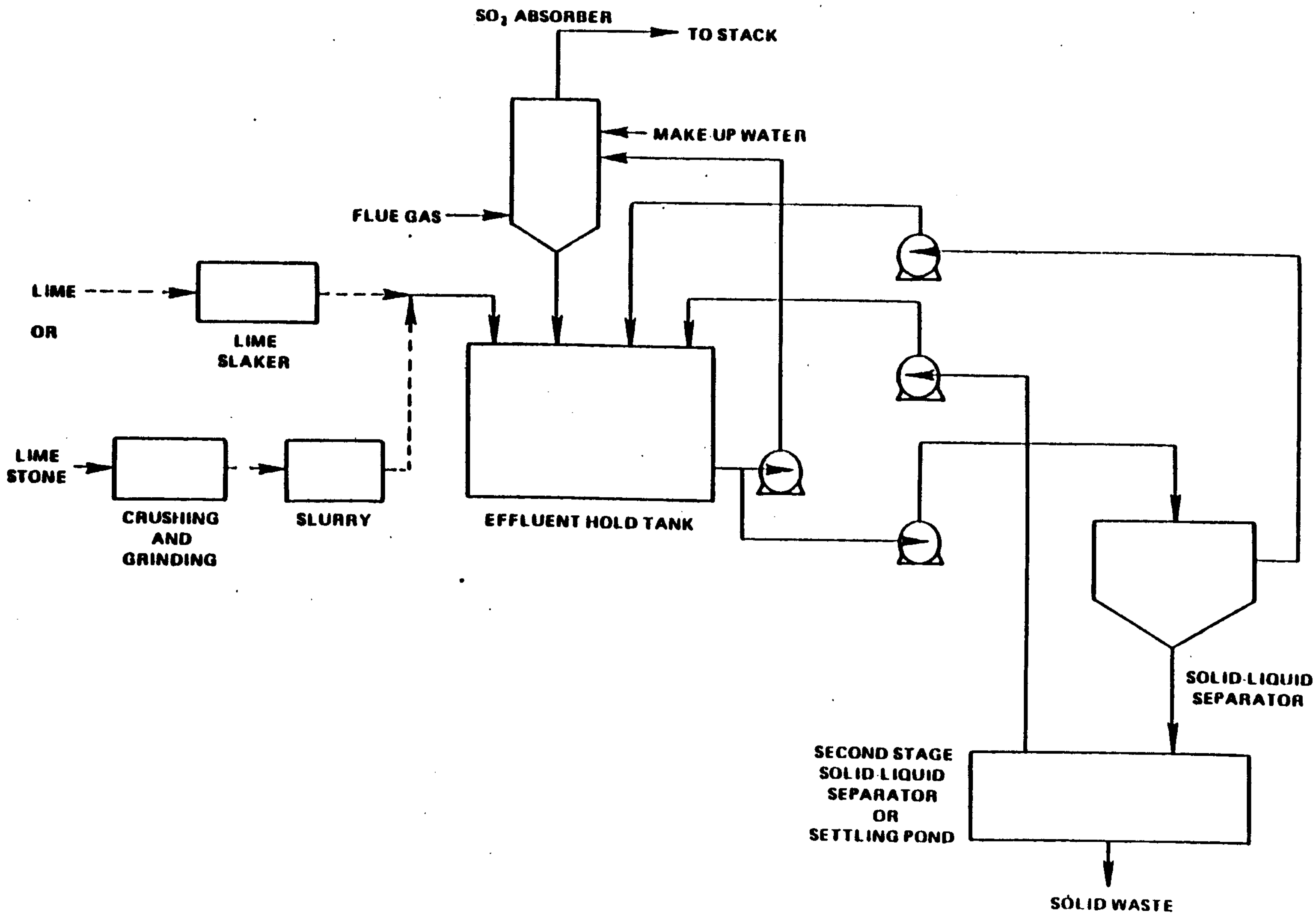

Figure 3-14. Process Flow Diagram for a Typical Lime or Limestone Wet Scrubbing System

the potential for acid corrosion of this equipment. Reaction products, fly ash, and unreacted sorbent are collected with either a fabric filter or ESP.

Acid gas removal efficiency with DSI depends on the method of sorbent injection, flue gas temperature, sorbent type and feed rate, and the extent of sorbent mixing with the flue gas. Flue gas temperature at the point of sorbent injection can range from 350 to 600^oF depending on the sorbent being used and the design of the process. Sorbents that have been successfully tested include hydrated lime ($Ca(OH)_2$), soda ash (NaOH), and sodium bicarbonate ($NaHCO_3$). Based on published data for hydrated lime, some DSI systems can achieve removal efficiencies comparable to spray dryers. Removals of 60 to 95 percent for HCl and 40 to 70 percent for SO_2 have been reported. Limestone ($CaCO_3$) has also been tested, but is relatively unreactive at temperatures of 350 to 600^oF.[12-17]

By combining flue gas cooling with DSI, it may be possible to increase the potential for removing dioxins and furans (CDD/CDF) which is believed to occur through a combination of vapor condensation and adsorption onto the sorbent surface. Cooling may also benefit PM control by decreasing the effective flue gas flow rate (i.e., acfm) and reducing the resistivity of the particles.

Furnace sorbent injection involves the injection of powdered alkali sorbents into the furnace section of a combustor. This can be accomplished by addition of sorbent to the overfire air, injection through separate ports, or mixing with the waste prior to feeding to the combustor. As with DSI, reaction products, flyash, and unreacted sorbent are collected using a fabric filter or ESP.

The basic chemistry of FSI--reaction of sorbent with acid gases to form alkali salts--is similar to DSI. However, several key differences exist in these two technologies. First, by injecting sorbent directly into the furnace (at temperatures of 1,600 to 2,200^oF) limestone can be calcined in the combustor to become more reactive (forms lime), thereby allowing use of less expensive (than hydrated lime or pebble lime) limestone as a sorbent.[18] Second, at these temperatures, SO_2 and lime react in the combustor, thus providing a mechanism for effective removal of SO_2 at relatively low sorbent feed rates. Third, by injecting sorbent into the furnace rather than into a downstream duct, additional time is available for mixing and reaction between the sorbent and acid gases. As a result, it may be possible to remove HCl and SO_2 from the flue gas at lower sorbent stoichiometric ratios than with DSI. Fourth, if a significant portion of the HCl is removed before the flue gas exits the combustor, it may be possible to reduce the chlorination of dioxins and furans (CDD/CDF) in latter sections of the flue gas ducting. However, HCl and lime do not react with each other at temperatures above 1,400^{o}F.[19] This is the flue gas temperature that exists in the heat exchanger sections of the combustor train.

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4. EMISSION FACTORS

Emission factors have been developed for the various pollutants emitted from MWCs. These factors relate the amount of pollutant emitted in the flue gas to the amount of waste combusted and may be used to estimate emissions from a facility. Flue gas emissions are the only significant source of air toxics emissions from municipal waste combustors. The estimated emissions should be used with caution, however, because the emission factors are generally averages from several facilities and are not necessarily representative of the emissions from any particular facility. Additionally, because of limited data, a representative number of facilities could not always be used in evaluating an emission factor. Also, variations in waste composition affect the resulting emissions. If more accurate emission factors are needed, source testing should be done. Data collected should include MSW input composition and rate, ash composition, and stack emissions. The actual air toxics emissions from any given facility are a function of variables such as capacity, throughput, operating characteristics, and air pollution control device operations. The effect of these factors need to be considered when testing.

In this document, emission factors are presented for acid gases including hydrogen chloride (HCl), hydrogen fluoride (HF), and sulfur trioxide (SO_3); metals including arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), mercury (Hg), and nickel (Ni); and organics including chlorinated dibenzo-p-dioxins and dibenzofurans (CDD and CDF), polychlorinated biphenyls (PCB), formaldehyde, benzo(a)pyrene (BaP), chlorinated benzene (CB), and chlorinated phenol (CP). Emission factors for lead, criteria pollutants, and volatile organic compounds (VOC) are presented in the EPA document, "Compilation of Air Pollutant Emission Factors, AP-42."[1]

Average emission factors for each pollutant were evaluated per combustor type (see Section 3.2) and emission control type (see Section 3.3). These overall averages were derived by combining the average emission factors for each facility of the same general combustor and emission control type. For facilities where multiple operating conditions were evaluated or multiple tests were performed over different years, the average emission factor from each test condition or test date was used in deriving the overall average per combustor and emission control type.

The individual emission factors at each facility were derived by dividing the mass emission rate of the pollutant by the measured or estimated waste feed rate. When a pollutant was not detected, the detection limit was used. Based on the theoretical nature of the F-factor and the lack of heating value data, this method was not used to calculate emission factors.

Emission factors for the different types of combustors and emission controls are presented in Sections 4.1 to 4.8.

4.1 EMISSION FACTORS FOR MASS BURN REFRACTORY-WALL COMBUSTORS

Emission factors for mass burn refractory-wall combustors are presented in Tables 4-1 and 4-2 in System International (SI) and English units, respectively. The emission factors are for uncontrolled flue gas emissions as well as controlled flue gas emissions. Emission factors for controlled emissions are separated by the different types of emission controls used with mass burn combustors which include: PM control only, and spray drying with PM control. These types of emission controls are described in detail in Section 3.

4.2 EMISSION FACTORS FOR OLDER MASS BURN WATERWALL COMBUSTORS

Emission factors for mass burn waterwall combustors built prior to 1980 are presented in Tables 4-3 and 4-4 in SI and English units, respectively. In general, state-of-the-art combustion technology was not widespread until the early 1980s. Because these older combustors are not able to provide as thorough combustion as recently installed units, uncontrolled emissions are generally higher than for new units, especially for organics. When combined with particulate control devices that are generally not as effective as new units, higher controlled emissions generally results as well. Because older units generally do not have acid gas controls, controlled emission factors are for PM control only. If acid gas and new PM controls were added later, the controlled emission factors would be expected to be similar to those for new units of the same size. An exception exists for the case of medium size units (250 to 800 tons/day). Older medium size units generally have emissions

TABLE 4-1. EMISSION FACTORS IN SI UNITS FOR MASS BURN REFRACTORY-WALL MUNICIPAL WASTE COMBUSTORS

rameter	Uncontrolled Average	Uncontrolled Range	References	After ESP Only Average	After ESP Only Range	References	After Acid Gas and PM Control: Spray Drying Average	Spray Drying Range	Dry Sorbent Injection[c] Average	Dry Sorbent Injection[c] Range	References
id Gases, kg/Mg											
HCl	-	- - -	-	1.4	0.63 - 2.1	2	0.031[a]	- - -	-	- - -	3
HF	0.0025[a]	- - -	3	0.041	0.023 - 0.050	4	0.0015[a]	- - -	-	- - -	3
SO_3	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
tals, mg/Mg											
Arsenic	200[a]	- - -	3	-	- - -	-	0.80[a]	- - -	-	- - -	3
Beryllium	150[a]	- - -	3	1.8	0.73 - 4.0	4	0.80[a]	- - -	-	- - -	3
Cadmium	-	- - -	-	-	- - -	-	55[a]	- - -	-	- - -	3
Chromium	8,000[a]	- - -	3	-	- - -	-	13[a]	- - -	-	- - -	3
Mercury	6,000[a]	- - -	3	5,600	4,300 - 6,700	4	450[a]	- - -	-	- - -	3
Nickel	7,000[a]	- - -	3	-	- - -	-	750[a]	- - -	-	- - -	3
ganics[b], ug/Mg											
2378-TCDD	-	- - -	-	50	49 - 50	2	-	- - -	-	- - -	-
2378-TCDF	-	- - -	-	180	140 - 210	2	-	- - -	-	- - -	-
Total TCDD	-	- - -	-	1,700	1,500 - 1,800	2	-	- - -	-	- - -	-
Total TCDF	-	- - -	-	3,800	3,000 - 4,500	2	-	- - -	-	- - -	-
CDD	-	- - -	-	12,000	12,000 - 12,000	2	-	- - -	-	- - -	-
CDF	-	- - -	-	13,000	12,000 - 14,000	2	-	- - -	-	- - -	-
PCB	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
Formaldehyde	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
B(a)P	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CB	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CP	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-

e data point only.

y to organics: 2378-TCDD = 2378-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin; Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins; CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene; CP = chlorinated phenol.

me applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-2. EMISSION FACTORS IN ENGLISH UNITS FOR MASS BURN REFRACTORY-WALL MUNICIPAL WASTE COMBUSTORS

rameter	Uncontrolled Average	Uncontrolled Range	References	After ESP Only Average	After ESP Only Range	References	After Acid Gas and PM Control: Spray Drying Average	Spray Drying Range	Dry Sorbent Injection[c] Average	Dry Sorbent Injection[c] Range	References
id Gases, lb/ton											
HCl	-	- - -	-	2.8	1.3 - 4.2	2	0.062[a]	- - -	-	- - -	3
HF	0.0050[a]	- - -	3	0.082	0.046 - 0.12	4	0.0030[a]	- - -	-	- - -	3
SO_3	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
tals, lb/ton x 10^6											
Arsenic	400[a]	- - -	3	-	- - -	-	1.6[a]	- - -	-	- - -	3
Beryllium	300[a]	- - -	3	3.6	1.5 - 8.0	4	1.6[a]	- - -	-	- - -	3
Cadmium	-	- - -	-	-	- - -	-	110[a]	- - -	-	- - -	3
Chromium	16,000[a]	- - -	3	-	- - -	-	26[a]	- - -	-	- - -	3
Mercury	12,000[a]	- - -	3	11,000	8,600 - 13,000	4	900[a]	- - -	-	- - -	3
Nickel	14,000[a]	- - -	3	-	- - -	-	1500[a]	- - -	-	- - -	3
ganics[b], lb/ton x10^9											
2378-TCDD	-	- - -	-	100	98 - 100	2	-	- - -	-	- - -	-
2378-TCDF	-	- - -	-	360	280 - 420	2	-	- - -	-	- - -	-
Total TCDD	-	- - -	-	3,400	3,000 - 3,600	2	-	- - -	-	- - -	-
Total TCDF	-	- - -	-	7,600	6,000 - 9,500	2	-	- - -	-	- - -	-
CDD	-	- - -	-	24,000	24,000 - 24,000	2	-	- - -	-	- - -	-
CDF	-	- - -	-	26,000	24,000 - 28,000	2	-	- - -	-	- - -	-
PCB	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
Formaldehyde	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
B(a)P	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CB	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CP	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-

e data point only.

y to organics: 2378-TCDD = 2378-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin;
Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins;
CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene;
CP = chlorinated phenol.

me applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-3. EMISSION FACTORS IN SI UNITS FOR OLDER MASS BURN WATERWALL MUNICIPAL WASTE COMBUSTORS[a]

rameter	Uncontrolled			After ESP Only			After Acid Gas and PM Control				
							Spray Drying		Dry Sorbent Injection[d]		
	Average	Range	References	Average	Range	References	Average	Range	Average	Range	References
id Gases, kg/Mg											
HCl	6.5[b]	-	5	1.5	1.1 - 1.9	6,7	-	-	1.8[b]	-	5
HF	0.009[b]	-	8	0.005[b]	-	7	-	-	-	-	-
SO_3	0.074[b]	-	8	-	-		-	-	-	-	-
als, mg/Mg											
Arsenic	4,000	420 - 7,500	8,9	610	130 - 1,100	7,9	-	-	-	-	-
Beryllium	0.24[b]	-	9	0.17	0.092 - 0.24	7,9	-	-	-	-	-
Cadmium	11,000	3,700 - 26,000	5,8,9	1,600	1,200 - 2,300	7,9,10	-	-	36[b]	-	5
Chromium	8,400	1,800 - 15,000	8,9	800	290 - 1,300	7,9	-	-	-	-	-
Mercury	700	83 - 18,000	5,8,9	5,200	110 - 10,700	7,9	-	-	1,100[b]	-	5
Nickel	10,000[b]	-	8	1,100[b]	-	7	-	-	-	-	-
anics[c], ug/Mg											
2378-TCDD	-	-	-	110	2.1 - 290	7,10-14	-	-	-	-	-
2378-TCDF	-	-	-	520	110 - 1,100	7,12-14	-	-	-	-	-
Total TCDD	-	-	-	1,400	32 - 3,000	6,7,10-14	-	-	-	-	-
Total TCDF	-	-	-	5,600	450 - 17,000	6,7,10-14	-	-	-	-	-
CDD	-	-	-	12,000	24,000 - 24,000	6,10-14	-	-	-	-	-
CDF	-	-	-	24,000	8,000 - 41,000	6,10-14	-	-	-	-	-
PCB	-	-	-	2,700	210 - 5,000	6,10,11	-	-	-	-	-
Formaldehyde	-	-	-	7,900[b]	-	7	-	-	-	-	-
B(a)P	-	-	-	4,800	42,000 - 54,000	7,11	-	-	-	-	-
CB	10,000[b]	-	10	410,000	8,900 - 1,400,000	6,7,10,12	-	-	-	-	-
CP	-	-	-	610,000	18,000 - 970,000	6,10,12	-	-	-	-	-

data in this table are from combustors built before 1980. Note: For medium size units (250-800 t/day) use Table 4-5 or 4-7.

data point only.

to organics: 2378-TCDD = 2738-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin;
Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins;
CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene;
CP = chlorinated phenol.

e applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-4. EMISSION FACTORS IN ENGLISH UNITS FOR OLDER MASS BURN WATERWALL MUNICIPAL WASTE COMBUSTORS[a]

	Uncontrolled			After ESP Only			After Acid Gas and PM Control				
							Spray Drying		Dry Sorbent Injection[d]		
meter	Average	Range	References	Average	Range	References	Average	Range	Average	Range	References
Gases, lb/ton											
HCl	13	- - -	5	3.8	2.2 - 3.8	6,7	-	- - -	3.6[b]	- - -	5
HF	0.018	- - -	8	0.010[b]	- - -	7	-	- - -	-	- - -	-
SO_3	0.15	- - -	8	-	- - -	-	-	- - -	-	- - -	
ls, lb/ton x 10^6											
Arsenic	8,000	840 - 15,000	8,9	1,200	260 - 2,200	7,9	-	- - -	-	- - -	-
Beryllium	0.48[b]	- - -	9	0.34	0.18 - 0.48	7,9	-	- - -	-	- - -	-
Cadmium	22,000	7,400 - 51,000	5,8,9	3,200	2,400 - 4,600	7,9,10	-	- - -	72[b]	- - -	5
Chromium	17,400	3,600 - 30,000	8,9	1,600	580 - 2,600	7,9	-	- - -	-	- - -	-
Mercury	1,400	170 - 3,600	5,8,9	10,000	220 - 20,000	7,9	-	- - -	2,200[b]	- - -	5
Nickel	20,000[b]	- - -	8	22,000[b]	- - -	7	-	- - -	-	- - -	-
ics[c], lb/ton x 10^9											
2378-TCDD	-	- - -	-	220	4.2 - 580	7,10-14	-	- - -	-	- - -	-
2378-TCDF	-	- - -	-	1,000	220 - 2,200	7,12-14	-	- - -	-	- - -	-
Total TCDD	-	- - -	-	2,800	64 - 6,000	6,7,10-14	-	- - -	-	- - -	-
Total TCDF	-	- - -	-	11,000	900 - 34,000	6,7,10-14	-	- - -	-	- - -	-
CDD	-	- - -	-	24,000	340 - 54,000	6,10-14	-	- - -	-	- - -	-
CDF	-	- - -	-	48,000	1,600 - 82,000	6,10-14	-	- - -	-	- - -	-
PCB	-	- - -	-	5,400	420 - 10,000	6,10,11	-	- - -	-	- - -	-
Formaldehyde	-	- - -	-	16,000[b]	- - -	7	-	- - -	-	- - -	-
B(a)P	-	- - -	-	96,000	84,000 - 110,000	7,11	-	- - -	-	- - -	-
CB	20,000[b]	- - -	10	820,000	18,000 - 2,800,000	6,7,10,12	-	- - -	-	- - -	-
CP	-	- - -	-	1,200,000	36,000 - 1,900,000	6,10,12	-	- - -	-	- - -	-

data in this table are from combustors built before 1988. Note: For medium size units (250-800 t/day) use Table 4-6 or 4-8.

data point only.

to organics: 2378-TCDD = 2378-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin;
Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins;
CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene;
CP = chlorinated phenol.

applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

comparable to newer medium size units. For medium size mass burn waterwall combustors, regardless of age, use the emission factors in Tables 4-5, 4-6, 4-7, or 4-8.

4.3 EMISSION FACTORS FOR NEW SMALL TO MEDIUM-SIZED MASS BURN WATERWALL COMBUSTORS

Emission factors for mass burn waterwall combustors built after 1980 and with capacities less than 600 ton/day are presented in Tables 4-5 and 4-6 in SI and English units, respectively. Emission factors are presented for uncontrolled and controlled emissions. The controlled emission factors are differentiated by type of emission control, which includes PM control only, dry sorbent injection with PM control, and spray drying with PM control.

4.4 EMISSION FACTORS FOR NEW LARGE MASS BURN WATERWALL COMBUSTORS

Emission factors for mass burn waterwall combustors built after 1980 and with capacities greater than 600 ton/day are presented in Tables 4-7 and 4-8 in SI and English units, respectively. Emission factors are for uncontrolled and controlled emissions. The controlled emission factors are differentiated by type of emission control, which includes PM control only and spray drying with PM control. Emission factors with dry sorbent injection and PM control are expected to be similar to those for spray drying and PM control.

4.5 EMISSION FACTORS FOR ROTARY-WATERWALL MASS BURN COMBUSTORS

Emission factors for rotary-waterwall mass burn combustors are presented in Tables 4-9 and 4-10 in SI and English units, respectively. Emission factor data are available for only two units and do not include any organics data. Uncontrolled and controlled emission factors are available for some pollutants, but are only for units with PM control. The emission factors for the pollutants without data are expected to be similar to the emission factors for mass burn waterwall combustors of similar size and with the same emission control.

4.6 EMISSION FACTORS FOR MODULAR STARVED-AIR COMBUSTORS

Emission factors for modular starved-air combustors are presented in Tables 4-11 and 4-12 in SI and English units, respectively. Emission factors are for uncontrolled and controlled emissions. The controlled emission factors reflect PM control only. Acid gas controls have been used on these

TABLE 4-5. EMISSION FACTORS IN SI UNITS FOR SMALL TO MEDIUM-SIZED MASS BURN WATERWALL MUNICIPAL WASTE COMBUSTORS[a]

Parameter	Uncontrolled			After ESP Only			After Acid Gas and PM Control				
							Spray Drying		Dry Sorbent Injection[d]		
	Average	Range	References	Average	Range	References	Average	Range	Average	Range	References
Acid Gases, kg/Mg											
HCl	4.5	3.1 - 5.9	15-19	3.4	2.4 - 4.5	20-22	0.21	0.069 - 0.48	0.56	0.17 - 1.1	15-19,23,24
HF	-	- - -	-	0.023	0.022 - 0.024	22	0.0010	0.00016 - 0.0019	-	- - -	16,17
SO_3	1.2[b]	- - -	19	0.063	0.039 - 0.086	20,22	0.28[b]	- - -	-	- - -	19
Metals, mg/Mg											
Arsenic	-	- - -	-	21	5.2 - 35	21	1.0[b]	- - -	0.020[b]	- - -	19,24
Beryllium	-	- - -	-	0.012[b]	- - -	22	0.0065	0.0019 - 0.0019	-	- - -	19,25
Cadmium	4,100[b]	- - -	17	250	91 - 410	21	24	12 - 35	20[b]	- - -	17,19,24
Chromium	1,600[b]	- - -	17	64	32 - 99	21	2,000	0.73 - 4,000	1.0[b]	- - -	17,19,24
Mercury	1,400[b]	- - -	16	3,200	1,800 - 4,300	21,22	1,300	1,100 - 1,400	-	- - -	16,25
Nickel	47[b]	- - -	17	34	22 - 40	21	960	14 - 1,900	0.83[b]	- - -	17,19,24
Organics[c], ug/Mg											
2378-TCDD	1.4[b]	- - -	17	0.85	0.40 - 1.3	20,22	0.29[b]	- - -	0.29	0.051 - 0.52	17,23,24,58
2378-TCDF	18	- - -	17	10	9.5 - 11	20,22	0.28[b]	- - -	4.4	0.71 - 15	17,23,24,58
Total TCDD	3.4[b]	- - -	17	16	6.3 - 26	20,22	0.74[b]	- - -	10	5.4 - 12	17,23,24,58
Total TCDF	34[b]	- - -	17	110	29 - 200	20,22	1.3[b]	- - -	51	27 - 110	17,23,24,58
CDD	93[b]	- - -	17	500	75 - 1,500	20-22	4.5[b]	- - -	72	56 - 96	17,23,24,58
CDF	55[b]	- - -	17	690	61 - 1,600	20-22	1.7[b]	- - -	99	73 - 170	17,23,24,58
PCB	-	- - -	-	19,000	8,800 - 34,000	21	-	- - -	-	- - -	-
Formaldehyde	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
B(a)P	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CB	-	- - -	-	29,000	12,000 - 52,000	21	-	- - -	-	- - -	-
CP	-	- - -	-	67,000	22,000 - 130,000	21	-	- - -	-	- - -	-

[a] Data are from combustors built after 1980 and having capacities of 600 tpd or less.

[b] One data point only.

[c] Key to organics: 2378-TCDD = 2378-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin; Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins; CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene; CP = chlorinated phenol.

[d] Some applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-6. EMISSION FACTORS IN ENGLISH UNITS FOR SMALL TO MEDIUM-SIZED MASS BURN WATERWALL MUNICIPAL WASTE COMBUSTORS[a]

rameter	Uncontrolled		References	After ESP Only		References	After Acid Gas and PM Control				References
							Spray Drying		Dry Sorbent Injection[d]		
	Average	Range		Average	Range		Average	Range	Average	Range	
id Gases, lb/ton											
HCl	9.0	6.2 - 12	15-19	6.8	4.8 - 9.8	20-22	0.42	0.14 - 0.96	1.1	0.34 - 2.2	15-19,23,24
HF	-	- - -	-	0.046	0.044 - 0.048	22	0.0020	0.00032 - 0.0038	-	- - -	16,17
SO_3	2.4[b]	- - -	19	0.13	0.078 - 0.17	20,22	0.56[b]	- - -	-	- - -	19
tals, lb/ton x 10^6											
Arsenic	-	- - -	-	42	10 - 70	21	3.6[b]	- - -	0.040[b]	- - -	19,24
Beryllium	-	- - -	-	0.024[b]	- - -	22	0.013	0.0038 - 0.022	-	- - -	19,25
Cadmium	8,200[b]	- - -	17	500	180 - 820	21	48	24 - 70	4.0[b]	- - -	17,19,24
Chromium	3,200[b]	- - -	17	130	64 - 200	21	4,000	1.5 - 8,000	3.6[b]	- - -	17,19,24
Mercury	2,800[b]	- - -	16	6,400	3,600 - 8,600	21,22	2,600	2,200 - 2,800	-	- - -	16,25
Nickel	94[b]	- - -	17	68	44 - 80	21	1,900	28 - 3,800	1.7[b]	- - -	17,19,24
anics[c], lb/ton x 10^9											
2378-TCDD	2.8[b]	- - -	17	1.7	0.80 - 2.6	20,22	0.58[b]	- - -	0.58	0.10 - 1.0	17,23,24,58
2378-TCDF	36	- - -	17	20	19 - 22	20,22	0.56[b]	- - -	8.8	1.4 - 30	17,23,24,58
Total TCDD	6.4[b]	- - -	17	32	13 - 52	20,22	1.5[b]	- - -	20	11 - 24	17,23,24,58
Total TCDF	64[b]	- - -	17	220	58 - 400	20,22	2.6[b]	- - -	100	54 - 220	17,23,24,58
CDD	190[b]	- - -	17	1,800	150 - 3,000	20-22	9.0[b]	- - -	140	110 - 190	17,23,24,58
CDF	110[b]	- - -	17	1,400	120 - 3,200	20-22	3.4[b]	- - -	200	150 - 340	17,23,24,58
PCB	-	- - -	-	38,000	1,800 - 68,000	21	-	- - -	-	- - -	-
Formaldehyde	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
B(a)P	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CB	-	- - -	-	58,000	24,000 - 100,000	21	-	- - -	-	- - -	-
CP	-	- - -	-	130,000	44,000 - 260,000	21	-	- - -	-	- - -	-

a are from combustors built after 1980 and having capacities of 600 tpd or less.

data point only.

to organics: 2378-TCDD = 2738-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin; Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins; CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene; CP = chlorinated phenol.

e applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-7. EMISSION FACTORS IN SI UNITS FOR LARGE MASS BURN WATERWALL MUNICIPAL WASTE COMBUSTORS[a]

Parameter	Uncontrolled Average	Uncontrolled Range	References	After ESP Only Average	After ESP Only Range	References	After Acid Gas and PM Control: Spray Drying Average	Spray Drying Range	Dry Sorbent Injection[e] Average	Dry Sorbent Injection[e] Range	References
Acid Gases, kg/Mg											
HCl	4.2	3.3 - 5.5	26,27	2.9	0.96 - 4.7	26,28,29,57	0.11	0.042 - 0.17	-	-	27
HF	-	-	-	0.038	0.024 - 0.055	28,29,57	0.0047	0.00039 - 0.0055	-	-	27
SO_3	-	-	-	-	-	-	0.063	0.060 - 0.065	-	-	27
Metals, mg/Mg											
Arsenic	1,400[b]	-	30	22	13 - 30	28,30	19	17 - 21	-	-	27
Beryllium	-	-	-	0.062[b]	-	28	2.0[c]	1.9[c] - 2.0[c]	-	-	27
Cadmium	-	-	-	90	29 - 150	28,29	88	80 - 95	-	-	27
Chromium	11,000[b]	-	30	59	17 - 100	28,30	350	220 - 480	-	-	27
Mercury	-	-	-	3,200[b]	-	28	3,500	2,600 - 4,400	-	-	27
Nickel	-	-	-	9.4[b]	-	28	88	65 - 110	-	-	27
Organics[d], ug/Mg											
2378-TCDD	2.9	0.57 - 7.2	26,28,31,59	1.2	0.27 - 5.0	26,28,31,32	0.35[b]	-	-	-	27
2378-TCDF	45	3.4 - 54	26,28,31,59	34	3.6 - 100	26,28,31,32	3.0[b]	-	-	-	27
Total TCDD	39	11 - 80	26,28,31,59	11	4.6 - 14	26,28,31,32	5.5[b]	-	-	-	27
Total TCDF	330	66 - 710	26,28,31,59	200	82 - 400	26,28,31,32	76[b]	-	-	-	27
CDD	440	93 - 750	26,28,31,59	370	130 - 970	26,28,31,32	56[b]	-	-	-	27
CDF	840	130 - 1,800	26,28,31,59	520	120 - 1,100	26,28,31,32	185[b]	-	-	-	27
PCB	13,000[b,c]	-	25	13,000[b,c]	-	26	-	-	-	-	-
Formaldehyde	-	-	-	2,500,000[b]	-	32	-	-	-	-	-
B(a)P	61,000[b,c]	-	25	61,000[b,c]	-	26	-	-	-	-	-
CB	3,200[b,c]	-	25	3,200	2,800 - 3,500	26,28	-	-	-	-	-
CP	6,300[b,c]	-	25	4,600	4,000 - 5,200	26,28	-	-	-	-	-

[a] Data are from combustors built after 1980 with capacities greater than 600 tpd.

[b] One data point only.

[c] Not detected. Detection limits reported.

[d] Key to organics: 2378-TCDD = 2378-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin; Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins; CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene; CP = chlorinated phenol.

[e] Some applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-8. EMISSION FACTORS IN ENGLISH UNITS FOR LARGE MASS BURN WATERWALL MUNICIPAL WASTE COMBUSTORS[a]

arameter	Uncontrolled		References	After ESP Only		References	After Acid Gas and PM Control				
							Spray Drying		Dry Sorbent Injection[e]		
	Average	Range		Average	Range		Average	Range	Average	Range	References
cid Gases, lb/ton											
HCl	8.4	6.6 - 11	26,27	5.8	1.9 - 9.4	26,28,29,57	0.22	0.084 - 0.34	-	- - -	27
HF	-	- - -	-	0.076	0.048 - 0.11	28,29,57	0.0094	0.0078 - 0.011	-	- - -	27
SO_3	-	- - -	-	-	- - -	-	0.13	0.12 - 0.13	-	- - -	27
etals, lb/ton x 10^6											
Arsenic	2,800[b]	- - -	30	44	26 - 60	28,30	38	34 - 42	-	- - -	27
Beryllium	-	- - -	-	0.12[b]	- - -	28	4.0[c]	3.8[c] - 4.8[c]	-	- - -	27
Cadmium	-	- - -	-	180	58 - 300	28,29	180	160 - 190	-	- - -	27
Chromium	22,000[b]	- - -	30	120	34 - 200	28,30	700	440 - 960	-	- - -	27
Mercury	-	- - -	-	6,400[b]	- - -	28	7,000	5,200 - 8,800	-	- - -	27
Nickel	-	- - -	-	19[b]	- - -	28	180	130 - 220	-	- - -	27
rganics[d], lb/ton x 10^9											
2378-TCDD	5.8	1.1 - 14	26,28,31,59	2.4	0.54 - 10	26,28,31,32	0.70[b]	- - -	-	- - -	27
2378-TCDF	90	6.8 - 110	26,28,31,59	68	7.2 - 200	26,28,31,32	6.0[b]	- - -	-	- - -	27
Total TCDD	78	22 - 160	26,28,31,59	22	9.2 - 28	26,28,31,32	11[b]	- - -	-	- - -	27
Total TCDF	660	130 - 1,400	26,28,31,59	400	160 - 800	26,28,31,32	150[b]	- - -	-	- - -	27
CDD	880	190 - 1,500	26,28,31,59	740	250 - 1,900	26,28,31,32	110[b]	- - -	-	- - -	27
CDF	1,700	260 - 3,600	26,28,31,59	1,000	420 - 2,300	26,28,31,32	370[b]	- - -	-	- - -	27
PCB	26,000[b,c]	- - -	26	26,000[b,c]	- - -	26	-	- - -	-	- - -	-
Formaldehyde	-	- - -	-	5,000,000[b]	- - -	32	-	- - -	-	- - -	-
B(a)P	120,000[b,c]	- - -	26	120,000[b,c]	- - -	26	-	- - -	-	- - -	-
CB	6,400[b,c]	- - -	26	6,400	5,600 - 7,000	26,28	-	- - -	-	- - -	-
CP	13,000[b,c]	- - -	26	9,200	8,000 - 10,000	26,28	-	- - -	-	- - -	-

ata are from combustors built after 1980 with capacities greater than 600 tpd.

ne data point only.

ot detected. Detection limit given.

y to organics: 2378-TCDD = 2378-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin;
Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins;
CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene;
CP = chlorinated phenol.

me applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-9. EMISSION FACTORS IN SI UNITS FOR MASS BURN ROTARY-WATERWALL MUNICIPAL WASTE COMBUSTORS

rameter	Uncontrolled			After ESP Only			After Acid Gas and PM Control				
							Spray Drying		Dry Sorbent Injection[c]		
	Average	Range	References	Average	Range	References	Average	Range	Average	Range	References
d Gases, kg/Mg											
HCl	2.6[a]	- - -	33	3.2[a]	- - -	34	-	- - -	-	- - -	-
HF	0.016[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
SO_3	1.0[a]	- - -	33	0.83[a]	- - -	34	-	- - -	-	- - -	-
als, mg/Mg											
Arsenic	1,600[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
Beryllium	24[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
Cadmium	12,000[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
Chromium	3,900[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
Mercury	860[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
Nickel	170[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
anics[b], ug/Mg											
2378-TCDD	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
2378-TCDF	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
Total TCDD	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
Total TCDF	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CDD	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CDF	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
PCB	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
Formaldehyde	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
B(a)P	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CB	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CP	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-

e data point only.

y to organics: 2378-TCDD = 2738-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin;
Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins;
CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene;
CP = chlorinated phenol.

e applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-10. EMISSION FACTORS IN ENGLISH UNITS FOR MASS BURN ROTARY-WATERWALL MUNICIPAL WASTE COMBUSTORS

ameter	Uncontrolled			After ESP Only			After Acid Gas and PM Control				
							Spray Drying		Dry Sorbent Injection[c]		
	Average	Range	References	Average	Range	References	Average	Range	Average	Range	References
d Gases, lb/ton											
HCl	5.2[a]	- - -	33	6.4	- - -	34	-	- - -	-	- - -	-
HF	0.032[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
SO_3	2.0[a]	- - -	33	1.7	- - -	34	-	- - -	-	- - -	-
als, lb/ton x 10^6											
Arsenic	3,200[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
Beryllium	48[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
Cadmium	24,000[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
Chromium	7,800[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
Mercury	1,700[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
Nickel	340[a]	- - -	33	-	- - -	-	-	- - -	-	- - -	-
nics[b], lb/ton x 10^9											
2378-TCDD	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
2378-TCDF	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
Total TCDD	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
Total TCDF	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CDD	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CDF	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
PCB	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
Formaldehyde	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
B(a)P	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CB	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CP	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-

data point only.

to organics: 2378-TCDD = 2738-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin; Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins; CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene; CP = chlorinated phenol.

e applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-11. EMISSION FACTORS IN SI UNITS FOR MODULAR STARVED-AIR MUNICIPAL WASTE COMBUSTORS

ameter	Uncontrolled Average	Uncontrolled Range	References	After ESP Only Average	After ESP Only Range	References	After Acid Gas and PM Control: Spray Drying Average	Spray Drying Range	Dry Sorbent Injection[d] Average	Dry Sorbent Injection[d] Range	References
d Gases, kg/Mg											
HCl	3.1	0.93 - 4.4	35-37	4.6	2.6 - 8.3	38-40	-	- - -	-	- - -	-
HF	0.034	0.0040 - 0.049	35,36	-	- - -	-	-	- - -	-	- - -	-
SO_3	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
als, mg/Mg											
Arsenic	170	26 - 500	35-37,41	98	22 - 160	38-41	-	- - -	-	- - -	-
Beryllium	1.3	0.43 - 1.8	35,37,42	0.32	0.22 - 0.41	39-40	-	- - -	-	- - -	-
Cadmium	2,700	1,000 - 3,800	35-37,42	400	83 - 870	38-40	-	- - -	-	- - -	-
Chromium	780	17 - 3,600	35-37,41,42	100	14 - 190	38-41	-	- - -	-	- - -	-
Mercury	2,400	560 - 3,600	35-37	4,100	2,600 - 5,600	39,40	-	- - -	-	- - -	-
Nickel	1,500	31 - 3,900	35,37,42	110	8.3 - 320	38,40	-	- - -	-	- - -	-
anics[a], ug/Mg											
2378-TCDD	4.4	2.3 - 6.5	35,37	6.0	0.08 - 12[b]	39,40	-	- - -	-	- - -	-
2378-TCDF	12[c]	- - -	37	1,300	3.4 - 2,500	39,40	-	- - -	-	- - -	-
Total TCDD	28	4.8 - 81	35-37	910	13 - 1,800	39,40	-	- - -	-	- - -	-
Total TCDF	220	43 - 530	35-37	7,600	110 - 15,000	39,40	-	- - -	-	- - -	-
CDD	370	230 - 520	36,37	33,000	570 - 65,000	39,40	-	- - -	-	- - -	-
CDF	270	97 - 860	36,37	37,000	510 - 74,000	39,40	-	- - -	-	- - -	-
PCB	2,500	250 - 5,700	36,37	-	- - -	-	-	- - -	-	- - -	-
Formaldehyde	1,400	140 - 2,600	35,37	1,500[c]	- - -	39	-	- - -	-	- - -	-
B(a)P	3,900[c]	- - -	37	-	- - -	-	-	- - -	-	- - -	-
CB	17,000	13,000 - 22,000	36	-	- - -	-	-	- - -	-	- - -	-
CP	18,000	11,000 - 29,000	36	-	- - -	-	-	- - -	-	- - -	-

to organics: 2378-TCDD = 2378-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin; Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins; CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene; CP = chlorinated phenol.

detected. Detection limit given.

data point only.

applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-12. EMISSION FACTORS IN ENGLISH UNITS FOR MODULAR STARVED-AIR MUNICIPAL WASTE COMBUSTORS

Parameter	Uncontrolled Average	Uncontrolled Range	References	After ESP Only Average	After ESP Only Range	References	After Acid Gas and PM Control: Spray Drying Average	Spray Drying Range	Dry Sorbent Injection[d] Average	Dry Sorbent Injection[d] Range	References
Acid Gases, lb/ton											
HCl	6.2	1.9 - 8.8	35-37	9.2	5.2 - 17	38-40	-	- -	-	- -	-
HF	0.068	0.0080 - 0.098	35,36	-	- -	-	-	- -	-	- -	-
SO_3	-	- -	-	-	- -	-	-	- -	-	- -	-
etals, lb/ton x 10^6											
Arsenic	340	52 - 1,000	35-37,41	200	44 - 330	38-41	-	- -	-	- -	-
Beryllium	2.6	0.86 - 3.6	35,37,42	0.64	0.44 - 0.82	39-40	-	- -	-	- -	-
Cadmium	5,400	2,000 - 7,600	35-37,42	800	170 - 1,700	38-40	-	- -	-	- -	-
Chromium	1,600	34 - 7,200	35-37,41,42	200	28 - 380	38-41	-	- -	-	- -	-
Mercury	4,800	1,100 - 7,200	35-37	8,200	5,200 - 11,000	39,40	-	- -	-	- -	-
Nickel	3,000	62 - 7,800	35,37,42	220	17 - 640	38,40	-	- -	-	- -	-
rganics[a], lb/ton x 10^9											
2378-TCDD	8.8	4.6 - 13	35,37	12.0	0.16 - 24[b]	39,40	-	- -	-	- -	-
2378-TCDF	24[c]	- -	37	2,600	6.8 - 5,000	39,40	-	- -	-	- -	-
Total TCDD	56	8.0 - 160	35-37	1,800	26 - 3,600	39,40	-	- -	-	- -	-
Total TCDF	440	86 - 1,100	35-37	15,000	220 - 30,000	39,40	-	- -	-	- -	-
CDD	740	460 - 1,000	36,37	66,000	1,100 - 130,000	39,40	-	- -	-	- -	-
CDF	540	190 - 1,700	36,37	74,000	1,000 - 150,000	39,40	-	- -	-	- -	-
PCB	5,000	500 - 11,000	36,37	-	- -	-	-	- -	-	- -	-
Formaldehyde	2,800	280 - 5,200	35,37	3,000[c]	- -	39	-	- -	-	- -	-
B(a)P	7,800[c]	- -	37	-	- -	-	-	- -	-	- -	-
CB	34,000	26,000 - 44,000	36	-	- -	-	-	- -	-	- -	-
CP	36,000	22,000 - 58,000	36	-	- -	-	-	- -	-	- -	-

ey to organics: 2378-TCDD = 2378-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin;
Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins;
CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene;
CP = chlorinated phenol.

ot detected. Detection limit given.

ne data point only.

ome applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

systems, but no data are currently available. Emission factors for a modular starved-air unit with acid gas and PM control are expected to be similar to the results from a modular excess-air unit.

4.7 EMISSION FACTORS FOR MODULAR EXCESS-AIR COMBUSTORS

Emission factors for modular excess-air combustors are presented in Tables 4-13 and 4-14 in SI and English units, respectively. Emission factors are for uncontrolled and controlled emissions. The controlled emission factors are differentiated by type of emission control, which includes PM control only and dry sorbent injection with PM control. Emission factors for a system with spray drying and PM control are anticipated to be similar to the emission factors for dry sorbent injection with PM control.

4.8 EMISSION FACTORS FOR RDF COMBUSTORS

Emission factors for RDF combustors are presented in Tables 4-5 and 4-6 in SI and English units, respectively. These emission factors are for systems combusting 100 percent RDF and do not cover systems which co-fire RDF with other fuels. The emission factors are for uncontrolled and controlled flue gas emissions and represent the amount of pollutant emitted per amount of RDF combusted. The uncontrolled flue gas emission factors are not differentiated by the different types of RDF and RDF combustors described in Section 3.2.3. Different types of RDF may be fired in the same combustor type. The controlled flue gas emission factors are for systems with PM control only and for system with spray drying and PM control.

4.9 OTHER COMBUSTOR TYPES

Emission factors for the other combustor type described in Section 3.2.4, fluidized-bed combustors, have not been separately prepared because of insufficient data. The expected emissions from a fluidized bed combustor cannot be quantified with the available data.

TABLE 4-13. EMISSION FACTORS IN SI UNITS FOR MODULAR EXCESS-AIR MUNICIPAL WASTE COMBUSTORS

Parameter	Uncontrolled		References	After ESP Only		References	After Acid Gas and PM Control				
							Spray Drying		Dry Sorbent Injection[d]		
	Average	Range		Average	Range		Average	Range	Average	Range	References
Acid Gases, kg/Mg											
HCl	2.1	0.35 - 4.6	43,44	3.4	1.9 - 4.6	45,46	-	- - -	0.0032[a]	- - -	47
HF	0.00083[a]	- - -	43	-	- - -	-	-	- - -	-	- - -	-
SO_3	3.3[a]	- - -	43	0.36	0.35 - 0.37	45	-	- - -	-	- - -	-
Metals, mg/Mg											
Arsenic	-	- - -	-	4.5	4.3 - 4.6	45-46	-	- - -	0.000050[a]	- - -	47
Beryllium	-	- - -	-	9.6[b]	2.1[b] - 17[b]	45-46	-	- - -	-	- - -	-
Cadmium	-	- - -	-	68[a]	- - -	45	-	- - -	0.000060[a]	- - -	47
Chromium	-	- - -	-	130[a]	- - -	45	-	- - -	0.00075[a]	- - -	47
Mercury	-	- - -	-	730	460 - 1,000	45,46	-	- - -	0.00090[a]	- - -	47
Nickel	-	- - -	-	250[a]	- - -	45	-	- - -	0.00085[a]	- - -	47
Organics[c], ug/Mg											
2378-TCDD	-	- - -	-	0.51	0.51 - 0.51	45,46	-	- - -	0.022[a]	- - -	47
2378-TCDF	-	- - -	-	19	4.4 - 33	45,46	-	- - -	0.17[a]	- - -	47
Total TCDD	-	- - -	-	20	6.8 - 33	45,46	-	- - -	1.1[a]	- - -	47
Total TCDF	-	- - -	-	100	63 - 140	45,46	-	- - -	4.3[a]	- - -	47
CDD	-	- - -	-	570	150 - 990	45,46	-	- - -	7.3[a]	- - -	47
CDF	-	- - -	-	630	410 - 840	45,46	-	- - -	13[a]	- - -	47
PCB	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
Formaldehyde	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
B(a)P	-	- - -	-	23,000[a]	- - -	46	-	- - -	-	- - -	-
CB	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-
CP	-	- - -	-	-	- - -	-	-	- - -	-	- - -	-

[a] One data point only.

[b] Not detected. Detection limit given.

[c] Key to organics: 2378-TCDD = 2378-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin; Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins; CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene; CP = chlorinated phenol.

[d] Some applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-14. EMISSION FACTORS IN ENGLISH UNITS FOR MODULAR EXCESS-AIR MUNICIPAL WASTE COMBUSTORS

Parameter	Uncontrolled					After ESP Only					After Acid Gas and PM Control								
											Spray Drying				Dry Sorbent Injection[d]				
	Average	Range			References	Average	Range			References	Average	Range			Average	Range			References
Acid Gases, lb/ton																			
HCl	4.2	0.70	-	9.2	43,44	6.8	3.8	-	9.2	45,46	-	-	-	-	0.0032[a]	-	-	-	47
HF	0.0017[a]	-	-	-	43	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SO_3	6.6[a]	-	-	-	43	0.72	0.70	-	0.74	45	-	-	-	-	-	-	-	-	-
Metals, lb/ton x 10^6																			
Arsenic	-	-	-	-	-	9.0	8.6	-	9.2	45-46	-	-	-	-	0.00010[a]	-	-	-	47
Beryllium	-	-	-	-	-	19[b]	4.2[b]	-	34[b]	45-46	-	-	-	-	-	-	-	-	-
Cadmium	-	-	-	-	-	14[a]	-	-	-	45	-	-	-	-	0.00012[a]	-	-	-	47
Chromium	-	-	-	-	-	260[a]	-	-	-	45	-	-	-	-	0.0015[a]	-	-	-	47
Mercury	-	-	-	-	-	1,500	920	-	2,000	45,46	-	-	-	-	0.0018[a]	-	-	-	47
Nickel	-	-	-	-	-	500[a]	-	-	-	45	-	-	-	-	0.0017[a]	-	-	-	47
Organics[c], lb/ton x 10^9																			
2378-TCDD	-	-	-	-	-	1.0	1.0	-	1.0	45,46	-	-	-	-	0.044[a]	-	-	-	47
2378-TCDF	-	-	-	-	-	38	8.8	-	66	45,46	-	-	-	-	0.34[a]	-	-	-	47
Total TCDD	-	-	-	-	-	40	14	-	66	45,46	-	-	-	-	2.2[a]	-	-	-	47
Total TCDF	-	-	-	-	-	200	130	-	280	45,46	-	-	-	-	8.6[a]	-	-	-	47
CDD	-	-	-	-	-	1,100	300	-	2,000	45,46	-	-	-	-	15[a]	-	-	-	47
CDF	-	-	-	-	-	1,300	820	-	1,700	45,46	-	-	-	-	26[a]	-	-	-	47
PCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Formaldehyde	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B(a)P	-	-	-	-	-	46,000[a]	-	-	-	46	-	-	-	-	-	-	-	-	-
CB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[a]One data point only.

[b]Not detected. Detection limit given.

[c]Key to organics: 2378-TCDD = 2378-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin; Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins; CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene; CP = chlorinated phenol.

[d]Some applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-15. EMISSION FACTORS IN SI UNITS FOR RDF-FIRED MUNICIPAL WASTE COMBUSTORS

ameter	Uncontrolled Average	Uncontrolled Range	References	After ESP Only Average	After ESP Only Range	References	After Acid Gas and PM Control: Spray Drying Average	Spray Drying Range	Dry Sorbent Injection[d] Average	Dry Sorbent Injection[d] Range	References
d Gases, kg/Mg											
HCl	5.2	2.4 - 7.9	48,49	2.3	1.7 - 2.6	50-52	0.024[a]	- -	-	- -	49
HF	-	- -	-	0.0080[a]	- -	50	-	- -	-	- -	-
SO_3	-	- -	-	-	- -	-	-	- -	-	- -	-
als, mg/Mg											
Arsenic	3,500	1,500 - 5,500	49,53	190	93 - 380	50-52	23[b]	10[b] - 36[b]	-	- -	49,53
Beryllium	-	- -	-	50	0.48 - 100	51,52	-	- -	-	- -	-
Cadmium	3,300	3,300 - 3,300	48,49	450	160 - 920	50-52	19[a,b]	- -	-	- -	49
Chromium	6,500	4,700 - 8,200	49,53	11,000	450 - 32,000	50-52	330	17[b] - 650	-	- -	49,53
Mercury	2,300	1,100 - 4,600	48,49,53	1,400	460 - 21,000	50-52	260	16[b] - 520	-	- -	49,53
Nickel	2,800[a]	- -	53	6,100	320 - 18,000	50-52	2,600[a]	- -	-	- -	53
anics[c], ug/Mg											
2378-TCDD	6.9	3.7 - 10	49,53	19	0.46 - 36	50,51,54,55	0.017	0.012[b] - 0.022	-	- -	49,53
2378-TCDF	81	70 - 91	49,53	39	4.4 - 130	50,51,54,55	0.24	0.055 - 0.42	-	- -	49,53
Total TCDD	170	120 - 220	49,53	240	6.6 - 640	50,51,54-56	0.27	0.045 - 0.50	-	- -	49,53
Total TCDF	1,000	660 - 1,300	49,53	660	96 - 1,700	50,51,54-56	2.0	1.0 - 2.9	-	- -	49,53
CDD	1,300	800 - 1,800	49,53	2,900	82 - 8,900	51,54-56	2.7	1.7 - 3.7	-	- -	49,53
CDF	2,700	1,600 - 3,700	49,53	1,700	220 - 5,000	51,54-56	5.2	2.3 - 8.1	-	- -	49,53
PCB	-	- -	-	1,300[a]	- -	51	-	- -	-	- -	-
Formaldehyde	-	- -	-	610	430 - 800	50,51	-	- -	-	- -	-
B(a)P	-	- -	-	130,000[a]	- -	51	-	- -	-	- -	-
CB	-	- -	-	8,800[a]	- -	56	-	- -	-	- -	-
CP	-	- -	-	88,000[a]	- -	56	-	- -	-	- -	-

data point only.

detected. Detection limit given.

to organics: 2378-TCDD = 2378-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin; Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins; CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene; CP = chlorinated phenol.

applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

TABLE 4-16. EMISSION FACTORS IN ENGLISH UNITS FOR RDF-FIRED MUNICIPAL WASTE COMBUSTORS

Parameter	Uncontrolled			After ESP Only			After Acid Gas and PM Control				
							Spray Drying		Dry Sorbent Injection[d]		
	Average	Range	References	Average	Range	References	Average	Range	Average	Range	References
Acid Gases, lb/ton											
HCl	10	4.8 - 16	48,49	4.6	3.4 - 5.2	50-52	0.048[a]	-	-	-	49
HF	-	-	-	0.016[a]	-	50	-	-	-	-	-
SO_3	-	-	-	-	-	-	-	-	-	-	-
Metals, lb/ton x 10^6											
Arsenic	7,000	3,000 - 11,000	49,53	380	190 - 760	50-52	46[b]	20[b] - 72[b]	-	-	49,53
Beryllium	-	-	-	100	0.96 - 200	51,52	-	-	-	-	-
Cadmium	6,600	6,600 - 6,600	48,49	900	320 - 1,820	50-52	38[a,b]	-	-	-	49
Chromium	13,000	9,400 - 16,000	49,53	22,000	900 - 64,000	50-52	640	34[b] - 1,300	-	-	49,53
Mercury	4,600	2,200 - 9,200	48,49,53	2,800	920 - 4,200	50-52	520	32[b] - 1,000	-	-	49,53
Nickel	5,600[a]	-	53	12,000	640 - 35,000	50-52	5,200[a]	-	-	-	53
Organics[c], lb/ton x 10^9											
2378-TCDD	14	7.4 - 20	49,53	38	0.92 - 72	50,51,54,55	0.034	0.024[b] - 0.044	-	-	59,53
2378-TCDF	160	140 - 180	49,53	78	8.8 - 260	50,51,54,55	0.48	0.11 - 0.84	-	-	49,53
Total TCDD	340	240 - 440	49,53	480	13 - 1,300	50,51,54-56	0.54	0.090 - 1.8	-	-	49,53
Total TCDF	2,000	1,300 - 2,600	49,53	1,300	190 - 3,400	50,51,54-56	4.8	2.8 - 5.8	-	-	49,53
CDD	2,600	1,600 - 3,600	49,53	5,800	160 - 18,000	51,54-56	5.4	3.4 - 7.4	-	-	49,53
CDF	5,400	3,200 - 7,400	49,53	3,400	440 - 10,000	51,54-56	10	4.6 - 16	-	-	49,53
PCB	-	-	-	2,600[a]	-	51	-	-	-	-	-
Formaldehyde	-	-	-	1,200	860 - 1,600	50,51	-	-	-	-	-
B(a)P	-	-	-	260,000[a]	-	51	-	-	-	-	-
CB	-	-	-	19,000[a]	-	56	-	-	-	-	-
CP	-	-	-	190,000[a]	-	56	-	-	-	-	-

[a] One data point only.

[b] Not detected. Detection limit given.

[c] Key to organics: 2378-TCDD = 2738-tetrachlorodibenzo-p-dioxin; 2378-TCDF = 2378-tetrachlorodibenzofuran; Total TCDD = total tetrachlorodibenzo-p-dioxin; Total TCDF = total tetrachlorodibenzofuran; CDD = sum of tetra- through octa-chlorinated dibenzo-p-dioxins; CDF = sum of tetra- through octa-chlorinated dibenzofurans; PCB = polychlorinated biphenyls; B(a)P = benzo(a)pyrene; CB = chlorinated benzene; CP = chlorinated phenol.

[d] Some applications of Duct Sorbent Injection have control efficiencies comparable to Spray Drying (see discussion in section 3.3.2). When this is the case, the emission factors for Spray Drying should be used.

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5. SAMPLING AND ANALYSIS PROCEDURES

The purpose of this section is to provide a brief discussion of the EPA reference methods and/or generally accepted methods of sampling and analysis used to gather emissions data on air toxics emitted from municipal waste combustors. Most of these methods are discussed in detail in Reference 1. Different sampling and analytical methods than the ones listed have been used previously. Slight modifications of the methods listed may be specified by some State agencies to make results consistent with their regulatory compliance results. However, the sampling methods described in this section and in Reference 1 are widely used and accepted and should yield results comparable with data from other facilities.

Acid gases (HCl, HF, and SO_3) are tested by a variety of sampling and analytical methods. Sampling for HCl is performed with an EPA Reference Method 5 sampling train with either water, NaOH, or sodium carborate in the impingers. An example Method 5 train is shown in Figure 5-1. Continuous emission monitors for HCl are currently being evaluated. Sampling for SO_3 (H_2SO_4) is performed with a Method 5 train using hydrogen peroxide in the impingers in accordance with EPA Reference Method 8 procedures.[2] Sampling for HF is performed in accordance with EPA Reference Method 13A procedures, again using a Method 5 train.[2] Analytical techniques for these three acid gases include ion chromatography (for HCl, SO_3, and HF), the mercuric nitrate method (for HCl), and ion selective electrode (for HCl, SO_3, and HF).

Sampling for metals (As, Be, Cd, Cr, Ni, and Hg) is done by a variety of methods. Arsenic is sampled using EPA Reference Method 108. Beryllium is sampled using EPA Reference Method 104.[3] Sampling for Hg is performed using EPA Reference Method 101A.[3] The sampling trains used for these metals are similar to the EPA Reference Method 5 trains. Cadmium, total chromium, and nickel are sampled according to EPA Reference Method 12. Because of the cost for individual metal sampling, a draft protocol for combined metals sampling has been proposed by EPA.[4] Analyses for cadmium, chromium, nickel, arsenic, and beryllium are performed using atomic absorption spectroscopy or inductively coupled plasma spectroscopy. Mercury is analyzed using manual cold vapor atomic absorption spectrophotometry.

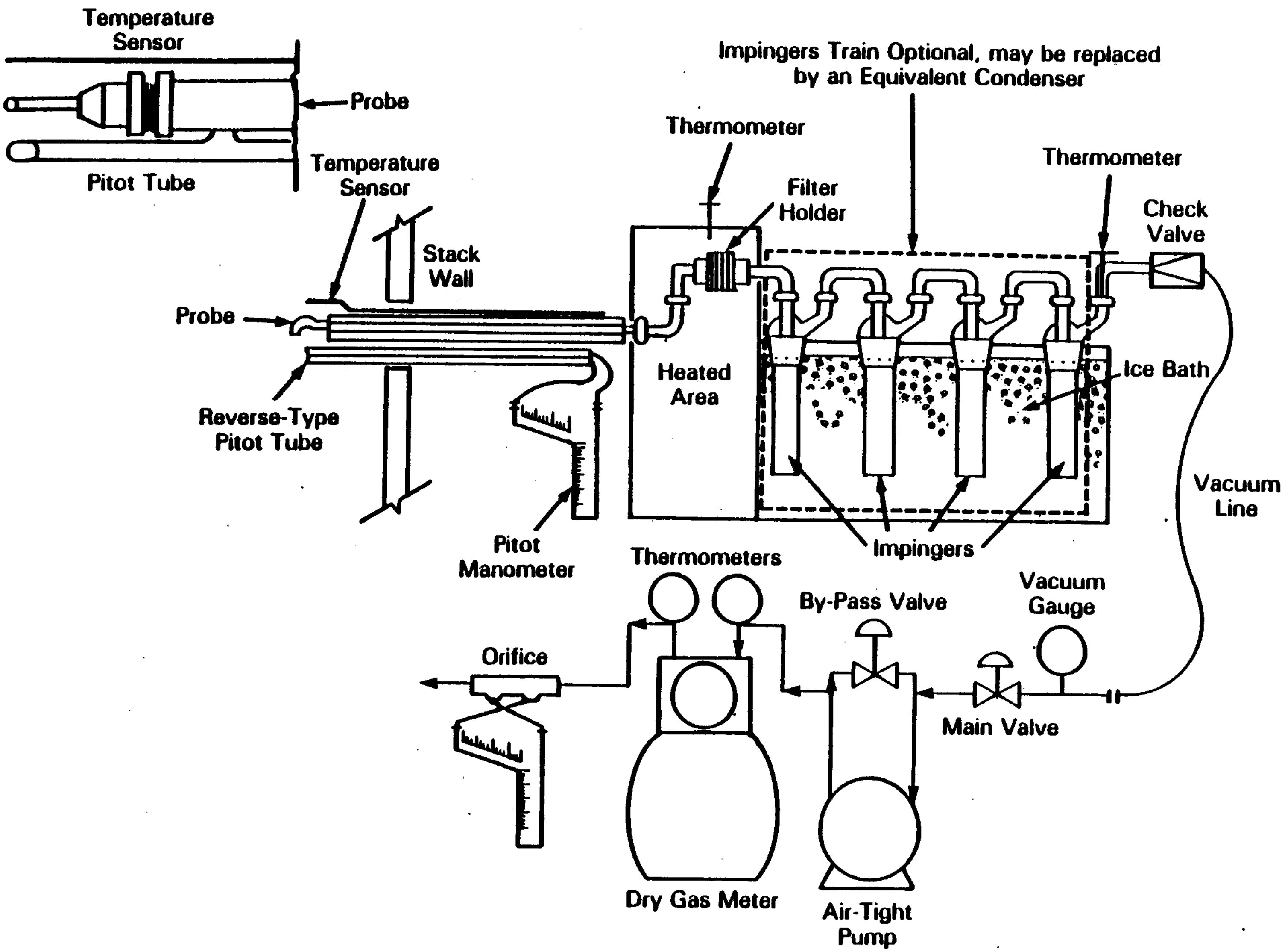

Figure 5-1. Example EPA Reference Method 5 Sampling Train

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Semivolatile organic compounds are sampled by using a modified EPA Reference Method 5 train. A water-cooled condenser and XAD-2 resin cartridge are placed immediately before the impinger section. The organics are extracted off the resin by using toluene or benzene. The aqueous components and rinses are extracted using methylene chloride. Analysis of the organics is accomplished by using gas chromatography and mass spectroscopy.

Requests for additional information on reference and experimental methods should be sent to:

Chief, Emissions Measurement Branch (MD-14)
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

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APPENDIX A
EXISTING MUNICIPAL WASTE COMBUSTION FACILITIES
(As of September 16, 1988)

TABLE A-1. EXISTING MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY COMBUSTION TECHNOLOGY

City	State	Type[a]	No. of Units	Unit Size (tpd)	Year of Start-up	Heat Recovery	Air Pollution Control Device
Traveling Grate Refractory-Wall Combustors (6)							
Honolulu	HA	MB	2	300	1970	No	Electrostatic Precipitator
East Chicago	IN	MB	2	225	1971	No	Venturi Wet Scrubber
Berkley (S.E. Oakland Co.)	MI	MB	2	300	1965	No	Wet Scrubber
New York (Betts Avenue)	NY	MB	4	250	1980	Yes	Electrostatic Precipitator
Philadelphia (Northwest Unit)	PA	MB	2	375	1957	No	Electrostatic Precipitator
Philadelphia (E.Central Unit)	PA	MB	2	375	1965	No	Electrostatic Precipitator
Rocking/Reciprocating Grate Refractory-Wall Combustors (10)							
Stamford II	CT	MB	1	360	1974	Yes	Electrostatic Precipitator
New Canaan	CT	MB	1	125	1971	No	Venturi Wet Scrubber
Washington(Solid Waste Red.Cent.I)	DC	MB	4	250	1972	No	Electrostatic Precipitator
Fall River	MA	MB	2	300	1972	No	Venturi Wet Scrubber
Baltimore (Pulaski)	MD	MB	4	300	1982	No	Electrostatic Precipitator
Clinton (Grosse Pointe)	MI	MB	2	300	1972	No	Electrostatic Precipitator
Brooklyn(N Henry St./Greenpoint,SW)	NY	MB	4	240	1959	No	Electrostatic Precipitator
Euclid	OH	MB	2	100	1955	No	Electrostatic Precipitator
Sheboygan	WI	MB	2	120	1965	No	Wetted Baffles
Waukesha	WI	MB	2	88	1971	Yes	Electrostatic Precipitator
Grate/Rotary Kiln Refractory-Wall Combustors (5)							
Tampa	FL	MB	4	250	1985	Yes	Electrostatic Precipitator
Louisville	KY	MB	4	250	1960	No	Venturi Wet Scrubber
Framingham	MA	MB	2	250	1970	No	Spray Dryer/Fabric Filter
N.Dayton	OH	MB	3	300	1970	No	Electrostatic Precipitator
S.Dayton	OH	MB	3	300	1970	No	Electrostatic Precipitator
Katy-Sehgers Refractory-Wall Design (2)							
Savannah	GA	MB	NA	500[b]	1987	Yes	Electrostatic Precipitator
Davis County	UT	MB	1	400	1987	Yes	NA
Refractory-Wall Rotary Kiln Only (1)							
Galax	VA	MB	1	56	NA	Yes	Fabric Filter
Batch-fed Refractory-Wall Combustors (8)							
Moore County	TX	MB	1	90	1972	No	None
Port Washington	WI	MB	1	75	1965	No	Electrostatic Precipitator
Hereford	TX	MB	1	90	1965	No	None
Stamford I	CT	MB	1	200	1974	Yes	Electrostatic Precipitator
Huntington	NY	MB	3	150	NA	No	Wet Scrubber
Lewisburg	TN	MB	1	60	1980	Yes	Wet Scrubber
Readsboro	VT	MB	1	10	1974	No	None
Stamford	VT	MB	1	10	1973	No	NA

NA = Information not available
[a] MB = Mass Burn; RDF = Refuse-derived fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air; FBC = Fluidized Bed Combustor
[b] Total plant capacity (tpd)

TABLE A-1. EXISTING MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY COMBUSTION TECHNOLOGY (cont.)

City	State	Type[a]	No. of Units	Unit Size (tpd)	Year of Start-up	Heat Recovery	Air Pollution Control Device
Mass Burn Waterwall Combustors (24)							
Bridgeport	CT	MB	3	750	1988	Yes	Spray Dryer/Fabric Filter
Pinellas Co.	FL	MB	3	1000	1983	Yes	Electrostatic Precipitator
Saugus	MA	MB	2	750	1975	Yes	Electrostatic Precipitator
North Andover	MA	MB	2	750	1985	Yes	Electrostatic Precipitator
Millbury	MA	MB	2	750	1988	Yes	Spray Dryer/Electrostatic Precipitator
Baltimore (Resco)	MD	MB	3	750	1985	Yes	Electrostatic Precipitator
Westchester Co.	NY	MB	3	750	1984	Yes	Electrostatic Precipitator
Commerce (Los Angeles Co.)	CA	MB	1	300	1987	Yes	Spray Dryer/Fabric Filter
Hillsborough County	FL	MB	3	400	1987	Yes	Electrostatic Precipitator
Chicago (NW)	IL	MB	4	400	1970	Yes	Electrostatic Precipitator
Tulsa	OK	MB	2	375	1986	Yes	Electrostatic Precipitator
Marion County	OR	MB	2	275	1986	Yes	Spray Dryer/Fabric Filter
Harrisburg	PA	MB	2	360	1973	Yes	Electrostatic Precipitator
Nashville	TN	MB	3	360-400	1974	Yes	Electrostatic Precipitator
Alexandria/Arlington	VA	MB	3	325	1987	Yes	Electrostatic Precipitator
Key West (Monroe Co.)	FL	MB	2	75	1986	Yes	Electrostatic Precipitator
Jackson	MI	MB	2	100	1987	Yes	Spray Dryer/Fabric Filter
Rochester (Olmstead County)	MN	MB	2	100	1987	Yes	Electrostatic Precipitator
Wilmington (New Hanover Co.)	NC	MB	2	100	1984	Yes	Electrostatic Precipitator
Claremont	NH	MB	2	100	1987	Yes	Duct Sorbent Injection/Fabric Filter
Glen Cove	NY	MB	2	125	1983	Yes	Electrostatic Precipitator
Norfolk (Sewell Pt. Navy Station)	VA	MB	2	180	1967	Yes	Electrostatic Precipitator
Harrisonburg	VA	MB	2	50	1982	Yes	Electrostatic Precipitator
Hampton	VA	MB	2	100	1980	Yes	Electrostatic Precipitator
Rotary Waterwall Combustors (3)							
Panama City (Bay County)	FL	MB	2	255	1987	Yes	Electrostatic Precipitator
Dutchess County (Poughkeepsie)	NY	MB	2	253	1987	Yes	Fabric Filter
Gallatin	TN	MB	2	100	1981	Yes	Electrostatic Precipitator
RDF-Fired Combustors (19)							
Hartford	CT	RDF	3	667	1988	Yes	Spray Dryer/Fabric Filter
Dade Co.	FL	RDF	4	750	1982	Yes	Electrostatic Precipitator
Haverhill/Lawrence	MA	RDF	3	1000	1984	Yes	Electrostatic Precipitator
Niagra Falls	NY	RDF	2	1000	1981	Yes	Electrostatic Precipitator
Penobscot	ME	RDF	2	360	1988	Yes	Spray Dryer/Fabric Filter
Biddeford/Saco	ME	RDF	2	350	1987	Yes	Spray Dryer/Fabric Filter
Red Wing (NSP Co.)	MN	RDF	2	360	1988	Yes	Electrostatic Precipitator
Mankato	MN	RDF	2	360	1987	Yes	Electrostatic Precipitator
Albany	NY	RDF	2	300	1981	Yes	Electrostatic Precipitator
Columbus	OH	RDF	6	400	1983	Yes	Electrostatic Precipitator
Akron	OH	RDF	2	300	1979	Yes	Electrostatic Precipitator

NA = Information not available
[a] MB = Mass Burn; RDF = Refuse-derived fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air; FBC = Fluidized Bed Combustor
[b] Total plant capacity (tpd)

TABLE A-1. EXISTING MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY COMBUSTION TECHNOLOGY (cont.)

City	State	Type[a]	No. of Units	Unit Size (tpd)	Year of Start-up	Heat Recovery	Air Pollution Control Device
RDF-Fired Combustors (cont.)							
Portsmouth (Norfolk Navy Yard)	VA	RDF	4	500	1988	Yes	Electrostatic Precipitator
Lakeland	FL	RDF	3	100	1981	Yes	Electrostatic Precipitator
Ames	IA	RDF	2	100	1975	Yes	Electrostatic Precipitator
Keokuk	IA	RDF	NA	NA	NA	NA	NA
Madison (Oscar Mayer)	WI	RDF	1	400	1983	Yes	Electrostatic Precipitator
Sioux Center (Dordt College)	IA	RDF	NA	NA	NA	NA	NA
Sioux Center (Community Schools)	IA	RDF	NA	NA	NA	NA	NA
Madison (Gas and Electric Co.)	WI	RDF	2	200	1979	Yes	Cyclone/Electrostatic Precipitator
Modular Starved-air Combustors (60)							
Edgewood (Harford County)	MD	MOD/SA	4	90	1987	Yes	Electrostatic Precipitator
City of Red Wing	MN	MOD/SA	1	90	1982	Yes	Electrostatic Precipitator
Hampton	SC	MOD/SA	3	90	1985	Yes	Electrostatic Precipitator
Portsmouth	VA	MOD/SA	2	80	1971	Yes	Electrostatic Precipitator
Tuscaloosa	AL	MOD/SA	4	75	1984	Yes	Electrostatic Precipitator
Perham (Quadrant)	MN	MOD/SA	2	57	1987	Yes	Electrostatic Precipitator
Portsmouth	NH	MOD/SA	4	50	1982	Yes	Fabric Filter
Auburn	ME	MOD/SA	4	50	1981	Yes	Fabric Filter
Batesville	AR	MOD/SA	2	50	1981	Yes	None
Bellingham	WA	MOD/SA	2	50	1986	Yes	None
Oneida Co. (Rome)	NY	MOD/SA	4	50	1985	Yes	Electrostatic Precipitator
Johnsonville	SC	MOD/SA	1	50	NA	Yes	Electrostatic Precipitator
Dyersburg	TN	MOD/SA	1	50	1980	Yes	None
Oswego County (Volney)	NY	MOD/SA	4	50	1986	Yes	Electrostatic Precipitator
Pittsfield	NH	MOD/SA	1	48	NA	No	None
City of Fergus Falls	MN	MOD/SA	2	47	1987	Yes	Venturi Wet Scrubber
Barron County	WI	MOD/SA	2	40	1986	No	Electrostatic Precipitator
Fosston (Polk Co.)	MN	MOD/SA	2	40	1988	Yes	Electrostatic Precipitator
Livingston	MT	MOD/SA	2	38	1982	Yes	None
Cuba (Cattaraugus Co.)	NY	MOD/SA	3	38	1983	Yes	None
Carthage City	TX	MOD/SA	1	36	1985	Yes	None
Center	TX	MOD/SA	1	36	1985	Yes	None
Windham	CT	MOD/SA	3	36	1981	Yes	Fabric Filter
Blytheville	AR	MOD/SA	2	36	1983	No	None
Durham	NH	MOD/SA	3	36	1980	Yes	Cyclone
Newport News (Ft. Eustis)	VA	MOD/SA	1	35	1980	Yes	None
Skaneateless	NY	MOD/SA	1	35	1975	No	None
Wilton	NH	MOD/SA	1	30	1979	No	None
Fort Leonard Wood	MO	MOD/SA	3	26	NA	Yes	None
North Little Rock	AR	MOD/SA	4	25	1977	Yes	None
Greensburg (Westmoreland Co.)	PA	MOD/SA	2	25	1987	Yes	Electrostatic Precipitator
Huntsville (Walker County)(DOC)	TX	MOD/SA	1	25	1984	No	None

NA = Information not available
[a]MB = Mass Burn; RDF = Refuse-derived fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air; FBC = Fluidized Bed Combustor
[b]Total plant capacity (tpd)

TABLE A-1. EXISTING MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY COMBUSTION TECHNOLOGY (cont.)

City	State	Type[a]	No. of Units	Unit Size (tpd)	Year of Start-up	Heat Recovery	Air Pollution Control Device
Modular Starved-air Combustors (cont.)							
Brazoria County (DOC)	TX	MOD/SA	1	25	1983	No	None
Burley (Cassia County)	ID	MOD/SA	2	25	1982	Yes	None
Windham	ME	MOD/SA	2	25	1973	No	None
Wrightsville Beach	NC	MOD/SA	2	25	1981	No	None
Waxahachie	TX	MOD/SA	2	25	1982	Yes	None
Coos County (I)	OR	MOD/SA	2	25	1978	No	None
Osceola	AR	MOD/SA	2	25	1980	Yes	None
Gatesville (DOC)	TX	MOD/SA	1	25	1984	No	None
Salem	VA	MOD/SA	4	25	1970	Yes	None
Grimes County (DOC)	TX	MOD/SA	1	25	1984	No	None
Anderson County (DOC)	TX	MOD/SA	1	25	1980	No	None
Brookings	OR	MOD/SA	2	24	1979	No	None
Groveton	NH	MOD/SA	1	24	1980	Yes	None
Coos County (II)	OR	MOD/SA	1	24	1980	Yes	Electrostatic Precipitator
Lincoln	NH	MOD/SA	1	24	1980	No	None
Stuttgart	AR	MOD/SA	3	23	1971	No	None
Litchfield	NH	MOD/SA	1	22	NA	No	None
Ft. Dix	NJ	MOD/SA	4	20	1986	Yes	Wet Scrubber/Fabric Filter
Plymouth	NH	MOD/SA	1	16	1976	No	None
Candia	NH	MOD/SA	1	15	NA	No	None
Miami	OK	MOD/SA	3	13	1982	Yes	None
Hot Springs	AR	MOD/SA	8	13	NA	No	None
Pelham	NH	MOD/SA	NA	10	1980	No	NA
Canterbury	NH	MOD/SA	1	10	NA	No	None
Wolfeboro	NH	MOD/SA	2	8	1975	No	None
Harpswell	ME	MOD/SA	1	6	1975	No	None
Auburn	NH	MOD/SA	1	5	1979	No	None
Franklin (Simpson Co.)	KY	MOD/SA	2	38	NA	Yes	None
Modular Excess-air Combustors (10)							
Sitka	AK	MOD/EA	2	13	1985	Yes	Electrostatic Precipitator
Wilmington (Pigeon Point)	DE	MOD/EA	5	120	1987	Yes	Electrostatic Precipitator
Mayport Naval Station	FL	MOD/EA	1	48	1978	Yes	Cyclone
Pittsfield	MA	MOD/EA	3	120	1981	Yes	Electrified Gravel Bed
Aroostook County (Frenchville)	ME	MOD/EA	NA	50[b]	1982	NA	None
Alexandria (Pope/Douglas Co.)	MN	MOD/EA	1	100	1986	Yes	Electrostatic Precipitator
Pascagoula	MS	MOD/EA	2	75	1985	Yes	Electrostatic Precipitator
Nottingham	NH	MOD/EA	1	8	1972	No	None
Cleburne	TX	MOD/EA	3	38	1986	Yes	Electrostatic Precipitator
Rutland	VT	MOD/EA	2	110	1987	Yes	Electrostatic Precipitator

NA = Information not available
[a] MB = Mass Burn; RDF = Refuse-derived fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air; FBC = Fluidized Bed Combustor
[b] Total plant capacity (tpd)

TABLE A-1. EXISTING MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY COMBUSTION TECHNOLOGY (conc.)

City	State	Type[a]	No. of Units	Unit Size (tpd)	Year of Start-up	Heat Recovery	Air Pollution Control Device
Fluidized Bed Combustors (3)							
Duluth	MN	FBC	2	200	1986	Yes	Cylcone/Venturi
La Crosse County	WI	FBC	2	200	1987	Yes	Electrified Gravel Bed
Tacoma	WA	FBC	NA	500[b]	1988	NA	NA
Unknown (10)							
Prudhoe Bay	AK	UNK	NA	100[b]	1981	NA	NA
Chilton	WI	UNK	NA	NA	NA	NA	NA
Shreveport	LA	UNK	1	200	NA	No	NA
Long Beach (CED Corp)	NY	UNK	NA	200[b]	NA	NA	NA
Miami Internat'l Airport	FL	UNK	NA	NA	NA	NA	NA
Savage	MN	UNK	2	450	1985	Yes	Electrostatic Precipitator
Anchorage	AK	UNK	NA	NA	NA	NA	NA
Cedarville	OH	UNK	NA	NA	NA	NA	NA
Elkhart Lake	WI	UNK	1	48	1969	No	Wet Scrubber
Juneau	AK	UNK	NA	70[b]	1986	No	NA

NA = Information not available
[a]MB = Mass Burn; RDF = Refuse-derived fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air; FBC = Fluidized Bed Combustor
[b]Total plant capacity (tpd)

TABLE A-2. EXISTING MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY STATE

City	State	Type[a]	No. of Units	Unit Size (tpd)	Year of Start-up	Heat Recovery	Air Pollution Control Device
Anchorage	AK	NA	NA	NA	NA	NA	NA
Juneau	AK	NA	NA	70[b]	1986	No	NA
Prudhoe Bay	AK	NA	NA	100[b]	1981	NA	NA
Sitka	AK	MOD/EA	2	13	1985	Yes	Electrostatic Precipitator
Tuscaloosa	AL	MOD/SA	4	75	1984	Yes	Electrostatic Precipitator
Batesville	AR	MOD/SA	2	50	1981	Yes	None
Blytheville	AR	MOD/SA	2	36	1983	No	None
Hot Springs	AR	MOD/SA	8	13	NA	No	None
North Little Rock	AR	MOD/SA	4	25	1977	Yes	None
Osceola	AR	MOD/SA	2	25	1980	Yes	None
Stuttgart	AR	MOD/SA	3	23	1971	No	None
Commerce (Los Angeles Co.)	CA	MB	1	300	1987	Yes	Spray Dryer/Fabric Filter
Bridgeport	CT	MB	3	750	1988	Yes	Spray Dryer/Fabric Filter
Hartford	CT	RDF	3	667	1988	Yes	Spray Dryer/Fabric Filter
New Canaan	CT	MB	1	125	1971	No	Venturi Wet Scrubber
Stamford I	CT	MB	1	200	1974	Yes	Electrostatic Precipitator
Stamford II	CT	MB	1	360	1974	Yes	Electrostatic Precipitator
Windham	CT	MOD/SA	3	36	1981	Yes	Fabric Filter
Washington (Solid Waste Red.Cent.I)	DC	MB	4	250	1972	No	Electrostatic Precipitator
Wilmington (Pigeon Point)	DE	MOD/EA	5	120	1987	Yes	Electrostatic Precipitator
Dade Co.	FL	RDF	4	750	1982	Yes	Electrostatic Precipitator
Hillsborough County	FL	MB	3	400	1987	Yes	Electrostatic Precipitator
Key West (Monroe Co.)	FL	MB	2	75	1986	Yes	Electrostatic Precipitator
Lakeland	FL	RDF	3	100	1981	Yes	Electrostatic Precipitator
Mayport Naval Station	FL	MOD/EA	1	48	1978	Yes	Cyclone
Miami Internat'l Airport	FL	NA	NA	NA	NA	NA	NA
Panama City (Bay County)	FL	MB	2	255	1987	Yes	Electrostatic Precipitator
Pinellas Co.	FL	MB	3	1000	1983	Yes	Electrostatic Precipitator
Tampa	FL	MB	4	250	1985	Yes	Electrostatic Precipitator
Savannah	GA	MB	NA	500[b]	1987	Yes	Electrostatic Precipitator
Honolulu	HA	MB	2	300	1970	No	Electrostatic Precipitator
Ames	IA	RDF	2	100	1975	Yes	Electrostatic Precipitator
Keokuk	IA	RDF	NA	NA	NA	NA	NA
Sioux Center (Community Schools)	IA	RDF	NA	NA	NA	NA	NA
Sioux Center (Dordt College)	IA	RDF	NA	NA	NA	NA	NA
Burley (Cassia County)	ID	MOD/SA	2	25	1982	Yes	None
Chicago (NW)	IL	MB	4	400	1970	Yes	Electrostatic Precipitator
East Chicago	IN	MB	2	225	1971	No	Venturi Wet Scrubber
Franklin (Simpson Co.)	KY	MOD/SA	2	38	NA	Yes	None
Louisville	KY	MB	4	250	1960	No	Venturi Wet Scrubber
Shreveport	LA	NA	1	200	NA	No	NA
Fall River	MA	MB	2	300	1972	No	Venturi Wet Scrubber
Framingham	MA	MB	2	250	1970	No	Spray Dryer/Fabric Filter
Haverhill/Lawrence	MA	RDF	3	1000	1984	Yes	Electrostatic Precipitator

NA = Information not available

[a] MB = Mass Burn; RDF = Refuse-derived Fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air; FBC = Fluidized Bed Combustor

[b] Total plant capacity (tpd)

TABLE A-2. EXISTING MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY STATE (cont.)

City	State	Type[a]	No. of Units	Unit Size (tpd)	Year of Start-up	Heat Recovery	Air Pollution Control Device
Millbury	MA	MB	2	750	1988	Yes	Spray Dryer/Electrostatic Precipitator
North Andover	MA	MB	2	750	1985	Yes	Electrostatic Precipitator
Pittsfield	MA	MOD/EA	3	120	1981	Yes	Electrified Gravel Bed
Saugus	MA	MB	2	750	1975	Yes	Electrostatic Precipitator
Baltimore (Pulaski)	MD	MB	4	300	1982	No	Electrostatic Precipitator
Baltimore (Resco)	MD	MB	3	750	1985	Yes	Electrostatic Precipitator
Edgewood (Harford County)	MD	MOD/SA	4	90	1987	Yes	Electrostatic Precipitator
Aroostook County (Frenchville)	ME	MOD/EA	NA	50[b]	1982	NA	None
Auburn	ME	MOD/SA	4	50	1981	Yes	Fabric Filter
Biddeford/Saco	ME	RDF	2	350	1987	Yes	Spray Dryer/Fabric Filter
Harpswell	ME	MOD/SA	1	6	1975	No	None
Penobscot	ME	RDF	2	360	1988	Yes	Spray Dryer/Fabric Filter
Windham	ME	MOD/SA	2	25	1973	No	None
Berkley (S.E. Oakland Co.)	MI	MB	2	300	1965	No	Wet Scrubber
Clinton (Grosse Pointe)	MI	MB	2	300	1972	No	Electrostatic Precipitator
Jackson	MI	MB	2	100	1987	Yes	Spray Dryer/Fabric Filter
Alexandria (Pope/Douglas Co.)	MN	MOD/EA	1	100	1986	Yes	Electrostatic Precipitator
City of Fergus Falls	MN	MOD/SA	2	47	1987	Yes	Venturi Wet Scrubber
City of Red Wing	MN	MOD/SA	1	90	1982	Yes	Electrostatic Precipitator
Duluth	MN	FBC	2	200	1986	Yes	Cylcone/Venturi
Fosston (Polk Co.)	MN	MOD/SA	2	40	1988	Yes	Electrostatic Precipitator
Mankato	MN	RDF	2	360	1987	Yes	Electrostatic Precipitator
Perham (Quadrant)	MN	MOD/SA	2	57	1987	Yes	Electrostatic Precipitator
Red Wing (NSP Co.)	MN	RDF	2	360	1988	Yes	Electrostatic Precipitator
Rochester (Olmstead County)	MN	MB	2	100	1987	Yes	Electrostatic Precipitator
Savage	MN	NA	2	450	1985	Yes	Electrostatic Precipitator
Fort Leonard Wood	MO	MOD/SA	3	26	NA	Yes	None
Pascagoula	MS	MOD/EA	2	75	1985	Yes	Electrostatic Precipitator
Livingston	MT	MOD/SA	2	38	1982	Yes	None
Wilmington (New Hanover Co.)	NC	MB	2	100	1984	Yes	Electrostatic Precipitator
Wrightsville Beach	NC	MOD/SA	2	25	1981	No	None
Auburn	NH	MOD/SA	1	5	1979	No	None
Candia	NH	MOD/SA	1	15	NA	No	None
Canterbury	NH	MOD/SA	1	10	NA	No	None
Claremont	NH	MB	2	100	1987	Yes	Duct Sorbent Injection/Fabric Filter
Durham	NH	MOD/SA	3	36	1980	Yes	Cyclone
Groveton	NH	MOD/SA	1	24	1980	Yes	None
Lincoln	NH	MOD/SA	1	24	1980	No	None
Litchfield	NH	MOD/SA	1	22	NA	No	None
Nottingham	NH	MOD/EA	1	8	1972	No	None
Pelham	NH	MOD/SA	NA	10	1980	No	NA
Pittsfield	NH	MOD/SA	1	48	NA	No	None
Plymouth	NH	MOD/SA	1	16	1976	No	None
Portsmouth	NH	MOD/SA	4	50	1982	Yes	Fabric Filter

NA = Information not available
[a] MB = Mass Burn; RDF = Refuse-derived Fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air; FBC = Fluidized Bed Combustor
[b] Total plant capacity (tpd)

TABLE A-2. EXISTING MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY STATE (cont.)

City	State	Type[a]	No. of Units	Unit Size (tpd)	Year of Start-up	Heat Recovery	Air Pollution Control Device
Wilton	NH	MOD/SA	1	30	1979	No	None
Wolfeboro	NH	MOD/SA	2	8	1975	No	None
Ft. Dix	NJ	MOD/SA	4	20	1986	Yes	Wet Scrubber/Fabric Filter
Albany	NY	RDF	2	300	1981	Yes	Electrostatic Precipitator
Brooklyn(N Henry St./Greenpoint,SW)	NY	MB	4	240	1959	No	Electrostatic Precipitator
Cuba (Cattaraugus Co.)	NY	MOD/SA	3	38	1983	Yes	None
Dutchess County (Poughkeepsie)	NY	MB	2	253	1987	Yes	Fabric Filter
Glen Cove	NY	MB	2	125	1983	Yes	Electrostatic Precipitator
Huntington	NY	MB	3	150	NA	No	Wet Scrubber
Long Beach (CED Corp)	NY	NA	NA	200[b]	NA	NA	NA
New York (Betts Avenue)	NY	MB	4	250	1980	Yes	Electrostatic Precipitator
Niagra Falls	NY	RDF	2	1000	1981	Yes	Electrostatic Precipitator
Oneida Co. (Rome)	NY	MOD/SA	4	50	1985	Yes	Electrostatic Precipitator
Oswego County (Volney)	NY	MOD/SA	4	50	1986	Yes	Electrostatic Precipitator
Skaneateless	NY	MOD/SA	1	35	1975	No	None
Westchester Co.	NY	MB	3	750	1984	Yes	Electrostatic Precipitator
Akron	OH	RDF	2	300	1979	Yes	Electrostatic Precipitator
Cedarville	OH	NA	NA	NA	NA	NA	NA
Columbus	OH	RDF	6	400	1983	Yes	Electrostatic Precipitator
Euclid	OH	MB	2	100	1955	No	Electrostatic Precipitator
N.Dayton	OH	MB	3	300	1970	No	Electrostatic Precipitator
S.Dayton	OH	MB	3	300	1970	No	Electrostatic Precipitator
Miami	OK	MOD/SA	3	13	1982	Yes	None
Tulsa	OK	MB	2	375	1986	Yes	Electrostatic Precipitator
Brookings	OR	MOD/SA	2	24	1979	No	None
Coos County (II)	OR	MOD/SA	1	24	1980	Yes	Electrostatic Precipitator
Coos County (I)	OR	MOD/SA	2	25	1978	No	None
Marion County	OR	MB	2	275	1986	Yes	Spray Dryer/Fabric Filter
Greensburg (Westmoreland Co.)	PA	MOD/SA	2	25	1987	Yes	Electrostatic Precipitator
Harrisburg	PA	MB	2	360	1973	Yes	Electrostatic Precipitator
Philadelphia (E.Central Unit)	PA	MB	2	375	1965	No	Electrostatic Precipitator
Philadelphia (Northwest Unit)	PA	MB	2	375	1957	No	Electrostatic Precipitator
Hampton	SC	MOD/SA	3	90	1985	Yes	Electrostatic Precipitator
Johnsonville	SC	MOD/SA	1	50	NA	Yes	Electrostatic Precipitator
Dyersburg	TN	MOD/SA	1	50	1980	Yes	None
Gallatin	TN	MB	2	100	1981	Yes	Electrostatic Precipitator
Lewisburg	TN	MB	1	60	1980	Yes	Wet Scrubber
Nashville	TN	MB	3	360-400	1974	Yes	Electrostatic Precipitator
Anderson County (DOC)	TX	MOD/SA	1	25	1980	No	None
Brazoria County (DOC)	TX	MOD/SA	1	25	1983	No	None
Carthage City	TX	MOD/SA	1	36	1985	Yes	None
Center	TX	MOD/SA	1	36	1985	Yes	None
Cleburne	TX	MOD/EA	3	38	1986	Yes	Electrostatic Precipitator
Gatesville (DOC)	TX	MOD/SA	1	25	1984	No	None

NA = Information not available
[a] MB = Mass Burn; RDF = Refuse-derived Fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air; FBC = Fluidized Bed Combustor
[b] Total plant capacity (tpd)

TABLE A-2. EXISTING MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY STATE (conc.)

City	State	Type[a]	No. of Units	Unit Size (tpd)	Year of Start-up	Heat Recovery	Air Pollution Control Device
Grimes County (DOC)	TX	MOD/SA	1	25	1984	No	None
Hereford	TX	MB	1	90	1965	No	None
Huntsville (Walker County)(DOC)	TX	MOD/SA	1	25	1984	No	None
Moore County	TX	MB	1	90	1972	No	None
Waxahachie	TX	MOD/SA	2	25	1982	Yes	None
Davis County	UT	MB	1	400	1987	Yes	NA
Alexandria/Arlington	VA	MB	3	325	1987	Yes	Electrostatic Precipitator
Galax	VA	MB	1	56	NA	Yes	Fabric Filter
Hampton	VA	MB	2	100	1980	Yes	Electrostatic Precipitator
Harrisonburg	VA	MB	2	50	1982	Yes	Electrostatic Precipitator
Newport News (Ft. Eustis)	VA	MOD/SA	1	35	1980	Yes	None
Norfolk (Sewell Pt. Navy Station)	VA	MB	2	180	1967	Yes	Electrostatic Precipitator
Portsmouth	VA	MOD/SA	2	80	1971	Yes	Electrostatic Precipitator
Portsmouth (Norfolk Navy Yard)	VA	RDF	4	500	1988	Yes	Electrostatic Precipitator
Salem	VA	MOD/SA	4	25	1970	Yes	None
Readsboro	VT	MB	1	10	1974	No	None
Rutland	VT	MOD/EA	2	110	1987	Yes	Electrostatic Precipitator
Stamford	VT	MB	1	10	1973	No	NA
Bellingham	WA	MOD/SA	2	50	1986	Yes	None
Tacoma	WA	FBC	NA	500[b]	1988	NA	NA
Barron County	WI	MOD/SA	2	40	1986	No	Electrostatic Precipitator
Chilton	WI	NA	NA	NA	NA	NA	NA
Elkhart Lake	WI	NA	1	48	1969	No	Wet Scrubber
La Crosse County	WI	FBC	2	200	1987	Yes	Electrified Gravel Bed
Madison (Gas and Electric Co.)	WI	RDF	2	200	1979	Yes	Cyclone/Electrostatic Precipitator
Madison (Oscar Mayer)	WI	RDF	1	400	1983	Yes	Electrostatic Precipitator
Port Washington	WI	MB	1	75	1965	No	Electrostatic Precipitator
Sheboygan	WI	MB	2	120	1965	No	Wetted Baffles
Waukesha	WI	MB	2	88	1971	Yes	Electrostatic Precipitator

NA = Information not available
[a] MB = Mass Burn; RDF = Refuse-derived Fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air; FBC = Fluidized Bed Combustor
[b] Total plant capacity (tpd)

APPENDIX B

PLANNED MUNICIPAL WASTE COMBUSTION FACILITIES

(As of September 16, 1988)

TABLE B-1. PLANNED MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY COMBUSTION TECHNOLOGY

City	State	Type[a]	No. of Units	Total Plant Capacity (tpd)	Heat Recovery	Year of Start-up
Mass Burn Waterwall (70)						
Ukiah	CA	MB	NA	100	Yes	NA
Fayetteville	AR	MB	NA	150	Yes	1989
Hanover Borough	PA	MB	NA	200	Yes	NA
Long Beach	NY	MB	NA	200	Yes	1988
Eau Claire Co.	WI	MB	NA	225	Yes	1990
Middleton	CT	MB	NA	230	Yes	1989
Charlotte	NC	MB	NA	234	Yes	1989
St. Lawrence County	NY	MB	NA	250	Yes	1990
Warren County	NJ	MB	2	400	Yes	1989
Hudson Falls (Washington Co.)	NY	MB	2	400	Yes	1990
West Deptford	NJ	MB	NA	432	NA	1989
Concord	NH	MB	NA	500	NA	1989
Glendon	PA	MB	NA	500	Yes	1990
Broome County	NY	MB	NA	500	Yes	1991
Pennsauken	NJ	MB	2	500	Yes	1990
Portland	ME	MB	NA	500	Yes	1988
Gloucester County	NJ	MB	NA	575	Yes	1990
Chattanooga	TN	MB	NA	600	Yes	1989
Charleston	SC	MB	NA	600	Yes	1990
St. Louis (North) (Bi-State)	MO	MB	NA	600	Yes	1991
Preston	CT	MB	NA	600	Yes	1989
Kent County	MI	MB	NA	625	Yes	1990
Bristol	CT	MB	NA	650	Yes	1988
Huntsville	AL	MB	NA	690	Yes	1990
North Kingstown (Quonset)	RI	MB	NA	710	Yes	1990
Rockland County	NY	MB	NA	720	Yes	1991
Babylon	NY	MB	NA	750	Yes	1988
Huntington (Long Island)	NY	MB	3	750	Yes	1990
Pierce County	WA	MB	NA	800	Yes	1991
Dakota County	MN	MB	NA	800	Yes	1991
Spokane County/City	WA	MB	2	800	No	1990
Stanislaus Co. (Crows Landing)	CA	MB	3	800	Yes	1989
Austin	TX	MB	NA	850	Yes	1989
Pasco County	FL	MB	NA	900	Yes	1991
North Hempstead	NY	MB	NA	990	Yes	1991
Snohomish County	WA	MB	NA	1000	Yes	1990
Irwindale	CA	MB	NA	1000	Yes	1991
Oyster Bay	NY	MB	NA	1150	Yes	1991
Long Beach	CA	MB	NA	1170	Yes	1989

NA = Information not available
[a]MB = Mass Burn; RDF = Refuse-derived fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air

TABLE B-1. PLANNED MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY COMBUSTION TECHNOLOGY (cont.)

City	State	Type[a]	No. of Units	Total Plant Capacity (tpd)	Heat Recovery	Year of Start-up
<u>Mass Burn Waterwall (cont.)</u>						
Lancaster County	PA	MB	NA	1200	Yes	1990
Plymouth	PA	MB	NA	1200	Yes	1989
Montgomery Co. (Landsdale Tnshp)	PA	MB	NA	1200	Yes	1990
Berks County (Reading Area)	PA	MB	NA	1200	Yes	1990
Washington County (Greenwich Tnsp.)	NY	MB	NA	1200	Yes	1991
Hennepin County (Minneapolis)	MN	MB	2	1212	Yes	1989
Passaic County	NJ	MB	NA	1300	Yes	1991
Camden County	NJ	MB	NA	1400	Yes	1990
Boston	MA	MB	NA	1500	Yes	1990
Kansas City	MO	MB	NA	1500	NA	1988
Pasadena	TX	MB	2	1540	Yes	1988
West Haverhill	MA	MB	2	1650	Yes	1989
South Bronx	NY	MB	NA	1700	Yes	NA
San Antonio (Leon Creek)	TX	MB	2	1800	NA	1988
Broward Co.(North)	FL	MB	NA	2200	Yes	1989
Broward Co.(South)	FL	MB	NA	2250	Yes	1990
Hempstead	NY	MB	3	2250	Yes	1989
San Diego (Sander)	CA	MB	3	2250	Yes	1989
Essex County	NJ	MB	NA	2250	Yes	1991
Indianapolis	IN	MB	NA	2360	Yes	1989
Fairfax	VA	MB	4	3000	Yes	1990
Bergen County (Ridgefield)	NJ	MB	NA	3000	Yes	1990
Brooklyn Navy Yard	NY	MB	4	3000	Yes	1992
McCord AFB (Ft. Lewis)	WA	MB	NA	180	Yes	1988
Sussex Co.(Lafayette)	NJ	MB	NA	400	Yes	1988
Outgamie (County)	WI	MB	NA	450	Yes	1989
Gaston County RR	NC	MB	NA	450	Yes	1990
Crestwood	IL	MB	NA	450	NA	1989
Stratford	CT	MB	3	600	Yes	1991
Knox Co. (Knoxville)	TN	MB	NA	1000	Yes	1991
Union County RR	NJ	MB	NA	1440	NA	1991
<u>Rotary Waterwall (9)</u>						
Dutchess County	NY	MB	NA	NA	NA	1988
Skagit County (Mt. Vernon)	WA	MB	2	178	Yes	1988
Bloomington (Monroe Co.)	IN	MB	NA	220	Yes	1991
Lubbock	TX	MB	NA	500	Yes	1989
Islip	NY	MB	NA	710	Yes	1988
Bethlehem (Lehigh Valley)	PA	MB	NA	1000	Yes	1990
San Juan RR	PR	MB	3	1040	Yes	1990
York Co. (Manchester Tnshp)	PA	MB	3	1344	Yes	1990
Delaware County RR	PA	MB	NA	1500	Yes	1990

NA = Information not available
[a]MB = Mass Burn; RDF = Refuse-derived fuel; MOD/SA = Modular Starved-air;MOD/EA = Modular Excess-air

TABLE B-1. PLANNED MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY COMBUSTION TECHNOLOGY (cont.)

City	State	Type[a]	No. of Units	Total Plant Capacity (tpd)	Heat Recovery	Year of Start-up
Modular Excess-Air (6)						
Webster	MA	MOD/EA	2	360	Yes	1989
Naugatuck	CT	MOD/EA	NA	360	Yes	1988
Ansonia	CT	MOD/EA	NA	420	Yes	1989
Wallingford	CT	MOD/EA	3	420	Yes	1989
Springfield	MA	MOD/EA	3	480	Yes	1988
Manchester	NH	MOD/EA	4	560	Yes	1990
Modular Starved-Air (9)						
Potter County	PA	MOD/SA	NA	48	Yes	1989
Ketchikan	AK	MOD/SA	2	50	Yes	1990
El Dorado	AR	MOD/SA	NA	100	NA	1988
New Richmond (St. Croix County)	WI	MOD/SA	NA	115	Yes	1988
St. Tammany Parish (Mandeville)	LA	MOD/SA	2	120	Yes	1990
Edgewood/Harford	MD	MOD/SA	NA	120	Yes	1988
Winona County	MN	MOD/SA	NA	150	NA	NA
Monroe Co. (East Strausburg)	PA	MOD/SA	NA	300	Yes	1989
Hull	MA	MOD/SA	NA	150	Yes	1991
RDF-Fired (14)						
Weymouth	MA	RDF	NA	300	Yes	1990
Philadelphia Municipal (SW)	PA	RDF	NA	330	Yes	1991
Bangor (PERC) (Orrington)	ME	RDF	2	800	Yes	1988
Elk River	MN	RDF	NA	1080	Yes	1989
Portland (St. Helens)	OR	RDF	NA	1200	Yes	1990
San Marcos (San Diego Co.)	CA	RDF	NA	1600	Yes	1989
Rochester	MA	RDF	NA	1800	Yes	1990
Palm Beach County (North)	FL	RDF	NA	2000	Yes	1990
West Palm Beach Co.	FL	RDF	NA	2000	Yes	1989
Redwood City (San Mateo County)	CA	RDF	NA	2750	Yes	1991
Honolulu (Campbell Ind. Park)	HI	RDF	NA	2800	Yes	1989
Detroit	MI	RDF	NA	3300	Yes	1989
Cherokee County	SC	RDF	NA	4000	Yes	1991
Chester	PA	RDF	NA	4800	Yes	1991

NA = Information not available
[a] MB = Mass Burn; RDF = Refuse-derived fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air

TABLE B-1. PLANNED MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY COMBUSTION TECHNOLOGY (conc.)

City	State	Type[a]	No. of Units	Total Plant Capacity (tpd)	Heat Recovery	Year of Start-up
Unknown (12)						
Tacoma	WA	NA	1	300	Yes	1989
Coeur D' Alene	ID	NA	NA	349	NA	NA
Texas City (Galveston County)	TX	NA	NA	400	Yes	1990
Susquehanna	PA	NA	3	525	Yes	1991
Fresno County	CA	NA	NA	600	Yes	1988
Erie County	PA	NA	2	850	Yes	1990
Reno	NV	NA	2	1000	Yes	1988
Oakland County (Pontiac)	MI	NA	NA	1200	Yes	1991
SE Baltimore	MD	NA	NA	1200	NA	1990
Highgrove	CA	NA	1	40	NA	1989
Derry	NH	NA	NA	400	NA	1988
Somerset Co. (Bridgewater)	NJ	NA	NA	600	Yes	1989

NA = Information not available

[a]MB = Mass Burn; RDF = Refuse-derived fuel; MOD/SA = Modular Starved-air;MOD/EA = Modular Excess-air

TABLE B-2. PLANNED MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY STATE

City	State	Type[a]	No. of Units	Total Plant Capacity (tpd)	Heat Recovery	Year of Start-up
Ketchikan	AK	MOD/SA	2	50	Yes	1990
Huntsville	AL	MB	NA	690	Yes	1990
El Dorado	AR	MOD/SA	NA	100	NA	1988
Fayetteville	AR	MB	NA	150	Yes	1989
Fresno County	CA	UNK	NA	600	Yes	1988
Highgrove	CA	UNK	1	40	NA	1989
Irwindale	CA	MB	NA	1000	Yes	1991
Long Beach	CA	MB	NA	1170	Yes	1989
Redwood City (San Mateo County)	CA	RDF	NA	2750	Yes	1991
San Diego (Sander)	CA	MB	3	2250	Yes	1989
San Marcos (San Diego Co.)	CA	RDF	NA	1600	Yes	1989
Stanislaus Co.(Crows Landing)	CA	MB	3	800	Yes	1989
Ukiah	CA	MB	NA	100	Yes	NA
Ansonia	CT	MOD/EA	NA	420	Yes	1989
Bristol	CT	MB	NA	650	Yes	1988
Middleton	CT	MB	NA	230	Yes	1989
Naugatuck	CT	MOD/EA	NA	360	Yes	1988
Preston	CT	MB	NA	600	Yes	1989
Stratford	CT	MB	3	600	Yes	1991
Wallingford	CT	MOD/EA	3	420	Yes	1989
Broward Co.(North)	FL	MB	NA	2200	Yes	1989
Broward Co.(South)	FL	MB	NA	2250	Yes	1990
Palm Beach County (North)	FL	RDF	NA	2000	Yes	1990
Pasco County	FL	MB	NA	900	Yes	1991
West Palm Beach Co.	FL	RDF	NA	2000	Yes	1989
Honolulu (Campbell Ind. Park)	HI	RDF	NA	2800	Yes	1989
Coeur D' Alene	ID	UNK	NA	349	NA	NA
Crestwood	IL	MB	NA	450	NA	1989
Bloomington (Monroe Co.)	IN	MB	NA	220	Yes	1991
Indianapolis	IN	MB	NA	2360	Yes	1989
St. Tammany Parish (Mandeville)	LA	MOD/SA	2	120	Yes	1990
Boston	MA	MB	NA	1500	Yes	1990
Hull	MA	MOD/SA	NA	150	Yes	1991
Rochester	MA	RDF	NA	1800	Yes	1990
Springfield	MA	MOD/EA	3	480	Yes	1988
Webster	MA	MOD/EA	2	360	Yes	1989
West Haverhill	MA	MB	2	1650	Yes	1989
Weymouth	MA	RDF	NA	300	Yes	1990
Edgewood/Harford	MD	MOD/SA	NA	120	Yes	1988
Se Baltimore	MD	UNK	NA	1200	NA	1990
Bangor (Penc) (Orrington)	ME	RDF	2	800	Yes	1988

NA = Information not available
[a]MB = Mass Burn; RDF = Refuse-derived Fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air

TABLE B-2. PLANNED MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY STATE (cont.)

City	State	Type[a]	No. of Units	Total Plant Capacity (tpd)	Heat Recovery	Year of Start-up
Portland	ME	MB	NA	500	Yes	1988
Detroit	MI	RDF	NA	3300	Yes	1989
Kent County	MI	MB	NA	625	Yes	1990
Oakland County (Pontiac)	MI	UNK	NA	1200	Yes	1991
Dakota County	MN	MB	NA	800	Yes	1991
Elk River	MN	RDF	NA	1080	Yes	1989
Hennepin County (Minneapolis)	MN	MB	2	1212	Yes	1989
Winona County	MN	MOD/SA	NA	150	NA	NA
Kansas City	MO	MB	NA	1500	NA	1988
St. Louis (North) (Bi-State)	MO	MB	NA	600	Yes	1991
Charlotte	NC	MB	NA	234	Yes	1989
Gaston County RR	NC	MB	NA	450	Yes	1990
Concord	NH	MB	NA	500	NA	1989
Derry	NH	UNK	NA	400	NA	1988
Manchester	NH	MOD/EA	4	560	Yes	1990
Bergen County (Ridgefield)	NJ	MB	NA	3000	Yes	1990
Camden County	NJ	MB	NA	1400	Yes	1990
Essex County	NJ	MB	NA	2250	Yes	1991
Gloucester County	NJ	MB	NA	575	Yes	1990
Passaic County	NJ	MB	NA	1300	Yes	1991
Pennsauken	NJ	MB	2	500	Yes	1990
Somerset Co. (Bridgewater)	NJ	UNK	NA	600	Yes	1989
Sussex Co. (Lafayette)	NJ	MB	NA	400	Yes	1988
Union County RR	NJ	MB	NA	1440	NA	1991
Warren County	NJ	MB	2	400	Yes	1989
West Deptford	NJ	MB	NA	432	NA	1989
Reno	NV	UNK	2	1000	Yes	1988
Babylon	NY	MB	NA	750	Yes	1988
Brooklyn Navy Yard	NY	MB	4	3000	Yes	1992
Broome County	NY	MB	NA	500	Yes	1991
Dutchess County	NY	MB	NA	NA	NA	1988
Hempstead	NY	MB	3	2250	Yes	1989
Hudson Falls (Washington Co.)	NY	MB	2	400	Yes	1990
Huntington (Long Island)	NY	MB	3	750	Yes	1990
Islip	NY	MB	NA	710	Yes	1988
Long Beach	NY	MB	NA	200	Yes	1988
North Hempstead	NY	MB	NA	990	Yes	1991
Oyster Bay	NY	MB	NA	1150	Yes	1991
Rockland County	NY	MB	NA	720	Yes	1991
South Bronx	NY	MB	NA	1700	Yes	NA
St. Lawrence County	NY	MB	NA	250	Yes	1990

NA = Information not available
[a]MB = Mass Burn; RDF = Refuse-derived Fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air

TABLE B-2. PLANNED MUNICIPAL WASTE COMBUSTION FACILITIES SORTED BY STATE (conc.)

City	State	Type[a]	No. of Units	Total Plant Capacity (tpd)	Heat Recovery	Year of Start-up
Washington County (Greenwich Tnsp.)	NY	MB	NA	1200	Yes	1991
Portland (St. Helens)	OR	RDF	NA	1200	Yes	1990
Berks County (Reading Area)	PA	MB	NA	1200	Yes	1990
Bethlehem (Lehigh Valley)	PA	MB	NA	1000	Yes	1990
Chester	PA	RDF	NA	4800	Yes	1991
Delaware County Rr	PA	MB	NA	1500	Yes	1990
Erie County	PA	UNK	2	850	Yes	1990
Glendon	PA	MB	NA	500	Yes	1990
Hanover Borough	PA	MB	NA	200	Yes	NA
Lancaster County	PA	MB	NA	1200	Yes	1990
Monroe Co. (East Strausburg)	PA	MOD/SA	NA	300	Yes	1989
Montgomery Co. (Landsdale Tnshp)	PA	MB	NA	1200	Yes	1990
Philadelphia Municipal (SW)	PA	RDF	NA	330	Yes	1991
Plymouth	PA	MB	NA	1200	Yes	1989
Potter County	PA	MOD/SA	NA	48	Yes	1989
Susquehanna	PA	UNK	3	525	Yes	1991
York Co. (Manchester Tnshp)	PA	MB	3	1344	Yes	1990
San Juan Rr	PR	MB	3	1040	Yes	1990
North Kingstown (Quonset)	RI	MB	NA	710	Yes	1990
Charleston	SC	MB	NA	600	Yes	1990
Cherokee County	SC	RDF	NA	4000	Yes	1991
Chattanooga	TN	MB	NA	600	Yes	1989
Knox Co. (Knoxville)	TN	MB	NA	1000	Yes	1991
Austin	TX	MB	NA	850	Yes	1989
Lubbock	TX	MB	NA	500	Yes	1989
Pasadena	TX	MB	2	1540	Yes	1988
San Antonio (Leon Creek)	TX	MB	2	1800	NA	1988
Texas City (Galveston County)	TX	UNK	NA	400	Yes	1990
Fairfax	VA	MB	4	3000	Yes	1990
McCord AFB (Ft. Lewis)	WA	MB	NA	180	Yes	1988
Pierce County	WA	MB	NA	800	Yes	1991
Skagit County (Mt. Vernon)	WA	MB	2	178	Yes	1988
Snohomish County	WA	MB	NA	1000	Yes	1990
Spokane County/City	WA	MB	2	800	No	1990
Tacoma	WA	UNK	1	300	Yes	1989
Eau Claire Co.	WI	MB	NA	225	Yes	1990
New Richmond (St. Croix County)	WI	MOD/SA	NA	115	Yes	1988
Outgamie (County)	WI	MB	NA	450	Yes	1989

NA = Information not available

[a] MB = Mass Burn; RDF = Refuse-derived Fuel; MOD/SA = Modular Starved-air; MOD/EA = Modular Excess-air

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

This document is intended to assist groups interested in inventorying air emissions of various potentially toxic substances from municipal waste combustors. Its intended audience includes Federal, State and local air pollution personnel. The document presents information on the process description of the various types of municipal waste combustors and their air pollution control equipment. Emission factors are presented for each major type of municipal waste combustor for the following: acid gases including hydrogen chloride, hydrogen fluoride, and sulfur trioxide; metals including arsenics, beryllium, cadmium, chromium, mercury and nickel; and organics including chlorinated dibenzo-p-dioxins, dibenzofurans, polychlorinated biphenyls, formaldehyde, benzo(a)pyrene, chlorinated benzene, and chlorinated phenol.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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